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Offshore Platform Integration and Floatover Technology

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Preface

As recognized in the oil and gas industry, the beginning of the offshore industry was marked by the Kerr-McGee Rig 16's successful oil extraction in Ship Shoal Block 32 in November of 1947. In the following years, tremendous efforts were made both economically and technologically in the development of offshore platform concepts and subsea completion equipment applying devised strategies. It is considered that the offshore industry economic and technological foundation was formed in the GOM by the end of 1950s. Offshore industry development took part globally including the North Sea, the Middle East, the Far East, the Caspian Sea, etc.

Safety and cost-effectiveness have always been the critical issues of the platforms from design to installation. As most of the platforms including fixed platform, GBS, floating structures such as TLP and Semisubmersible have their topsides and substructures fabricated separately, the integration of the two parts, or in other words, the mating of the topsides with the substructures become one of the most vital steps in the platform construction. Up to then, platform integration had used HLCVs (Heavy Lifting Crane Vessel). It was obviously that the capacity of HLCVs could not catch up the pace of the increase of the dimension and weight of the topsides. This is especially true for the integrated topsides design appeared in the 1960s. The HIGHDECK floatover technology was a significant invention in late 1960s and had strong impacts on the offshore installation practice. It was immediately applied to the inshore platform integration for huge platforms including TLP and GBSs. The technology with evolutional development includes methodology variations carrying the same name of "floatover" has been widely applied worldwide. It is no longer considered as novel offshore installation approach for installation of various kinds of offshore platform. With lower risk and high cost-effectiveness especially the big cut of the work scope of offshore hookup and commissioning, floatover methodology becomes the favored selection of platform integration.

It can be noticed that the development of the floatover technology continues and goes beyond the offshore platform integration. New equipment including specially designed vessels are also applicable to the platform decommissioning and the offshore renewable energy facility installation. At the same time, the step change innovations like single vessel floatover using dynamic positioning vessels also appeared.

There have been many literatures, reports, brochures discussing relative topics on the floatover technology. The discussions cover various kinds of details including advantages of the method, the basic concepts, the equipment design, the success and lessons learned, etc. The discussions are often from different angles based on the experiences of the authors.

This book is written for the readers interested in the platform integration operation and the floatover technology basics and application. Their background in the offshore construction is not a requirement, since the depictions of basic concepts of offshore installation projects can be easily followed and comprehended. By presentation of real accomplished platform integration projects and discussion, the concepts of integrated topsides, comparison of installation by crane lifting and by floatover, importance of project management and planning, vital role of engineering in technology development and operation supporting, execution of platform integration, etc. are fully covered. We hope that the readers can have a relatively full picture on the platform integration and floatover technology after reading through this book.

Through the discussions, the following points of views are emphasized besides the technical contents:

- Safety and cost-effectiveness are the most critical factors to be considered in the technology development and project execution plan making.
- Platform integration projects similar to other offshore installation projects need synchronized efforts of the whole project team. A well-established project management team, efficient communication system and a solid quality assurance/quality control system are the keys for the success of the project.
- Engineering plays vital role in the success of the platform integration including the new technology development and supporting to the project management and offshore installation procedure/operation manual development.
- Every platform integration project is different, even for the same platform design. During the installation process, issues appeared have to be promptly addressed with correct solutions. A qualified engineer must have solid engineering background and accumulated experiences and the most important is the capability of handling on-site engineering challenges and providing engineering solutions.
- Offshore EPCI projects generally take a long time period in development and often the involvement of the installation team happens in the late stage of the project. However, to assure the success and the smooth execution of the EPCI, the installation project management team and the engineering supports should be involved in the very early stages.

The discussions on various topics are not evenly distributed in this book. More details are provided on the topics or examples less frequently appeared in the published literature, e.g., the discussion of the mating process of the topsides with the hull of the TLP Hutton, which is different from the floatover using leg mating units in projects carried out nowadays. In the same token, generally the calculation and analysis details are not included since they can be easily found in published articles.

Most of the photos are from published literatures, presentations, brochures, etc. which can be found in conference proceeding, patent documents and websites. Efforts have been made for the accuracy of the data presented, especially when inconsistency found among articles.

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Contents

Abbreviations

AHT	Anchor Handling Tug
AMC	Aker Marine Contractors
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CGBS	Concrete GBS
CM	Center Module
CMP	Communication Management Plan
COG	Center of Gravity
COOEC	China Offshore Oil Engineering Co
COSCO	China Ocean Shipping Company
COSL	China Oilfield Services Limited
CPC	Certification of Practical Completion
CPF	Central Production Facility
CP	Communication Plan
DB	Design Basis
DCS	Deepwater Construction Site
DDS	Deep Draft Semisubmersible
DOF	Degree of Freedom
DP	Dynamic Positioning
DPP	Drilling Production Platform
DSF	Deck Supporting Frame
DSIV	Decommissioning, Salvage & Installation Vessel
DSS	Deck Support Structure
DSU	Deck Support Unit
DTV	Deck Transportation Vessel
DWT	Dead Weight
EDP	Extended Draft Platform
EM	East Module
EPCI	Engineering, Procurement, Construction and Installation
ER	Elastomer Ring

ETPM	Entrepose GTM Pour les Travaux Petroliers et Maritimes
EU	Elastomer Unit
FE	Finite Element
FOHAG	Floatover of High Air Gap
FPS	Floating Production Structure
GIF	Gulf Island Fabricators
GM	Metacentric Height
GOM	Gulf of Mexico
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HFG	Heerema Fabrication Groups
HHI	Hyundai Heavy Industry
HLCV	Heavy Lifting Crane Vessel
HLV	Heavy Lifting Vessel
HMDC	Hibernia Management and Development Company Ltd.
HSE	Health, Safety and Environment
HSEQ	HSE and Quality
HUC	Hook Up and Commissioning
HVDC	High Voltage Direct Converter
IFC	Issued Form Construction
IM	Installation Manual
ITU	International Telecommunications Union
JSA	Job Safety Analysis
KBB	Kebabangan
KOS	Kiewit Offshore Services
KPOC	Kebabagan Petroleum Operating Company Sdn Bhd
LMS	Lateral Mooring System
LMU	Leg Mating Unit
LQ	Living Quarter
MMHE	Malaysia Marine and Heavy Engineering Sdn Bhd
MOAB	Mobile Offshore Application Barge
MSF	Module Supporting Frame
MWS	Marine Warranty Surveyor
OCC	Operational Control Centre
OCV	Offshore Construction Vessel
OIM	Offshore Installation Manager
PDCS	Project Document Control System
PEP	Project Execution Plan
PM	Project Manager
PMB	Project Mail-Box
POM	Project Operation Manager
QA	Quality Assurance
QC	Quality Control
QMR	Quality Management Representative
QMS	Quality Management System

R&P	Rack and Pinion
RAO	Respond Amplitude Operator
ROV	Remotely Operated Vehicle
SHI	Samsung Heavy Industry
SIP	Self-Installing Platform
SJL	Strand Jack Lifting
SLD	Specialized Lifting Device
SMI	SeaMetric International
SMLT	Sarens Modular Lifting Tower
SOW	Scope of Work
SPT	Suction Pile Technology
SSCV	Semisubmersible Crane Vessel
SURF	Structure Umbilical Riser Flowline
T&I	Transportation and Installation
TLR	Temporary Lateral Restraints
TML	Twin Marine Lifter
TOL	Tombua Landana
TPG	Technip-Geoproduction
TSG	Tecnomare Gravity Structure
VHF	Very High Frequency
VMO	Veritas Marine Operation
WM	West Module
WOW	Waiting on Weather

Chapter 1
Offshore Platform Topsides and Substructure

Abstract Offshore platforms are designed to perform exploration, production at offshore oil fields. An offshore platform structurally can be divided into two parts: the topsides and the substructure. The topsides is a steel structure providing spaces to hold various kinds of facilities for exploration/production and human activities. Substructures are necessary to support the topsides "sitting" at an elevation safely above the ocean free surface. In general, the topsides and the substructure of a platform are designed and fabricated separately. The completed topsides and the substructure are then integrated at inshore or offshore site. Integration methodology depends on the topsides and substructure design, at the same time, the selected integration method has strong impacts on the platform design, especially the design of the topsides. Discussion in this chapter starts from platform topsides and covers the various kind of topsides design philosophies. Through examples, it is shown that platform design is strongly related to the platform integration methodology, changing integration method at the later stage of platform design will impact the project in the negative way in general.

Discussion in this chapter is not on the procedure or details of platform topsides and substructure design, but the concept of the mutual impacts between the installation methodology and the design of the topsides as well as the substructure of platforms.

Functionally speaking, an oil and gas offshore platform no matter for exploration or for production will consist of a topsides and a supporting substructure. Except ship-shaped floating structures such as FPSO, FLNG, etc., the substructure and the topsides are designed and fabricated separately and then integrated together. The installation activities of pulling them together will be addressed in this book and the focus will be on one kind of installation approach, i.e., installing the topsides without heavy lifting derrick or cranes. Among various kinds of technologies, floatover technique will be intensively discussed.

Through discussion, it can be seen that among the factors impacting design of both topsides and substructure, platform integration methodology is an important one. Integration methodology should be selected in the very early stage of the

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project and offshore installation related engineering contents should be included in the work scope of the platform design. For example, to achieve a successful floatover integration of a fixed platform, the design of both the topsides and the jacket should be carried out considering the requirements from topsides transportation and mating operation. The earlier to start engineering efforts on the offshore construction the smoother in the project execution. It can be very costly to change the platform integration method in the process of platform design.

1.1 Platform Topsides

As well known in the offshore oil and gas industry, an offshore platform consists of two parts structurally—the upper part or the topsides and the lower part or the substructure. A topsides generally is a steel structure consisting of more than one deck holding various kinds of facilities for exploration or production. However, in the offshore industry daily practice, "topsides" and "deck" are often be used interchangeably in technical discussions, such as "*topsides installation*"/"*deck installation*", "*integrated topsides*"/"*integrated deck*", etc. In this book, in general, "topsides" is the selected word in discussion.

"Topsides" (please note: the word is in *plural* form) comes from the shipbuilding industry. The word is used to designate the above waterline portion of the hull of the vessels. There are more than one decks in the vessel hull, but a "*deck*" is often used to mean the upper deck of the vessel which forms the 'roof' of the hull of the vessel. Obviously, the concepts can be immediately applied to ship shaped floaters such as FPSO, FPO, FSO or FLNG. For an offshore platform, the topsides is high above the sea level and outside the splash zone by design.

The topsides holds all the facilities needed for functions by design and human activities. The topsides layout varies, depending on the field development concepts, the location of the fields, even the future potentials. For example, considering a production platform with required processing equipment such as production separators, acid gas removal, gas dehydration, gas exporting, control panels, etc., the topsides must be much larger than the topsides of a simple wellhead platform. If the platform is manned by design, even a well head platform, there has to be a living quarter onboard. Therefore, the overall weight and dimensions of a topsides are largely defined by the platform function. The topsides structural design in general plays a vital part in the topsides optimization. One important factor with strong impact on the topsides structural design is the selected method of the platform integration. Alternation of the topsides installation method in the process of the platform design leads to the needs of modification of the topsides structural design, which will be discussed in depth later in this chapter.

Supports from substructures are achieved in two different ways:

- For platforms such as fixed platform, compliant towers, GBS (Gravity Based Structure) and so on, the substructures rest on the sea floor to create reaction forces responding to static as well as dynamic loads on the platform.
- For floating structures, the buoyancy created by the submerged hull of floating offshore structures such as semisubmersibles, TLPs, SPAR, etc., will handle the vertical loads including weights and environmental loads. The external loading on the platforms in the horizontal plane will be accommodated by the mooring system including the tendons of the TLPs.

For either of the above mentioned approaches, the substructures also provide control of the topsides motion when external forces apply. In addition, the properties of the topsides by design such as main dimensions, weight and weight distribution, COG (Center of Gravity) are critical inputs for the substructure design.

As mentioned earlier, each offshore platform is specifically designed to fit in the needs of the corresponding oil field development. Platforms can be designed for oil field exploration as the drilling rigs, for oil and gas production as Floating Production Structures (FPS) or as the oil field service unit such as the FLOATEL. No matter what kind of functions the platform is designed for, the three (3) main topsides design elements are in common:

- Holding all equipment needed for operations
  For any kind of platforms, the designed functions must be fulfilled. For example, an exploration drilling platform must be able to carry all the drilling equipment including power generation and distribution system, drilling module, circulation system, as well as accommodation modules, etc. For a production platform, all the equipment should be arranged on the topsides to carry out the operations for safe and effective hydrocarbon production including produced hydrocarbon separation, gas processing, oil and gas exporting, well testing, produced water treatment and injection, seawater lift for cooling duty and injection, and so on. Of course, power generation and distribution system, living quarters are also necessary. Some production platforms are even equipped with drilling modules.

  Two examples of the topsides of the production platforms are shown in Fig. 1.1. On the left is the fixed platform Miller in the North Sea [1]; on the right is the GBS Hebron in offshore of Canada [2]. It can be noticed that both the topsides consist of several modules for performing specified tasks such as drilling module, utilities module, flare boom, living quarter, etc. Each module is fabricated and then positioned on a designated deck of the topsides frame.
- Providing a safe and sustainable healthy living environment
  The topsides of a platform is not designed merely as a steel frame providing enough spaces for packing all the facilities needed for assigned tasks. Even for unmanned platforms, there should be the arrangement for personnel to access and conduct various kinds of survey, repair, data collection, etc. Segregation of hazard sources, safe access to helideck, safety boats, high habitability standards, etc. should be carefully considered during the topsides design.

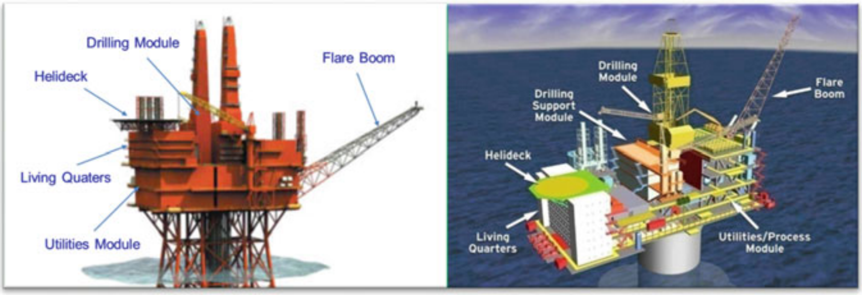

Fig. 1.1 Utilities and equipment on the *topside* of a platform (Courtesy of BP and Exxon respectively)

- Optimization of dimension and weights
  Different from on-shore plants, the size of the offshore platform topsides is limited; therefore, the optimization of the space usage is necessary. The combination of reduction of the size and volume of the equipment and compacted arrangement of the facilities on the topsides not only directly leads to its weight and cost reduction, but also benefit the design of the corresponding substructure. For light topsides with smaller wind projection area, the substructure can also be sized down in dealing with the platform motion control no matter it being the jacket of a fixed platform or the hull and mooring system for a floater. The results will be the reduction of the total cost of the platform and this is just the so-called cost-effective approach.

In the practice of the topsides design following the above-mentioned principles, the topsides is generally not a single layered flat deck structure packed with various kinds of equipment. The steel structure of a topsides consists of multi decks as shown in an already fabricated topsides populated with facilities (see Fig. 1.2).

In the sketch of an unmanned wellhead platform shown in Fig. 1.3, it is better illustrated where the different kind of the decks are located. The number of decks are not limited to what shown in this sketch. For example, for a large production platform there can be more than one main deck to hold modules with different size and weight. The layout arrangement is carefully made by design engineers. In Fig. 1.4, it shows a topsides was completely constructed at a fabrication yard and ready for loadout. The platform topsides like this one is recognized as an integrated topsides with all the equipment/modules being assembled. The concept of the integrated topsides will be discussed in details in the later section. The topsides design concept is directly impacted by the platform integration method.

How many decks will be needed and what will be the arrangement of the decks and what the layout of each deck, etc. are the tasks of the topsides design engineers. Main ideas and considerations in the design of offshore platform topsides and substructures will be discussed in the following section.

Fig. 1.2 A topsides shows multi-level decks populated with modules (Courtesy of Anadarko Petroleum Corporation [3])

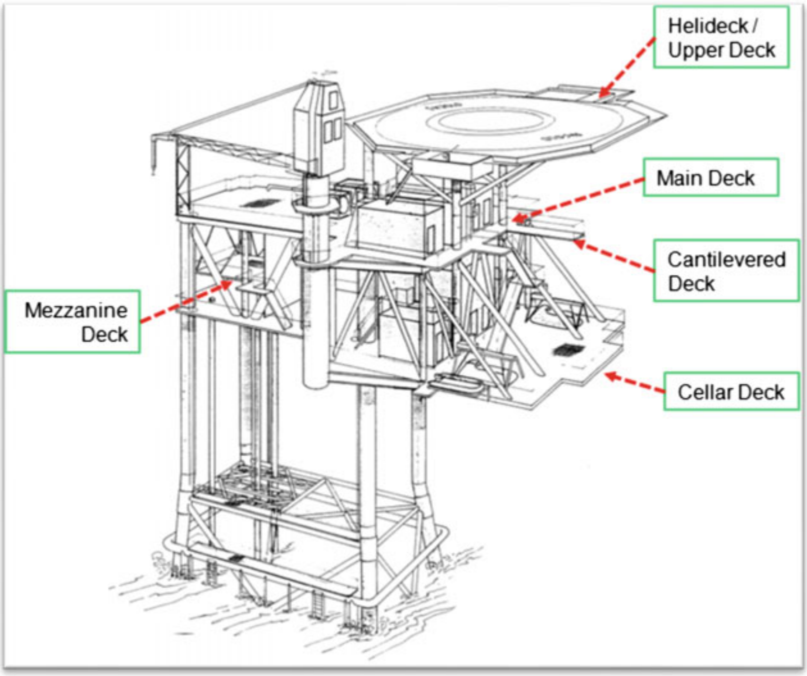

Fig. 1.3 Various kind of decks of an unmanned well head platform (Photo after Thomsen et al. [4])

Fig. 1.4 A completed topsides is ready for loadout (Courtesy of Nexen Petroleum U.K. [5])

1.2 Design of Offshore Platform Topsides and Substructures

1.2.1 Topsides Design in General

Supported by the substructure, the topsides can be taken as the heart of an offshore platform. It holds the facilities to perform the exploration of the field or to process oil and gas from the reservoir beneath the sea floor. A platform, either a drilling platform or a production platform, is designed to serve more than a decade, human safety and health are always vital in the design consideration. For a manned platform, living quarter is on the topsides for the crews. Segregation from hazard region and access to the safe-boat and helideck, etc. need also be carefully considered during the design. Equipment maintenance and replacement program should also be integrated into the topsides design. Furthermore, following the hub and spoke field development concept, as the water goes deeper at the offshore field, the topsides should also have the capacity for future expansion need such as riser tieback. This is also being covered at the design stage. Based on the design principles of the order of priority: safety, operability, maintainability, cost effectiveness. Factors affecting the topsides design can be summarized in the following:

- For manned platforms, the most important is the safety of the crew and the sustainable working conditions for them to carry out daily operations on the platform topsides. To achieve it, the topsides design should consider:

– To have the accommodation facility (living quarters) to meet the habitability standards and keep a friendly environment for crew's health. Noise dB level, illuminance, living space, decoration, fitness equipment, etc. are critical factors to be seriously examined.

  The location of the accommodation facility should also be arranged being maximally segregated from hazardous facilities mainly oil and gas processing equipment, flare tower, source of high dB noise, etc. With the limited spaces on the topsides, one of the choices is to put the nonhazardous facilities in-between the hazardous facilities and the living quarters to make the accommodate facilities farthest away from the source of pollution.

  When design the topsides for a production platform, since the platform position and orientation will already be set "permanently" before the commencement of the oil and gas production, impact of the environment also needs to be checked carefully. One of the examples is that after identifying the most likely wind direction annually, try to put the sources of fire and hazardous gas in the downwind side and as far as possible from the living quarters. Figure 1.5 shows the concept of module arrangement on the platform topsides.

– To arrange the helideck closer to the accommodation area and provide safe and convenient access to the crew. The same consideration applies to the location of working stations. The safe boats should be located with safe and convenient access to the places where the crews live and work on the

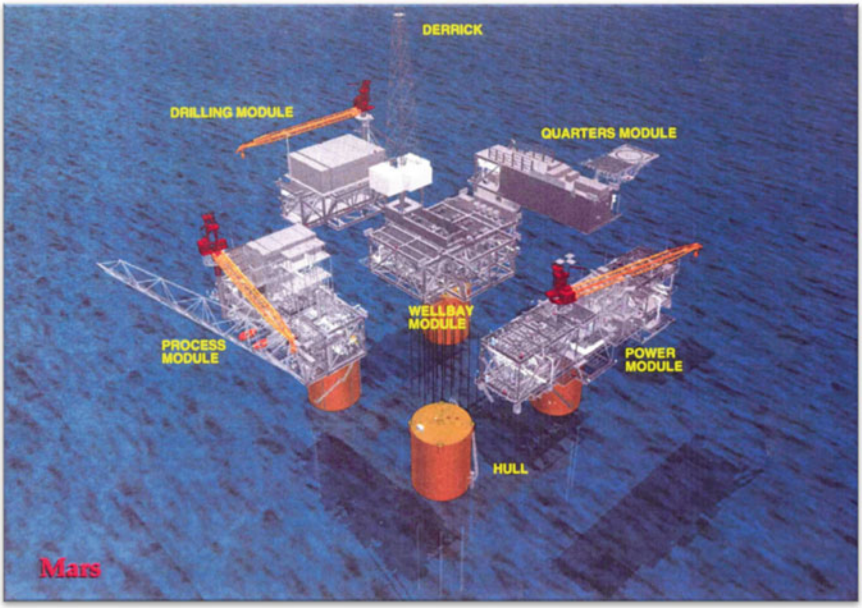

Fig. 1.5 Modules on the topsides of Mars TLP (Courtesy of BOEM [6])

platform. In Fig. 1.6, the topsides arrangement of the MCP-01 platform clearly demonstrates how to follow the design safety principles during the offshore platform topsides design.

- The weight and weight distribution of a platform topsides is a key factor contributing to the platform stability and the cost-effectiveness. A heavier topsides demands higher supporting capacity of the substructure and leads to the increase of the total weight of the platform. For the same topsides weight, lower COG will improve the stability during the topsides transportation and integration of the topsides and the substructure. It will also benefit the optimization in the substructure design for both fixed platform and floating system.
  Weight reduction starts from vendors' efforts on the equipment design and fabrication, but also comes from the optimization of the topsides structural design. Improvement of the topsides weight distribution goes through the topsides deck lay-out and arrangement. Carefully locating an equipment on a selected deck with a favored elevation can sometimes make big impact on the reduction of the COG of the topsides.
- Weight handling capacity of the topsides for future upgrading and loading change is another critical factor in topsides design. The probability of weight increase and adjustment of weight distribution request is not low for the production platforms with a long service life, especially for the deepwater platforms. On-site structural modification and strengthening is quite costly and should be avoided.
- For the same token, spaces on the topsides for potential future needs should also be considered at the design stage.

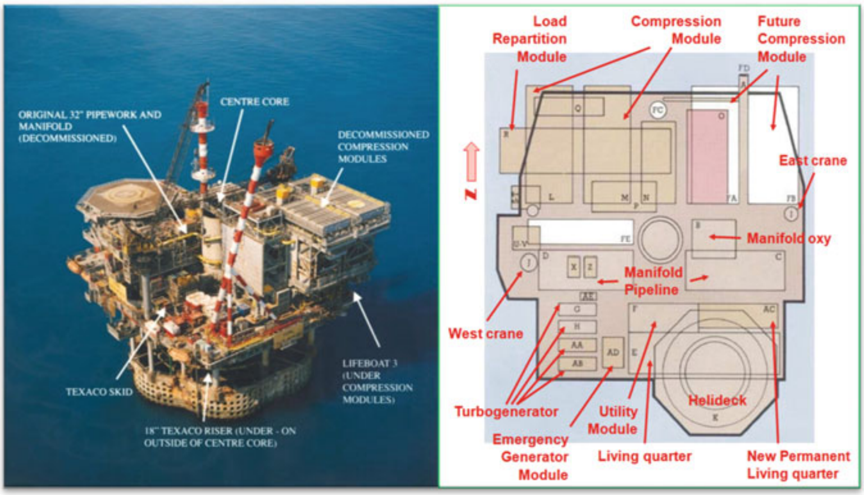

Fig. 1.6 Topsides layout of MCP-01 Platform. The design clearly follows the safety principle mentioned above (Courtesy of University of Abdeen)

As well known, the service life of a platform, no matter a drill rig or production platform, is more than a decade. It is wise and necessary to consider potential space need for future requests. This is especially true for production platforms selected for remote and deepwater field. Following the 'hub and spoke' field development concept, for a newly developed deepwater field, a platform will be designed capable of meeting future needs of tieback of risers from the under developing neighbor field. This already becomes a common practice in the industry.

- Optimization of the usage of the limited spaces at each deck of the topsides with no doubt is one of the design goals. However, when working on the floor layout, equipment maintenances and potential future replacement need to be seriously considered. There should be safe access to these equipment and necessary spaces need to be reserved as working friendly environment for technicians and engineers.

1.2.2 Modular Topsides, Integrated Topsides and Single Lift Topsides

After knowing the principles of topsides design for safety and functionality, the discussion in this section focuses on the approaches in topsides design practice in order to find a more cost/schedule effective solution. The important factors affecting the cost and schedule of the projects are the structural design, fabrication, transportation/installation as well as the HUC (Hook Up and Commissioning). Optimization of equipment design is not covered in the discussion and the focus is on how to achieve the cost and man-hour savings on the skeletonized topsides structure and the connection between equipment and/or modules. The definition of "module" is not very strict but means a unit consisting of elements from the breaking down of a big system. The module concept has been used quite often in the manufacture industry in dealing with batch manufacturing. A complicated machine or product is divided into smaller, self-sufficient parts during design and manufacturing in order to:

- Make complexity manageable
- Enable parallel work
- Accommodate future uncertainty.

In the offshore oil and gas industry, the completion of a platform construction must go through the step of the integration of the topsides with the corresponding substructure. A "module" of installation often means a block, as a part of the platform topsides to be installed onto the substructure. Therefore, for different projects the definition of module varies. Take the Miller platform in the North Sea as an example; the topsides was installed with twelve "modules" as shown in Fig. 1.7 [7].

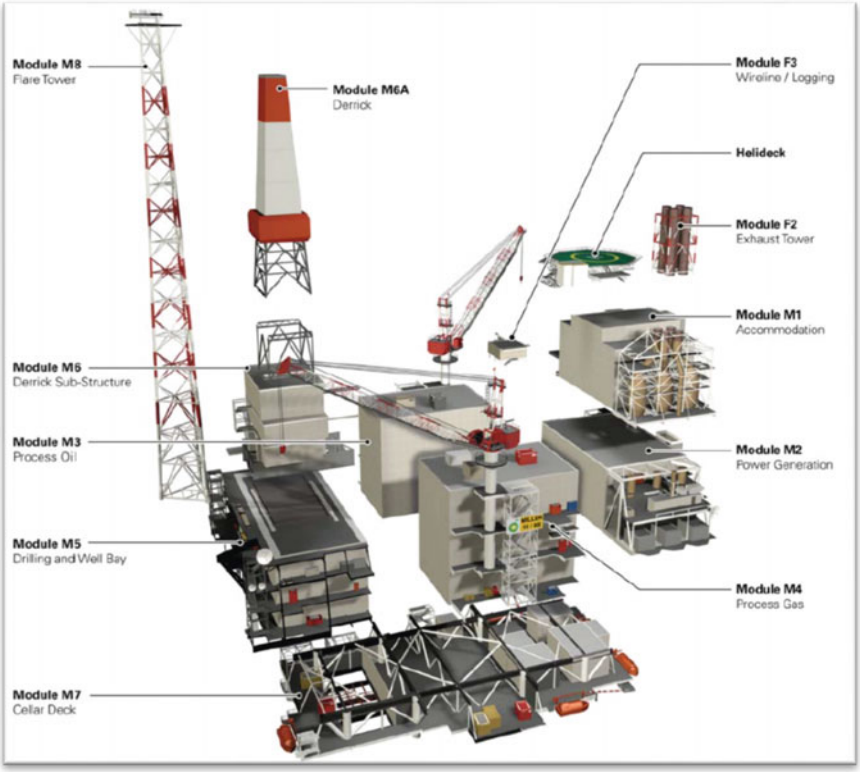

Fig. 1.7 Twelve (12) modules of the topsides of the Miller platform (Courtesy of BP)

While the topsides of the Chevron compliant tower Petronius consists of only two modules: the North Module and the South Module. The total weight of the topsides was 7500 tons and both of modules are quite large. Shown in Fig. 1.8 is the North Module, which weighs close to 4000 tons and consists of multi decks. The two modules were installed on the "tower" substructure by heavy lifting vessels at the offshore. Comparing to the Miller topsides, obviously the definitions of the modules are not the same. The "module" concept in functionality is obviously different from the "module" of installation. There should be some "sub-modules" in the Petronius North Module.

There have been two different approaches in platform topsides design/construction practice among the projects already completed. They are integrated topsides and modular topsides. For simple smaller topsides, an integrated topsides is the obvious selection. For example, for an unmanned wellhead platform, the topsides can be installation by a single lift offshore using heavy lift vessels with little availability issue. However, when the size of the topsides increases and the facilities are more complicated, the number of factors affecting the cost/schedule effectiveness increases. Sometimes, it becomes more complicated to choose

Fig. 1.8 The North Module is half of the whole Petronius topsides weighing 7500 t (Courtesy of Chevron)

between the integrated topsides and modular topsides in practice. The selection of the topsides design concept becomes a case-by-case situation depending on the project specifics.

- Modular Topsides [8–10]
  For a modular topsides, normally several modules are first defined as the blocks to be fabricated onshore, transported to the offshore site, and then put onto the MSF (Module Supporting Frame) mounted on the corresponding substructure. Although the fabricated modules such as utility modules, production module, power generating module, living quarter, etc. are commissioned onshore, the individual modules and the MSF will be installed at the integration site inshore or the offshore site. The HUC will be carried out after the platform integration. The offshore HUC scope of work is a big factor accounting for the costs and time expending of a project.

  The driving force for modular design in offshore industry is the combination of trying to accommodate the gap of the total topsides weight and the capacity of the existing crane vessels and attempting to simplify design complexity and let engineers/designers have a manageable system to work with. In theory, engineers will benefit from modularization through breaking the complexity down to self-sustainable elements with clearly defined system borders and demands for each of them. Therefore, the large and complex systems can be handled in a structured way.

  With the modular design approach, it may make the replacement of older modules by the new ones easier during the platform service life, if the standard interfaces between modules are implemented. However, the standardization of the module interfaces is complicated and may not be all positive for the cost effectiveness, which will be discussed a bit more in this section later.

Another benefit of modularization is that when the whole topsides is divided into several relative independent modules, it makes “parallel work” possible in the design and construction stages, i.e., each module can be developed and delivered in an independent schedule separate from the other modules. Therefore, for the topsides design and construction project, the planning and execution can be optimized through best locating time and resource with several modules being developed in parallel, with consideration of the differences among the modules in the leading time, the complexity, etc.

In addition, nowadays, the offshore industry is highly globalized and the technology and fabrication technique have been developed with fast pace but not very evenly for different countries and regions. Each individual module can be contracted to be built at the best-suited place or by the best-suited working force and then to be transported to a carefully selected assembly yard. It creates the opportunity of improving cost effectiveness at the same time to gain the best construction quality. As an example shown in Fig. 1.9, the living quarter of

Fig. 1.9 Living quarter of Miller platform (Courtesy of BP)

Miller platform's topsides is an independent module, but also the integrated living area of the topsides. It was a five level structure with 98 cabins filled with 196 beds with integrated bathroom facilities and was considered as the facility with superior quality and finish.

However, there are disadvantages and various kinds of challenges to the modularization concept when a module is treated as a relative self-sufficient part:

– One of the challenges is that apparently not all components on the topsides can be taken as independent building blocks. For example, piping and electrical wiring are typical components being difficult to modularize. Guidelines of dealing with these non-modular components have to be established after they are identified.
– Spatially, the topsides of an offshore platform is very compacted, sometimes a preliminary defined module may not be self-sufficient in order to make the module integration easily achieved, therefore compromises have to be made.
– For modular design approach, it's critical to establish standardization of interfaces between the connected modules. However, the interface

  standardization may not be very easy for a specific offshore platform topsides can result in extra weight and volumes even it's feasible.

– To set up the generic interfaces for all the modules when projects start can hardly be achieved. One suggested solution is to allow the connection components and systems to be implemented after each module configuration is completed. To do so, extra space need to be designated to the modules at the earlier design stage, so that no crises to be created for later assembly stage.
– When discussing the modularization advantage about module replacement, one must be aware that after years of service, the new replacement often is the upgraded one with alternation in volume and weight as well the weight distribution; therefore, impact on neighboring modules and/or the local structures is inevitable. More engineering work may be needed and the process may not be as simple as initially expected.
– The most talked disadvantage for modular topsides is to have big amount of offshore HUC work comparing to the integrated topsides concept.

  The following discussion is targeted to help enhancing the comprehension on the impact on cost/schedule effectiveness by offshore HUC.

  As one may know that activities of an offshore oil and gas development project following the selection of a platform concept often consist of:

    Platform and related subsea system design
    Procurement of materials and equipment with specifications
    Construction/fabrication of platform
    Platform, mooring system (if needed), subsea system installation
    HUC of platform including hook up of modules, hook up with riser and pipeline systems, equipment testing, repairing, etc.

HUC is highly demanding of both labor and support. As the platforms become bigger and more complicated, the complexities of hookup often led to overruns of budgets and delay in schedule. The effective measures in handling this challenge are:

Leave fewer modules for offshore installation although each of them may be much larger.
Allocate proper space between modules for interconnection.
Apply flexible connection to extent permissible for pipeline connections exposing to high operating pressure.

It's also essential to control the interconnecting tolerances during the fabrication of modules. Working offshore in the limited spaces with onboard modules, there exist more challenges comparing to working onshore. Temporary extra equipment, power supply, communication gears, ventilation system, etc. are needed. Also fire protection and health safety become extremely important because of the big amount of personnel and intensive activities. In carrying out hook-up, welding work weighing heavily and facing safety challenging. Motion of the platform under environment should also be considered carefully.
Offshore HUC covers commissioning of all equipment onboard the platform after the completion of the topsides installation and the risers and umbilicals being hooked up. It's vital to make sure that all the equipment are functioning as designed and all the necessary repairing work will be done before the first oil starts. The commissioning process for an offshore unit is more complex and more time consuming comparing to carry it out onshore, which is not merely the matter of moving the working location from onshore to offshore.
For a newly installed platform, it is necessary to have a structured approach for the HUC. It is supposed that the entire MC (Mechanical Completion) is already completed before the offshore commissioning starts. Then the main activities of the commissioning include:

Pre-commissioning
Commissioning execution
Commissioning documentation and handover to operation.

Pre-commissioning means that the activities to be performed after MC of a piece of equipment or system assure it being safe and ready to receive hydrocarbons/injection water and ready for commissioning. As many of the pre-commissioning activities as possible should be completed at the fabrication yard to minimize the offshore working time. The pre-commissioning tests carried out in the fabrication yard will be repeated offshore but only for assurance of the equipment being not damaged and in the same condition when tested onshore. Obviously, the offshore work scope is minimized.

The commissioning planning and definition of commissioning packages including detailed pre-commissioning plan should be established in the early stage of a project, so that the costs and schedule can be kept in line with the expectations. All the pre-commissioning activities should follow the guidelines by regulatory documents such as API–700, and corresponding procedures should be developed and approved prior to commencing work. The procedure should have detailed description of all the activities and the approaches of safe execution. The approved procedure shall be strictly followed during the commissioning.

Commissioning generally starts with living quarters and utility systems including the main power generators. The systems will then be started up, allowing workers to inhabit the platform during commissioning and the starting up of the process facilities. To be successful, commissioning requires intensive joined efforts from the operator, the contactor and the vendors. To better understand the discussion, take one of BP’s projects as an example, the tasks of commissioning five modules need 25,000 person-hours.

From the discussion above, it should be clear that offshore HUC costs more and the fewer modules to be installed offshore the better cost-effectiveness can be achieved.

- Integrated topsides [11, 12]
Different from the modular topsides design approach, on an integrated topsides, all the equipment are arranged and installed on the designated decks and hooked-up as well as commissioned during the assembling process on shore. It should be more challenging for engineers in the design stage, especially the information flow. However, by the accomplishment of the HUC of the topsides equipment on shore, the offshore HUC work is minimized.
The integrated topsides concept was first introduced in 1973 with a North Sea project. As is well known, the North Sea weather conditions are severe, especially in the northern part of the North Sea. For the shallow water oil field development, if the conventional fixed platforms were selected, the severe environment conditions would lead to the request of extra-large steel structures. The installation of the massive jacket would also become very complicated considering transportation, putting it vertically in position and piling, etc. At the same time, the extremely harsh weather conditions would narrow the offshore operation weather window and also make the offshore construction projects easily miss the schedule, sometimes the delay might be as long as six to eight months. Therefore, the GBS concept became the choice. The GBS could carrying the deck during the wet-tow to the offshore field and the installation of the platform did not need the piling operation. In addition, the required grouting operation duration was short normally less than five weeks.

The initial integrated topsides concept was born in the process of optimizing the topsides design for the GBS structures. Instead of using the MSF, the topsides was supported by the girder type plate deck mounted on the concrete towers. With this kind of design, the deck with the girder depth of seven to ten meters was capable of housing machinery and equipment. The steel weight of the topsides was significantly reduced by cutting down or eliminating modular steel. Apparently, the initiated efforts were NOT focusing on the platform installation but on the optimization of the topsides design. The equipment and modules would be installed by the lifting onto the deck mounted on the GBS towers.

Later, the pioneers of floatover concept from KBR, who developed the new integrated topsides concept "HIDECK" which was explicitly addressing the novel platform integration approaches. The integrated topsides design concept has been further developed and becoming widely used in the offshore industry (Fig. 1.10). With the integrated topsides concept, the construction of the topsides modules includes the fabrication of the corresponding MSF's. When all the structural members of MSF are ready, then the major equipment, piping spool and related utilities will be put in designed locations and the whole module assembly is completed. By design, the integrated topsides can probably be a more tailored solution with better performance in weight control and spatial arrangement comparing to the solution by modular design. With the integrated topsides, offshore installation and HUC durations can be drastically reduced, therefore integrated topsides concept has become popular in recent years, no matter the integration of the platform being performed inshore or offshore.

Fig. 1.10 An integrated topsides for floatover installation in Malaysia (KBB project) (Courtesy of KPOC)

Fig. 1.11 The Integrated topsides AMP1 for Amenam/Kpono project (Courtesy of Elf Petroleum Nigeria)

Take the Amenam/Kpono project as an example, the integrated topsides AMP1 weighed 11,970 tons and structurally consisted of three decks including a weather deck, the main deck and a cellar deck with an additional smaller mezzanine deck (see Fig. 1.11). After the construction of the whole topsides at the yard, it was then transported and installed using floatover method by Dockwise's Mighty Servant 3.

On the topsides, there were 130 systems to be installed, connected and commissioned at the yard. The processes and procedures required for commissioning in the yard were established well before integration of the modules, which resulted in the effective execution of the main commissioning program. The earlier commencement of the topsides equipment commissioning has the following advantages:

- Allow equipment vendors to carry out the installation and required tests much less dependent of weather conditions.
- By performing final mechanical integration, commissioning and testing for all topsides systems inshore before being transported to the offshore field, higher utilization of labor and equipment can be achieved.
- It can also create time for more testing work to be added to the planned work scope for verification of the integrity of the system, which leads to gaining greater confidence on reliable early production operation.

Fig. 1.12 Large SSCV's. On the *right* is HMC's Thialf of which the nominal lifting capacity is 14,200 t and on the *left* is SAIPEM 7000 with nominal lifting capacity of 14,000 t (Courtesy of HMC and Saipem)

- Offshore HUC work scope can then be minimized to the final hook-up of the subsea wells and equipment, offshore pipeline and the commencement of production.
- It may also create opportunity to make post-installation offshore HUC more cost effective. Representatives of operators, contractors and vendors form the aforementioned commissioning team. The intensive efforts inshore help building up mutual trust and enhancing team spirit, which will result in rapid restart of commissioning work after the topsides installation.

The challenge with an integrated topsides design process is that for large and complex systems, it often becomes inefficient at the design stage due to the amount of information to be managed as a whole. This may result in a design process that focuses on finding a feasible solution rather than finding a good solution.

Furthermore, the weight and the size of the integrated topsides installed to date before the invention and application of floatover technology had been limited by the capacities of the installation methods used, for example, the available heavy lifting vessels. Although the SSCV's (Semisubmersible Crane Vessel) such as Thialf of Heerema Marine Contractors and Saipem 7000 of Saipem S.p.A. are available with the nominal lifting capacity reaching 14,000 tons, the topsides with large dimensions needs an extended crane radius. The combination with dynamic effects and uncertainties in weight and COG, generally results in a considerable decrease in lifting capacity. Looking into the records of the SSCV, it shows that in 2000, Thialf, the largest one, set a world record of lifting Shell's Shearwater topsides of 11,883 tons by a single lift; later Saipem 7000 lifted the Sabratha topsides of 12,150 tons and has been keeping this new record since then (Fig. 1.12).

As a result, two options exist for accommodating the situation of installation using HLCVs (Heavy Lifting Crane Vessel). One of them is to lift the semi-integrated topsides and after that to install additional smaller modules on to the top of the already installed topsides, which is still more cost-effectiveness than modularized installation. The other is to reduce the topsides weight by the approach of Single Lift Topsides as already tried and succeeded by some projects.

- Single Lift Topsides [13–15]
The single lift topsides is an integrated topsides, which emphasizes the reduction of the total weight of the topsides so that the whole integrated topsides can be installed by single lift operation. Since the structural steel weight is the large portion of the total weight of the topsides (Some estimation says approximately half of the total weight), therefore the main efforts have been made on the weight reduction through the optimization spiral during the topsides structural design. Systematically optimized design leads to reduced pieces of equipment, less piping, less structural steel, reduced interconnecting for pipe and electrical cable, fewer junction boxes. Also the measures such as
  - locating heavy equipment at the spot with the most strength, say, directly on girders and trusses
  - using high strength steel when is possible
  - using lightweight decking for equipment, etc.

Fig. 1.13 Lightweight single lift topsides for Shell Perdido Spar was loaded out from Kiewit Ingleside yard (Courtesy of Shell) [16]

help to make the weight of the single lift lightweight topsides significantly less than the conventional topsides performing the same function.

One of the key results of a lightweight design is that the supporting substructure, whether fixed or floating, can be made smaller. On the surface, the lightweight single lift topsides is confined to as a solution corresponding to the limited capacity of available heavy lifting vessels. In fact, at the end, the successful design will benefit the substructure design as well as the whole project.

There are no simple guidelines for achieving the goal of the lightweight topsides design. It is a case-by-case matter and highly depends on the experiences and innovative initiation of engineers. For each project, the selection of equipment and distribution of the weights depend on multi-factors including working environment, operational requirement and human factors. The safety and functionality are still the important topics to be addressed although the efforts are made on weight reduction. In published articles, some details of the design of the lightweight single lift topsides of Shell Perdido spar were revealed. The highly intensive effort level can be felt when read them. The following are some brief discussions on it (Fig. 1.13).

The topsides of the Perdido spar consists of three decks to support the oil and gas processing systems, a drilling rig and the living quarter. The spar hull was built in Finland, while the topsides was built in Kiewit's Ingleside yard in Texas. According to the topsides design team, a 3-D model of the topsides with details was really useful and became a critical design tool. By going through 3-D modeling with equipment and systems, not only the weight distribution and supporting structural design could be checked and adjusted repeatedly, but the topsides design could be more human with considering the good habitability, working environment, maintenance convenience, safety assessment, etc. as well. Talking about the structural design, for heavy equipment such as the generator, besides making sure the solid supporting structures in position at the equipment standing spot, the strength and spatial clearance of the pathway during the repair

Fig. 1.14 On the *left* the lightweight single lift topsides is installed to the Perdido hull by HMC's Thialf with one single lift and then the living quarter module was put atop the topsides three days later (Courtesy of Shell)

and replacement in future could also be examined in details. Obviously, the comprehensive efforts in design led to better steel weight efficiency as well as the optimization of topsides functionality.

As shown in Fig. 1.14, in March of 2009, HMC installed the 9500-ton (8618 metric ton) single lift topsides on the Perdido spar hull using its SSCV Thialf and then put the living quarter atop it. It is the heaviest single lift topsides installed by HLCVs in the GOM. The water depth is almost 2500 m.

It is an indisputable fact that single lift topsides will save money and time of the project. Of course, the amount of savings is case by case for projects. As published articles mentioned, for some big project, the saving can reach \$60–\$100 mm in cost and 3–4 months on offshore HUC. It also reduces the safety risk.

1.2.3 *Jacket Design*

The discussion in this section does not cover the details of the platform jacket design but only on how does the selection of the topsides installation method affect the jacket design and the consequences of the late topsides installation method change when the jacket design is completed or near completed.

For non-FPSO multi-column floaters of which the spaces between the hull columns are large enough for installation vessels to go through; or for single columned floaters such as spars, the substructure design is dominated by the in-place performance requirement. There is little difference for the platform substructure design in responding to the selection of the platform integration method—either by heavy lifting or by floatover including catamaran floatover.

However, it will be quite a different story for the jacket design of a fixed platform. Ideally, the topsides installation method should be decided before the commencement of the jacket design and the selected method should not be changed through the project execution.

Look at Fig. 1.15, on the right side of the figure is a conventional jacket design with the topsides to be installed by HLCVs and on the left side, the jacket is specifically designed for the floatover topsides installation. Both are qualified jacket designs if purely consider the need of supporting the topsides weight and withstanding the environmental loads without including the topsides installation method as a design factor. Structurally, both of them are a steel space frame with tubular members and directly seated on the seafloor. The installation of themselves following the same operation steps: loading-out, transportation, launching, upending, piling and grouting.

If the topsides of the fixed platform is installed using the single barge floatover method, based on the topsides weight and the candidate floatover vessel, the open space between the jacket leg rows must be carefully identified for docking, mating and vessel removal. That means not only the distance between the two leg rows should be large enough, but also the depth of the opening should be large enough

Fig. 1.15 Jacket design with consideration of topsides installation (Courtesy of Chevron and COOEC respectively)

corresponding to the depth of the vessel considering the possible maximum draft of the vessel when she is ballasted down to be removed through the opening after the completion of mating operation.

When the above-mentioned opening is decided, obviously the load transferring of topsides weight to the jacket is different from the conventional jacket design. Take the jacket shown in Fig. 1.15, it is obvious, that the topsides weight load is directly passed to four legs of the jacket designed for floatover installation instead of eight legs for the conventional design. To strengthen the four legs and better distribute weight loads to the entire structural frame, more braces are added to the structure of the jackets designed for floatover operation. At the same time, the topsides structure design is affected correspondingly, especially on the weight distribution handling.

To optimize the jacket design, take the Bayu Undan project [17] as an example, the opening between the two leg rows are large enough for the Dockwise's semisubmersible heavy lifting vessel Black Marlin with the width of 43 m and the depth of 13.30 m to perform docking and withdrawing. The distances between the

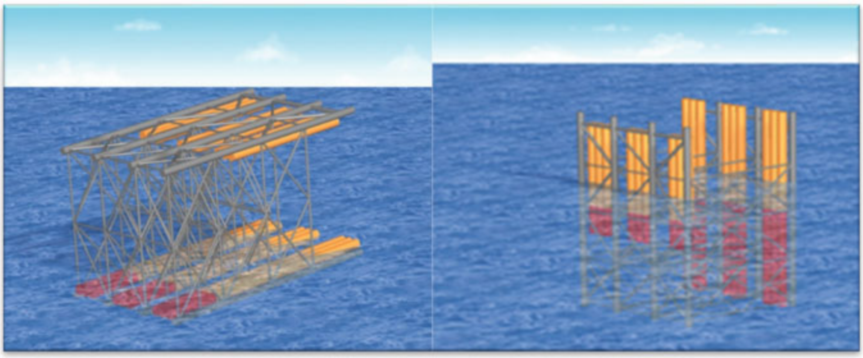

Fig. 1.16 One of the Bayu Undan platform jackets (Credit to Bayu Undan project)

adjacent legs of each row of legs are evenly distributed. The jacket design is for floatover installation from the beginning of the project.

Compare the two jacket designs shown in Fig. 1.15 on the right and in Fig. 1.16, the differences are huge. It is obvious that when the design of the jacket shown in Fig. 1.15 is completed, the design can hardly be converted to the jacket design shown in Fig. 1.16 through simple structural design modification. It is convincing that the platform integration method should be selected before the platform design starts, since the topsides installation methodology is an important input to the design of both topsides and the substructure.

In Sect. 1.3, the discussion will go in depth on the impacts of platform topsides installation method on the design and construction of the topsides and substructures. It will show the importance of deciding the integration method at the very early stage and keeping the selected method not changed through the whole project.

1.3 Consideration of Construction and Integration of Topsides and Substructure

Hope the discussion in the above section clearly listed the important factors for consideration in the platform topsides design. One important topic to discuss is how to integrate the topsides with the substructure after the fabrication completed separately. The entire discussion emphasizes the importance of selecting the topsides installation methods and sticking to the decision.

1.3.1 Platform Design Strongly Related to the Methodology of Platform Integration

It is well known that the oil and gas offshore field projects have been globalized. For large platform projects especially deepwater projects, platform fabrication is often by more than one construction yard. Quite often, the topsides fabrication and assembly are at one location and the construction of the jacket or hull is at a fabrication facility far away.

There are two main reasons for this kind of project arrangement. First, the offshore platform fabrication industry is very competitive, and the technology development with fast pace is not very balanced. Some yards with first classed advanced equipment and accumulated construction experience can make attractive cost-effective offer with high quality. Secondly, the operators have to make compromise in dealing with the requirement of local factors. The following are two project examples.

In Fig. 1.17, two real projects are taken as the examples. On the left side is the topsides transportation route map of the Lan Tay platform of BP Nam Con Son Gas

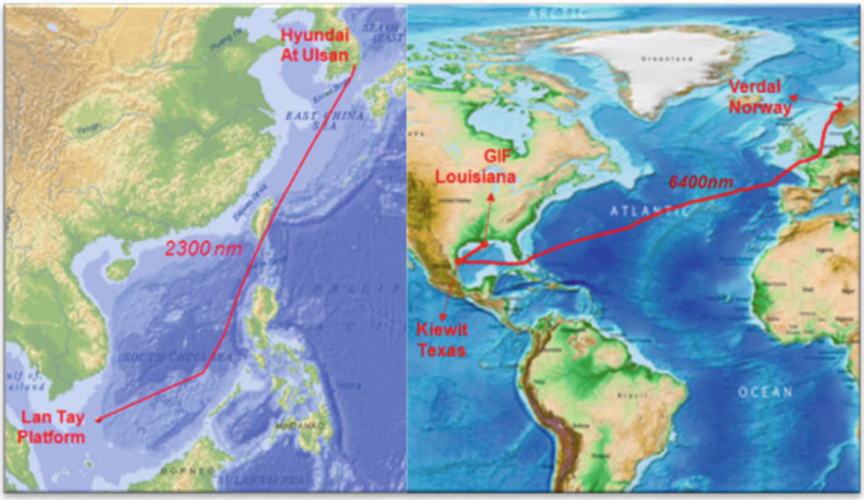

Fig. 1.17 The long journey of the topsides/hull to the integration site. On the *left* is the long journey of the transportation of Lan Tay topsides to the offshore installation site; on the *right*, it shows the transportation routes to the integration site of DDS Blind Faith—the hull from Norway and the topsides from Louisiana (Based on information from BP Lan Tay project and Chevron Blind Faith project respectively)

project. Hyundai Heavy Industry (HHI) in Ulsan, South Korea fabricated the topsides. After the completion of fabrication, the 5500 tonne topsides was transported by barge Semco Giant V from Ulsan South Korea to the offshore site of Lan Tay platform, where the topsides was mated with the already installed jacket.

The right side map is about the inshore integration of the Chevron DDS (Deep Draft Semisubmersible) Blind Faith production platform before the platform was integrated and wet-towed to the offshore field. Aker's Verdal yard in Norway fabricated the Blind Faith semisubmersible hull. Dockwise's HLV (Heavy Lifting Vessel) Tern transported the completed hull to KOS (Kiewit Offshore Services) yard in Ingleside near Corpus Christi, Texas. The heavy lifting facility of the yard performed the platform integration. The journey was about 6400 nm. KOS yard was the site of integrating the topsides and the hull.

The construction of the Blind Faith's topsides was not at KOS, but in GIF (Gulf Island Fabricators) Shipyard in Louisiana. After the fabrication, an American flagged Crowley barge "Marty J" transported the topsides from GIF to the KOS yard for platform integration.

The pictures in Fig. 1.18 show the completion of the construction of the above mentioned platform topsides. On the left, it shows the completed Lan Tay topsides at HHI (Hyundai Heavy Industry) Ulsan, Korea. The photo shows the topsides was loaded out to the transportation barge SEMCO Giant V barge. The picture on the right side is the topsides of Chevron DDS production platform Blind Faith that was ready for loadout.

Fig. 1.18 The topsides fabrications: On the *left*, it shows the loadout of Lay Tay topside and on the *right* is the completion of the topsides of Blind Faith (Credit to the BP Lan Tay and Chevron Blind Faith projects)

For Lan Tay platform, which is a fixed platform, the jacket had already been installed in the offshore field as shown in the left picture. The topsides of the platform were transported directly to the field and the entire platform integration would be completed through the mating of the topsides with the already installed jacket. The transportation barge SEMCO Giant V carrying topsides of the Lan Tay platform was towed more than 2300 nm from the HHI fabrication yard at Ulsan, South Korea to the Nam Con Son Gas field offshore Vietnam.

On the other hand, the integration site for the Blind Faith production platform was not offshore but at the KOS where before the topsides was transported from GIF shipyard, the hull had already arrived after a long journey on the Dockwise HLV Tern (Fig. 1.19). The Blind Faith topsides fabricated at GIF shipyard was loaded on the Crowley Marty J and towed in GOM (Gulf of Mexico) from Louisiana to Ingleside in Texas (Fig. 1.20).

The integration of the platform would happen at KOS and then the platform would be wet-towed to its offshore site and the installation would complete there after the DDS was hooked up with the pre-installed mooring system.

The topsides of the two platforms in discussion are both integrated topsides and minimized the offshore HUC work scope. The two examples show the application of the two different methods of the platform integration. The Lan Tay platform topsides was installed on the jacket by floatover, while the Blind Faith platform

Fig. 1.19 The mating sites for Lay Tay platform and DDS Blind Faith (Credit to the BP Lan Tay and Chevron Blind Faith projects)

Fig. 1.20 The topsides were transported to the mating sites: on the *left* the barge was towed to the offshore site and on the *right* the topsides was towed to KOS yard (Credit to the BP Lan Tay and the Chevron Blind Faith projects)

integration was done by using the huge cranes at KOS. The jacket of the Lan Tay platform design is specific for the floatover installation method. Although both topsides are integrated topsides, the topsides structural design for Lan Tay are optimized based on the consideration of transportation and the docking and mating operation. The design of the Blind Faith topsides considered the lifting operation in structural arrangement and weight distribution. Hypothetically, the two topsides hold exactly the same equipment; the two topsides designs will still not be exchangeable (Fig. 1.21).

Through the above discussion, hopefully it can be comprehended why early development of the platform integration methodology and careful operation planning are vital for the project to be successful.

Fig. 1.21 The platforms were integrated with different approaches—Floatover versus Heavy Lifting (Credit to the BP Lan Tay and the Chevron Blind Faith projects)

1.3.2 Impact of Changing Integration Method

In the oil and gas offshore industry, a field development project may take years from the beginning to the fabrication of the topsides and the substructure. Although selection of the methodology of platform integration has been made and corresponding plans has been in place in the early stage of the project, there are still possibilities of making final changes of the integration method because various reasons such as schedule change, installation vessel availability, etc. In recent years, this kind of situations happened to several fixed platforms. The original platform designs started based on the assumption of installing the topsides on the jacket through lifting by crane vessels. However, when the design of the jacket and the topsides reached the stage of fully or partially completed, a new decision came to install the topsides by applying the floatover technique.

To cope with the situation, taking fixed platforms as examples, then two options are available for consideration:

- Apply catamaran floatover by using two vessels and try to make minimum modification on the jacket.

  This option sometimes may not be feasible because of technical issues or cost effectiveness. Talking about the catamaran floatover, (detailed discussion will be covered in Chap. 6) generally, three vessels need to be hired to carry out the operation: one of them is used for the topsides loadout and transportation. The topsides will then be transferred to two parallel barges to form a catamaran near the installation site and complete the mating of the topsides and the jacket (Fig. 1.22).

  With this option being selected, there should be NO need for major modification of the jacket, but the modification of the topsides structure often is

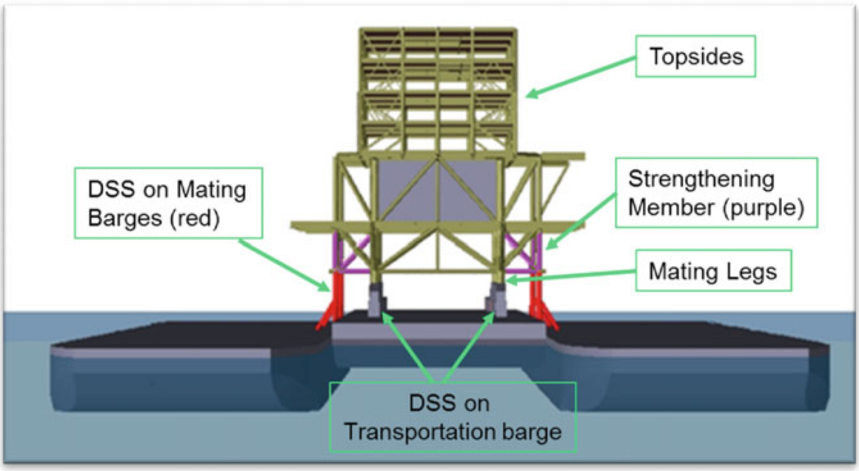

Fig. 1.22 DSSs related to the option of applying catamaran floatover method

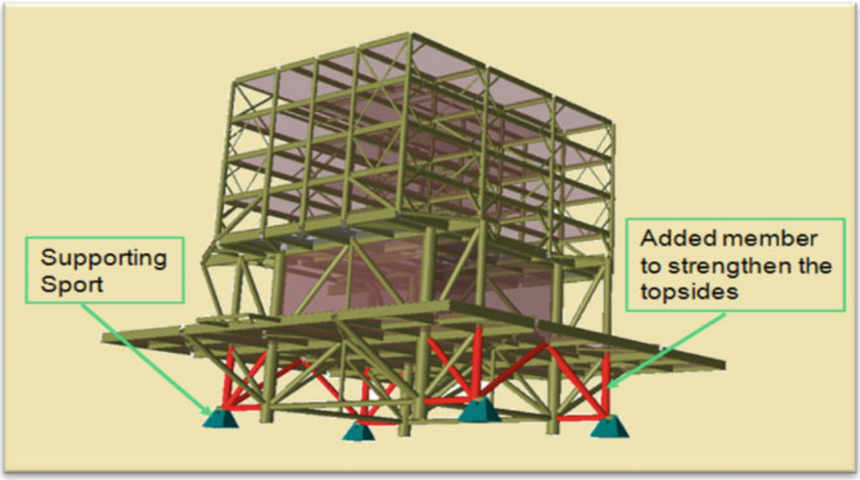

Fig. 1.23 The local strengthening members added to the topsides structure

necessary because of the need of supporting spots underneath the topsides of the DSS on the mating vessels besides the DSS on the transportation vessel for topsides transportation. Clearly, structural enhancement around the newly selected supporting spots is inevitable. At the same time, because of the large span between the DSSs on the two mating vessels, the design of the DSS on each mating vessel is quite challenging (Illustration is shown in Fig. 1.23).

When floatover method is applied to single column floater such as spar, there should be not much hull structure change required, but certain topsides strengthening efforts are inevitable.

- The other option is to apply floatover using a single vessel.
  The challenges for this option are tremendous when it happens to fixed platforms:
  - Jacket design modification
    If a fixed platform design is for platform integration by heavy lifting operation, the distances between the adjacent jacket legs are generally not large and no space to allow a sizeable vessel large enough to carry the platform topsides, to float in-between the two rows of the legs. Therefore, the creation of an opening with the cutting/removing jacket members is necessary. At the same time, to ensure the structural integrity of the jacket, adding structural elements and strengthening some of the retained structure elements are inevitable. When time allows, the design optimization should also be gone through. Sometimes, the work scope is almost close to the jacket re-design and there might be even tougher technical challenges than designing from scratch. It is not so hard to see that when decide to change the platform

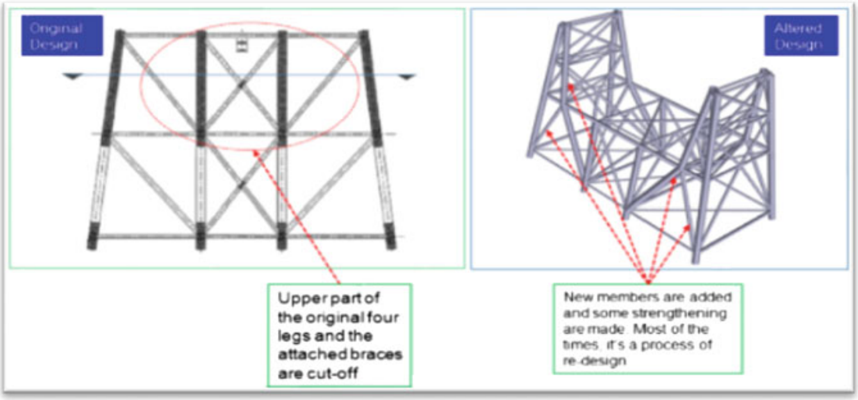

Fig. 1.24 An 8-leg fixed platform structure modification to fit in the needs of single vessel floatover topsides installation

integration method; the consequence is often quite complicated. Let us take the following case as an example for illustration.

The example shown in Fig. 1.24 comes from a real case study. The design of the 8-leg fixed platform was originally for the platform integration using crane vessel at the installation site. The eight legs of the platform will be anchored at the offshore site by driven piles. For this platform, looking along the longitudinal direction, the distance between the two rows of four legs is narrow and not enough to open a space for a floatover vessel. The only choice is to carry out the floatover operation by sliding in the floatover vessel in the transverse direction of the jacket. As shown in Fig. 1.24, four internal legs are cut off to create an opening large enough for the topsides carrying vessel to float in before the mating and to be able to withdraw after the completion of the integration. The cutting-off of the internal four jacket legs makes the topsides to lose four supporting spots. At the same time, on the jacket side, the loading distribution and load supporting mechanism are different from the original design. Modification must be made to the jacket structure design to re-arrange the load transfer and load distribution. In Fig. 1.24, the modification is close to a re-design in the efforts to make the re-distribution of the loads on the jacket optimized and still have a space large enough for the floatover operation.

Quite often, when the decision is made to change topsides installation method from heavy lifting to floatover, it is very desirable to avoid a complete jacket structural redesign because of the huge engineering workload and the tight schedule. Minimized alternation in structural design is pursued. For a case similar to the one in discussion, an option in consideration is to strengthen the outer four jacket legs by adding on structures attaching to the legs and braces without major changes to the remaining leg design (Just as shown in Fig. 1.25).

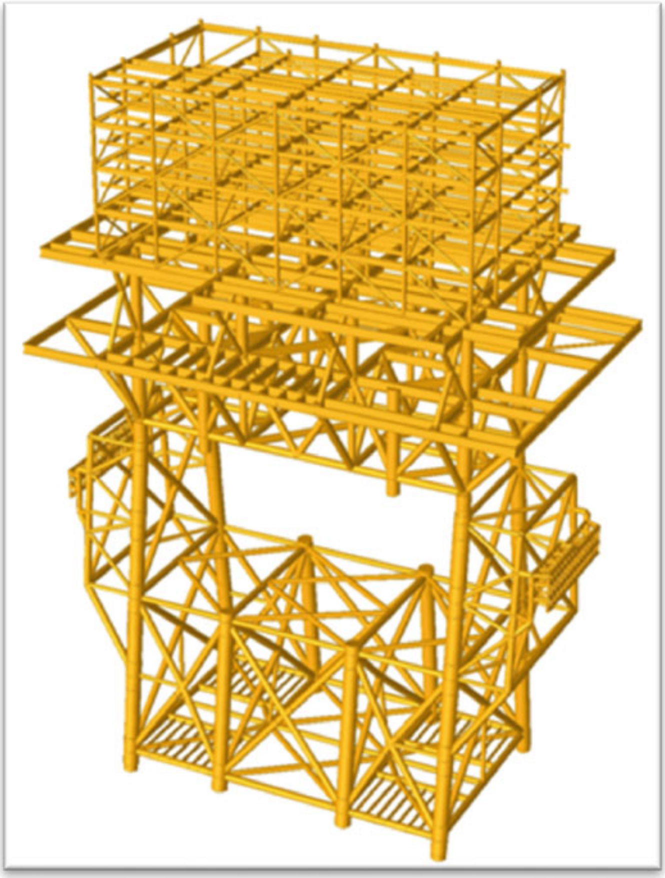

Fig. 1.25 An proposed concept to minimize the modification by adding strengthening structures

Of course, it depends on the original design, e.g., if the legs have no supporting capacity margin in the original design, then some major changes are inevitable. For this case, the driven pile size does not need to change either. The differences are the piles of the four internal legs are shorter and the installation being carried out by underwater hammer.

– The topsides design modification side
Comparing to the selection of catamaran floatover in option 1, for single vessel floatover option the impact of alternation of topsides installation methodology is much stronger on the topsides design. Working on the main load carrying members is often required.

When choosing to install the topsides on the substructure by heavy lifting, no matter it is a jacket or the hull of a floater, one must first to identify the "lift points" at the main structure of the topsides. There is a lift rigging

Fig. 1.26 The mechanism of the topsides lifting by crane (Courtesy of Shanghai Salvage Bureau)

system to be chosen or designed to connect the crane and the topsides through these lift points (Fig. 1.26).

Understandably, the loads for the topsides main column members near the lift point to undertake during the lifting operation are the pulling loads. The horizontal members also expose to the bending moments. Correspondingly, the structural members of the topsides steel frame will be selected and designed to provide the supports in an optimized way. When the installation method changed to floatover, this original design optimized for heavy lifting operation has to be modified to accommodate the load distribution change during loadout, transportation and mating operations.

First, let us look at the DSS on the transportation vessel.

When the topsides design is for mating by lifting, advantage can be taken by using the DSS directly supporting the topsides mating legs during the topsides transportation. The topsides weight distribution is well handled. For floatover, the DSSs will support the topsides at different spots beneath the topsides structure. The comparison is shown in Fig. 1.27.

Fig. 1.27 Differences in the structure design of topsides for transportation (Courtesy of Chevron and CNOOC)

On the left of Fig. 1.27, the topsides design is for mating with the jacket by an HLV. The four mating legs are directly seating on the DSS mounted on the transportation vessel during the transportation. The design distribute the weight of the topsides through the four topsides mating legs from the construction to the final platform integration by design. The entire topsides structural design also takes care of the lifting operation with assigned lifting spots.

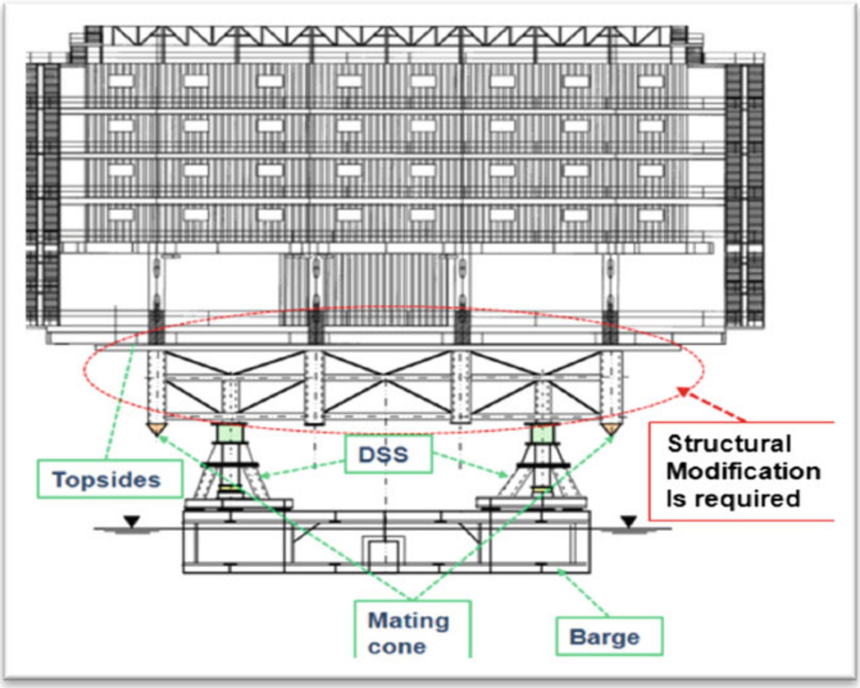

Fig. 1.28 Illustration of the modified topsides underneath part

On the right of the picture, the topsides design is originally for installation by floatover. During the transportation and before the mating, all the mating legs of the topsides are unattached in the air during the transportation, therefore the DSSs design should be able to safely support the weight of the topsides and properly distribute the topsides weight and the supporting load to keep the integrity of both the topsides and the transportation vessel.

The sketch in Fig. 1.28 shows the commonly chosen approach in the modification of the topsides structure when the installation method changes from heavy lifting to floatover. In the discussed case, the originally designed four internal mating legs will not share the topsides weight. To minimize the modification of the topsides structure frame but to have the best weight distribution supporting during the loadout and transportation at least the local structure near the DSS supporting spots need modification besides the local strengthening around the four outside mating legs.

As discussed earlier, when the installation method changes from lifting by crane to floatover, the loading mechanism is changed. The members bearing pulling stress in the original design may be under compressing loads after the installation method changes. Bending moments acting on the structures also change as the results of installation method change. Figure 1.29 shows the

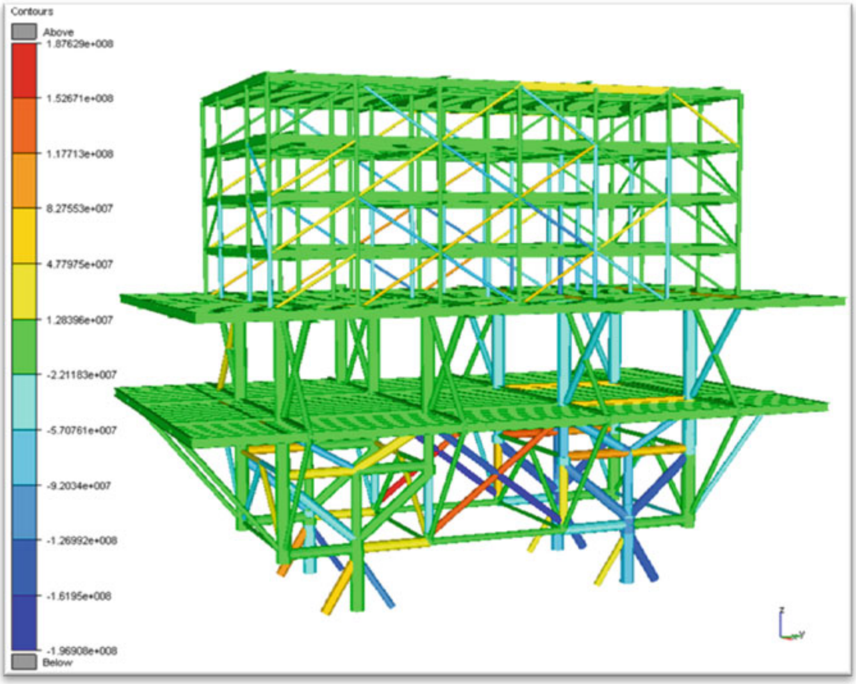

Fig. 1.29 Axial stress analysis results of the altered topsides structure

stress level code checking of the topsides after the topsides structure modification. The stress level checking results show that after the modification, the topsides structure can function during the installation and the in-place service.

In summary, for platforms designed with integrated topsides, the method of platform integration should be decided in the early project development stage and the decision should be stuck to through the entire project. Changing topsides installation method at late project stage, not only creates a large amount engineering work, but also brings negative impacts on project cost and schedule.

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Chapter 2
Platform Integration and Stationing

Abstract There are many kinds of platforms designed to be suitable for the specific working environment. For each platform design, there is a best corresponding platform integration method to make the operation safe and cost effective. Discussions in this chapter present various kinds of platforms and the corresponding integration method options. Through discussions with examples, the history of platform concept development and the corresponding platform installation technology are presented with information in certain depth. For fixed platform and floaters, the most used platform integration method is still by heavy lifting for both modularized topsides and integrated topsides. However, the design and fabrication of massive and heavy integrated topsides make the floatover method a better choice. The conclusion can be drawn from the installation activities of real projects carried out at different time along the offshore industry history.

In offshore industry, activities in offshore oil field need equipment be on site temporarily or permanently including platforms of both drilling and production. In this book, the word of "station" is used as a verb to mean putting the platforms to a position in the ocean ready for operations. To keep the platform at a selected spot with the constraint of moving horizontally is thus called stationkeeping. There are various ways to achieve stationkeeping of a platform. In water not so deep, fixed platform, compliant towers and jack-ups are directly standing on the sea floor through structures as jackets and legs by which the motion of topsides is under control. GBS including Condeeps sit on the sea floor and keep themselves at the spots by their heavy weight. For floaters like FPSOs, drilling semisubmersibles and drilling ships, DP (Dynamic Positioning) systems can also apply. TLPs station by high-tension tendons, while most of the FPSOs, semisubmersible production platforms and spars station by mooring systems. As we already touched the topic of platform design and construction, and clearly that for non-FPSO platforms, the topsides and the substructures are generally fabricated separately and then be integrated together. For some cases, platform integration happens before it is stationed in the field, but for others, the substructure is first stationed in the selected

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spots and then the topsides is integrated with the substructure on site as already briefly talked in the earlier chapter.

The focus of this chapter is neither on the DP systems nor on the FPSOs. The discussion will be on various kinds of operations for platform integration and the methodology corresponding to the platform integration operations. Discussions in certain level of depth in this chapter present various kinds of platform integration methods. Some discussions go with examples and the rest of them are only at the introduction level. Hope that the materials presented show the spectrum of platform integration methods including the well-known heavy lifting and floatover methods. Floatover method is the core of this book and all discussions with technical details will be concentrated in the following chapters.

2.1 Self Installable Platform

The meaning of "self-installing" in this section is that the topsides and the substructure of the platform are physically already combined into one before the platform is stationed to the selected location at the field. The substructure generally consists of movable legs attached to the topsides. When the platform arrives at the pre-selected location in the field, the supporting legs will lower down to the sea floor. The legs will then anchor the platform in the location and support the topsides. Through further adjustment the topsides, the air gap reaches the design value and the platform is ready to serve. The whole installation process may need assistance of installation vessels such as OCV (Offshore Construction Vessel), AHT (Anchor Handling Tug), although the "self-installation" is applied.

The self-installable platform concepts are generally suitable to the shallow water and platform with smaller topsides, some platforms developed with these concepts have already been built and in service. However, efforts have extended to the application of self-installation concept in deepwater; one well-known trying was the Technip's TPG 3300 and later evolved into EDP (Extended Draft Platform), which will be introduced briefly in this section. One of the intentions of developing these concepts is to create the advantage of relocating the platform during the service life. The design makes the relocation of the platform less complicated and cost effective.

A few concepts of self-installed platforms are introduced in this section: jack-ups, SPT (Suction Pile Technology)'s SIP (Self-Installing-Platform) II platform F3-FA and Technip's EDP concept.

2.1.1 Jack-Ups

The Jack-up platform sometimes called "self-elevating" platform is no stranger to the Oil & Gas industry and started to serve the offshore industry since 1950s [1]. A Jack-up platform, also called Jack-up rig or Jack-up barge, works mainly in the shallow water, some can go to the depth of 150 m and at most 190 m. The Jack-up concept distinguishes itself from other platform concepts by the characteristics of mobility and self-elevating capacity. So far, only a few Jack-up platforms in service are production platforms such as BP's Shah Deniz TPG500 platform in Caspian Sea [2, 3] (Fig. 2.1).

However, more of the jack-ups serve as drilling rigs and offshore supporting vessels including the ones carrying out offshore wind turbine installation in recent years. As an offshore drilling platform, jack-up platform can be moved to the drill site and quickly stands on the seabed by the legs lowered using onboard equipment and thus ready for the new well drilling (Fig. 2.2).

The first Jack-up platform was a drilling rig with three legs design by LeTourneau. The contract was signed on November 11, 1954. The platform was basically a large, shallow-draft barge, equipped with three electromechanically-operated lattice type legs. The construction of the platform was completed in December of 1955 and started the first drilling in March 1956 (Fig. 2.3).

The speed of reposition for new well drilling of Scorpion quite impressed the industry at that time, comparing only a few hours to days for other type of platforms. Jack-up platforms especially jack-up drilling platforms have been the most popular among various kinds of floating offshore structures in existence (Fig. 2.4). In the worldwide offshore rig fleet, there are more jack-up drilling platforms than MODU (Mobile Offshore Drilling Unit) such as semisubmersible drilling rigs and drilling ships. The total number of jack-up drilling rigs in the world was about 540 at the end of 2013.

There are many different designs of jack-up platform. However, the three (3) most important components are necessary, which are the water-tight floating hull providing required buoyancy for transportation, the supporting legs and the jacking systems lowering/lifting the legs when needed. Jack-up drilling platforms in earlier years had square or rectangular hulls with more than three legs, the earlier designed jack-up rig Mr. Louie in the North Sea even had sixteen legs. Most of the modern jack-up hull are triangular and with three lattice legs [4, 5].

Fig. 2.1 BP Shah Deniz TPG500 production platform which is a Jack-up with 3 legs (courtesy of BP and Keppel Group respectively)

Fig. 2.2 On the *left* is the three leg Jack-up drilling rig JU2000E of COOEC and on the *right* is the Jack-up offshore supporting vessel *Innovation* with four legs (courtesy of Shanghai Waigaoqiao Shipbuilding and Wikimedia commons respectively)

Fig. 2.3 The first jack-up scorpion is designed and fabricated by R. G. LeTourneau, Inc. The hull size is 186 × 150 × 24 ft and the steel legs (spuds) are 140 ft long. The platform weighed 4000-ton (courtesy of Rowan)

Fig. 2.4 On the *left*, it showed two different designs of jack-up drilling rigs waiting in Fourchon channel—one with *triangular* hull and lattice legs and the other with four columnar legs and a *rectangular* hull; The *right* photo is the British jack-up drilling rig with ten legs (Sea Gem) (courtesy of Houston Chronical and Duke Wood Oil Museum respectively)

The jack-up platforms including drilling rigs and production platforms can be moved with legs being jacked up in the air and the hull floating on the water surface by wet tow. However, most of the relocations were by dry tow using semisubmersible HLVs. The jack-up platform are floated on and sits on the deck of the submerged HLV and then being lifted up and transported to the new service stationing location (see Fig. 2.5). When choosing the vessel for dry tow, transportation stability need to be strictly checked along the selected route and the operation weather window. Not only the total weight is important, the COG of the jack-up platform is also critical since the legs are quite long and naturally the COG of them are high.

At the offshore site, as the hull still in the water providing buoyancy, the legs lowered down towards the seabed to set up the supporting foundation. The foundation is formed not merely by the legs themselves, but also including either the supporting mat attached to all the legs or one spud can be connected to a corresponding leg at its bottom (see Fig. 2.6). By these specially designed structures, a jack-up platform can stabilize itself with only a few feet of sea floor penetration thus make the relocation process much faster.

By using the mat or the spud can, the soil bearing area increases. On the left of Fig. 2.6, it shows a jack-up rig is on a rectangular flat “A” shaped structure with buoyancy chambers, which are flooded when submerge. The mat helps in weight distribution and reduces the bearing pressure on the seafloor. Mat structure are often used with columnar legs with the total weight of the platform not so high. It is not suitable for uneven seafloors or in areas where there are pipelines, boulders or debris on the seafloor [6, 7].

When using spud can for independent legs, the supported jack-ups can operate in regions that are more diverse: in soft and hard seafloor areas, uneven seafloor with slope, etc. For areas with pipelines, boulders or other debris, the position of the jack-up can be adjusted to avoid those obstacles. Spud cans work with lattice legs for most modern jack-up platforms. Figure 2.7 illustrate the stationing process of an independent leg supported jack-up platform.

Fig. 2.5 Transportation of jack-up platforms: the *left* shows “wet tow” by a tug boat and the *right* one shows “dry-tow” by a semi-submersible HLV (courtesy of COSL. and COSCO)

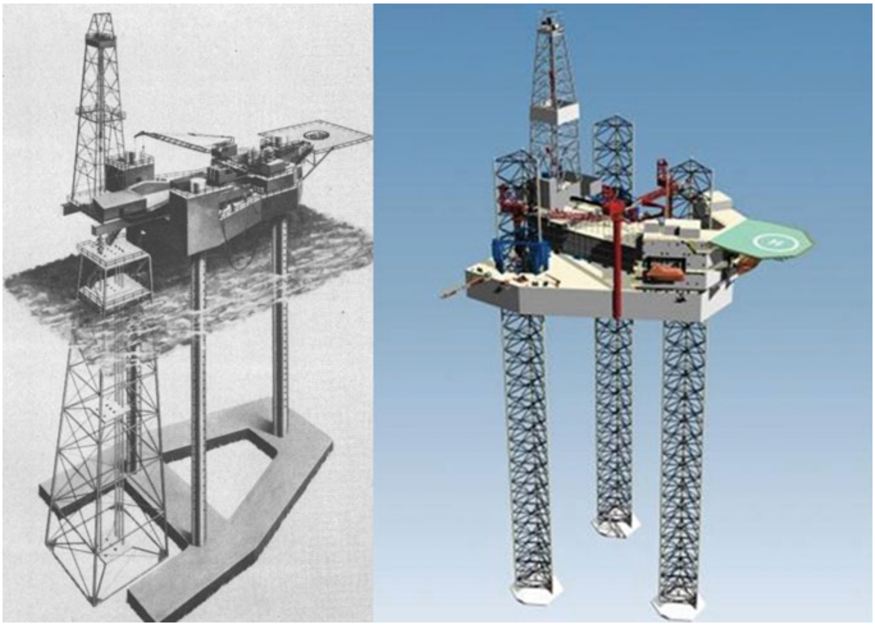

Fig. 2.6 Leg supporting structures: "Mat" versus "Spud Can" (courtesy of Maritime Communications and CIMC)

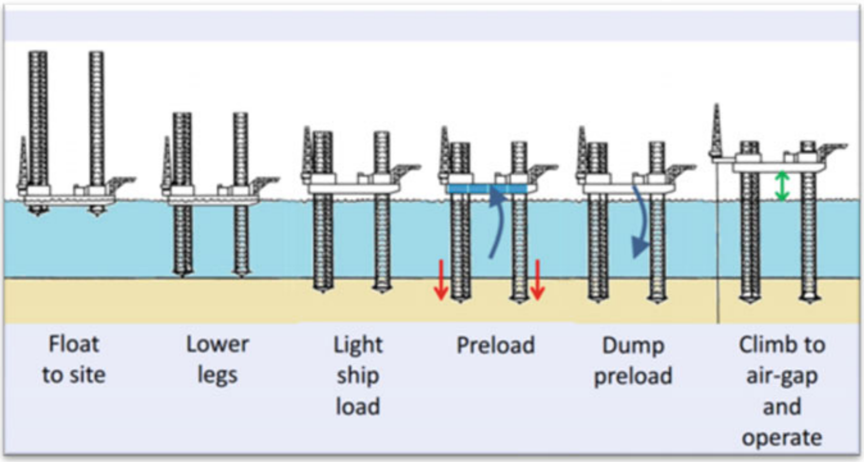

Fig. 2.7 The stationing operation process of an independent leg supported jack-up (after Poulos [8])

From the point of view of platform assembling, only when the topsides is jacked up to the designed working elevation with certain air-gap and locked, the platform is then fully assembled. Only starting from that moment the whole platform is ready to function. This applies to all jack-ups including drilling rigs, production platforms, offshore supporting unit as well as installation vessel for wind turbines. Therefore, the completion of platform integration should be at offshore, although it is generally accepted that the platform has already been integrated and the legs are installed into the hull openings inshore. Following the latter understanding, a jack-up is fully integrated after it left the yard and the stationing operation is the operation of self-installation. During the entire installation, no need of HLCVs and all depend on the hull and the jacking system aboard.

2.1.2 SIP II Platform [9]

The SIP II concept was developed by SPT Offshore, a Netherlands' company. The concept emphasizes that there is no need of HLCV during the offshore on-site stationing operation and the platform can be relocated with less complexity for re-use. The self-equipped jacking system can lower down the platform legs, anchor the platform with suction piles connected to the legs, and then lift the topsides up to the required elevation (Fig. 2.8).

Take the F3-FA platform as an example, there were two SIP II platforms built before it [10–12]. The platform has an integrated topsides with 5 level decks and weighing 4000 t. The topsides' dimension is 63 m × 42 m × 24 m. It was fabricated and outfitted deck-by-deck using the 'pancake' method at the yard of HFG (Heerema Fabrication Groups) at Vlissingen, Netherland. The substructure consists of four separated legs; each of them is connected to the anchoring suction pile together with a leg-stiffening frame. The configuration of the platform is illustrated in Fig. 2.9.

Fig. 2.8 SIP II concept platforms: on the *left* is Calder SIP II platform in 30 m water depth in Irish Sea, UKCS; on the *right* is F3-FA SIP II platform in 40 m water depth near Dogger Bank in the North Sea (courtesy of SPT Offshore)

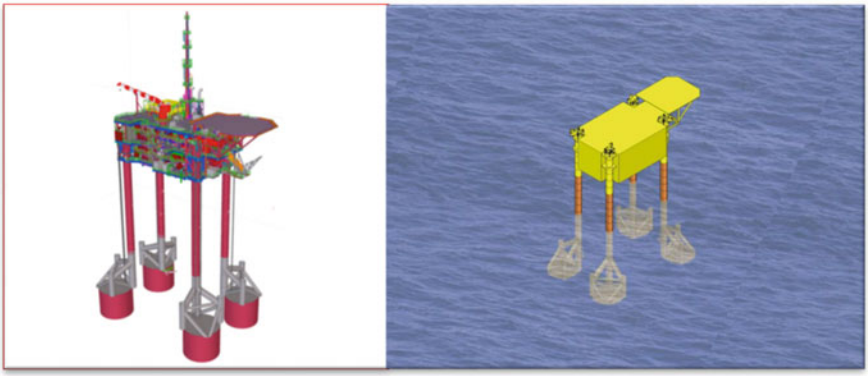

Fig. 2.9 3-D view of SIP II platform. The whole platform is already integrated as shown before being transported to the stationing location at the field (courtesy of iv-Gas and Oil and SPT Offshore respectively)

Fig. 2.10 On the *left*, the fabrication of the 4000 t topsides is completed and moved out from the fabrication hall and ready for the leg installation; on the *right* shown the installation of the legs by the yard crawler cranes (courtesy of Centrica Energy)

After the 4000 t topsides was completed and moved out of the fabrication yard, the four substructure legs are attached to the topsides by the crawler cranes with capacity of 1350 t in the same HFG yard. Each of the legs is 78 m long and 3.5 m diameter and weighs 350 t. By design, each leg would be held by a 9 m long guide sleeve fixed between the top and intermediate deck levels at each corner. A clamp was welded around each leg at the topsides cellar deck level (see Fig. 2.10).

Fig. 2.11 For each suction pile, the leg-stiffening frame was already welded to it and the assembly was ready to be connected to the platform leg (courtesy of Han Heilig, publisher of Offshore Holland, the Netherlands)

The concept of SIP II, by design, is to connect the legs with corresponding suction piles before the platform to be transported to offshore field, but not on the land.

First, each of the suction piles would be welded with the leg-stiffening frame of tubular members ready for attaching to the legs. This operation is completed on land at the HFG construction yard at Vlissingen and the pile assemblies were ready to be connected to the platform legs, which are already integrated into the topsides (Fig. 2.11).

The connection of the leg and the leg stiffening frame/suction pile assembly is carried out in the water after the topsides being loaded out to the transportation barge, which was BOA barge BB35. Considering the transportation and stationing operation at site including the environmental condition, the grillage on BB35 is 6.5 m high by design and it weighs 850 t. The total weight of the grillage and the topsides with four legs reached 6200 t. To cope with the constraint of maximum bending moment of the hull of BB35, the topsides assembly was first loaded out to the Heerema's barge H-451 and then be moved to BB35 (Fig. 2.12).

Fig. 2.12 Loadout of F3-FA topsides. On the *left*, it shows the topsides was being loaded out to the transportation barge at the fabrication yard. On the *right* the topsides was first moved on board Heerema barge H-541 and then positioned on Boa Barge 35 (courtesy of ©Heerema Fabrication Group)

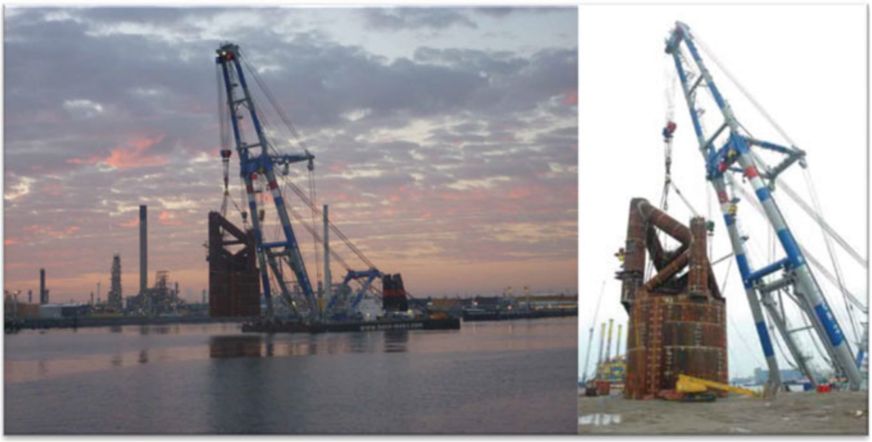

Fig. 2.13 Suction bucket with leg stiffening frame on the top is lifted by Matador 3 and put in position to be connected to the platform leg (courtesy of ©Heerema Fabrication Group)

Then, the suction pile assembly will be connected to the bottom of each leg with the assistance of the sheerleg crane Matador 3 of Bonn & Mees and the strain jacks temporarily installed on the topsides. Each pile assembly weighs 900 t (Fig. 2.13).

The leg stiffening frames together with suction piles are welded to the bottom of the corresponding legs. The frame helps to align the suction pile edge with the leg and make better load distribution. The attachment of the heavy suction piles helps to improve the transportation stability and raise no issues for transportation operation (Fig. 2.14).

Fig. 2.14 After the leg stiffening frame together with the suction pile is welded to each leg and the platform is ready to sail to the offshore site. It can be seen in the *right* that the whole 13 m long suction pile is submerged in the water (courtesy of iv-Oil and Gas)

Fig. 2.15 SIP II platform being transported to the field. The limited transportation weather window is H_s = 4.0 m (courtesy of BOA Group)

After all the sea-fastening structures in place, the total transportation weight on the BB35 barge reaches 10,150 t. Thanks to the large and heavy suction piles assembly, the transportation stability was very high—in the real transportation journey when caught by the wave with the maximum wave height of 6 m, the barge's roll angle was less than 2° (Fig. 2.15).

Fig. 2.16 Stationing operation at site. The center is a photo showing the BB35 with the F3-FA platform aboard during operation. The *left* illustrates the operation of the leg lowering; the *right* illustrates the completion of the F3-FA platform and BB35 being sailing away (courtesy of SPT Offshore)

Fig. 2.17 The F3-FA platform after the topsides & legs locked. The strain jacks can still be seen (courtesy of SPT Offshore)

Once arrived at the station location in the field, the sea-fastenings on the legs were quickly removed. The legs together with the suction piles were then lowered towards the seabed by the temporarily equipped hydraulically operated strand jacks on board. After the piles reach the bottom of the sea and penetrate the soil about 4 m by its own weight, the pumping system starts to work and empty the water inside the piles. The 13 m long piles will penetrate into the seabed by suction force, becoming the anchors to hold the platform in position and support the topsides

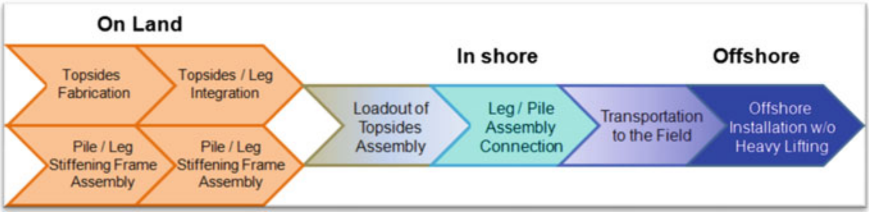

Fig. 2.18 The F3-FA platform from construction to offshore installation

weight. The pile installation only took 6 h. Going through the process, the weight of the platform is gradually passed to the piles until 100% is done (Fig. 2.16).

After the completion of the weight transfer, the welded connection between the topsides and the grillage was cut to make it ready for the separation of BB35. It was followed by the topsides' lifting up using the strand-jack system. With enough opening, BB35 was safely removed. The topsides and the legs will be locked together by super-bolts when it reaches the designed height (Fig. 2.17).

To summarize briefly, the design of SIP II is different from jack-ups in stationing operation. The topsides does not provide buoyancy as a floater hull at any stage of the installation. It is capable of self-installing in the sense of without using HLCVs. Temporarily equipped strain jack system was used for lowering legs as well as lifting up the topsides. A suitable transportation vessel is necessary. The platform is

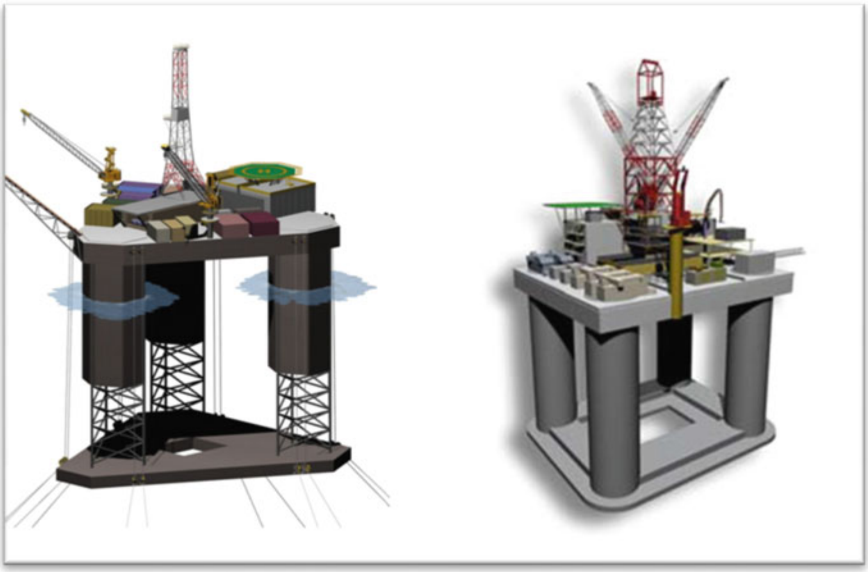

Fig. 2.19 The EDPs—three leg version and four leg version (credit to EDP concept development team)

reusable, but would not move as frequently as jack-up drilling platforms. The construction and the process of stationing operation is illustrated in Fig. 2.18.

However, the seabed soil conditions must be carefully examined for the feasibility of using suction piles. Especially, when consider the re-use of the platform in different offshore sites. Other factors such as the water depth, the variation of air gap requirement, as well as the environmental loading conditions may also have impacts on the design of supporting legs and suction piles.

2.1.3 EDP [13–15]

The concept of EDP (Extended Draft Platform) by Technip is an example of self-installation deepwater floating production platform. There are several versions of EDP concept (see Fig. 2.19) during the development. As can be seen from Fig. 2.19, an EDP platform comprises a topsides box, three or four columns and a heave plate attached to the columns.

EDP platforms are designed for deepwater application, either as the drilling rigs or as drilling/production platform. It can also be used for ocean science. The initial intention of development was for a deepwater dry tree semisubmersible to meet the strict motion requirement as well as cost-effectiveness offshore installation. It was evolved from the Technip's TPG 3300 and CSO-Aker's DPS 2001 concepts, while the heave plate concept was from truss spar. During the concept development stage, beside intensive analyses and model testing on the platforms' in-place performance, efforts had been on the mechanism of draft changing, topsides lifting up, etc., to make the self-installation offshore successful.

The TPG3300s idea of self-installing by moving the legs stems from TPG500 jack-up platform. The topsides also plays the role of a floating hull, although the lower pontoon also provides buoyancy. These kinds of characteristics naturally passed to the EDP concept (Fig. 2.20).

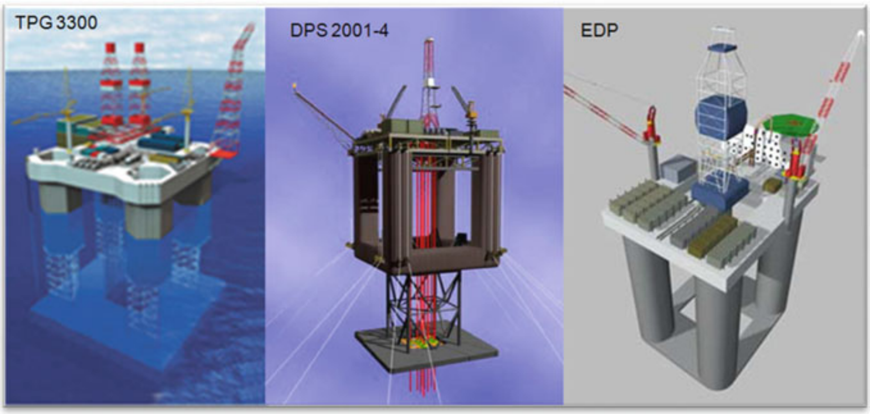

Fig. 2.20 EDP concept evolution (credit to EDP concept development team)

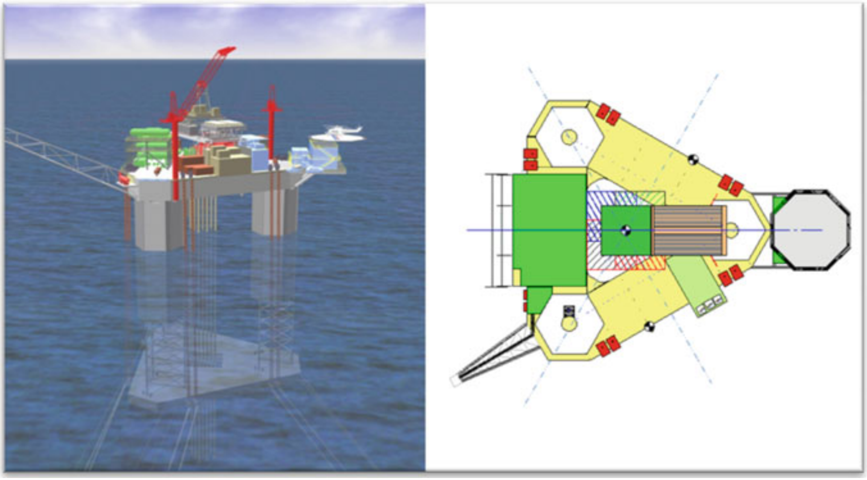

Fig. 2.21 The three leg EDP example (credit to EDP concept development team)

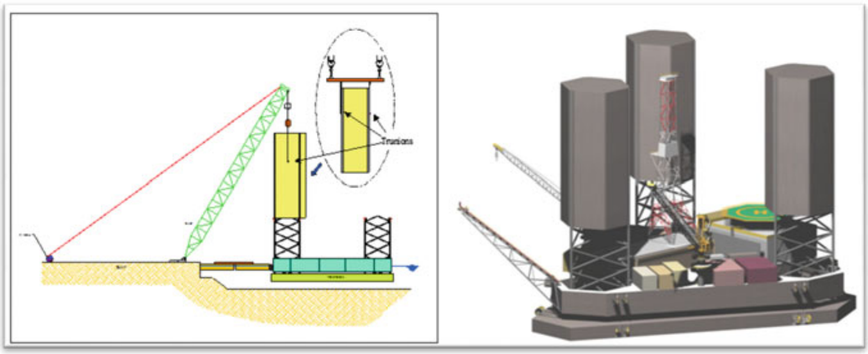

Fig. 2.22 Example of EDP platform integration (credit to EDP concept development team)

Look at the example of a three leg EDP shown in Fig. 2.21, the topsides is almost the same of a jack-up design. The position of the three legs are also similar, but not separate to each other—they sits on the heave plate, which helps to reduce the heave motion when the platform stationed in the deepwater.

However, the EDP is no longer a jack-up, but a deep draft semisubmersible in place. The function of the legs is no longer only providing supports to the payloads, but also providing stability when the EDP floats working in the field. The integration of the topsides and the legs is completed inshore in the assembling yard as the following (Fig. 2.22):

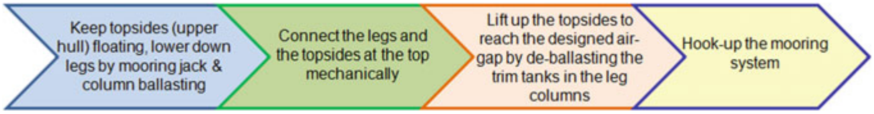

Fig. 2.23 Brief process of the offshore stationing operation

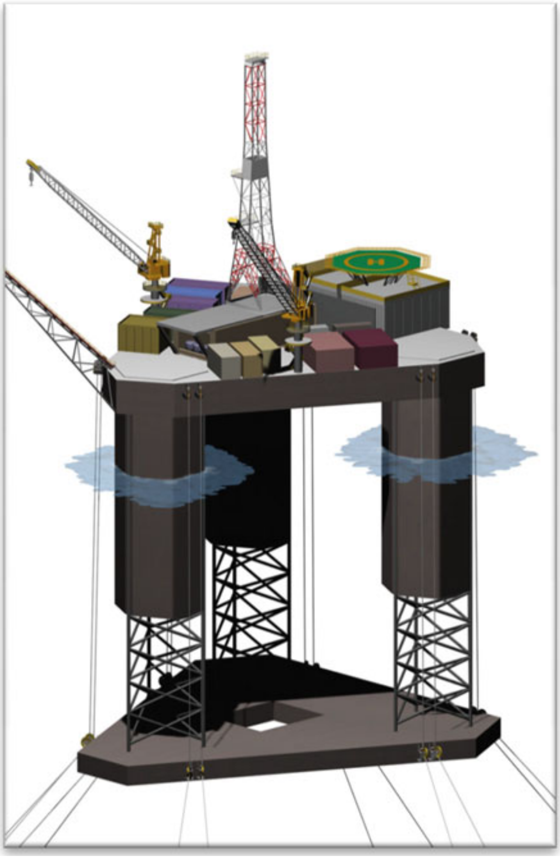

Fig. 2.24 An EDP platform after installation (credit to EDP concept development team)

- After putting together the topsides, heave plate and the lattice section of the legs at the fabrication yard, then transport the integrated structure to the assembling yard to get the top columnar section, and the topsides modules installed.
- The whole platform is then ready for transportation to the offshore side. It can be wet towed.

When the integrated EDP platform arrives at the stationing location, a preset mooring system should be in place. The brief stationing operation is summarized in Fig. 2.23.

The EDP platform is then ready for the offshore HUC operation with minimized workshop, since most of the commissioning work has been completed inshore (Fig. 2.24).

The stationing process of the EDP platform is similar to but different from either jack-up or SIP II. Comparing to jack-up platforms, the operations of the leg part are different, while comparing to the SIP II, the transportation barge is not involved during the offshore operation although the dry tow transportation to the site can be an option. However, for all of them one thing is in common, that is no need of the heavy lifting vessel on site and all the equipment for the stationing operation is on board the platform. They all are self-installable in this sense.

2.2 Inshore Integration [16]

As discussed in Chap. 1, for fixed platform, GBS and non-FPSO floaters especially in deepwater, generally the topsides and the substructures are fabricated separately and then integrated. After the introduction of self-installable platforms, the discussion is now focused on the platform integration operations. Considering the project as well as the operation involvement, it is well understood that the better option is to have least installation related work and HUC to be completed offshore. In this section, the discussion will be focus on the inshore platform integration. Methods with potential for inshore integration will be discussed at the relatively high level.

Inshore integration is not a simple process, a comprehensive plan and careful execution with systematic safety checking such as stability, structural integrity, etc. are essential.

- First, the integration or mating site for inshore platform integration needs to be carefully selected (Fig. 2.25).

Fig. 2.25 The integration site should be carefully selected for successful mating operation. On the *left* is the topsides installation by heavy lifting for WHO DAT topsides. On the *right*, it shows the topsides of Statfjord B being carried out on barges near the mating site ready for floatover (courtesy of KOS and StatOil)

No matter the mating operation is by crane lifting or other methods. The site should be a sheltered water area to avoid strong impacts from severe weather. At the same time, the location should provide adequate space including sufficient water depth for:

– Temporarily stationing the substructure
– Allowing the maneuvering of the vessel carrying the topsides or the construction vessels including the crane vessels
– Making possible the operation less complex and highly effective.

Not so many locations meet the requirement, only some Norwegian fjords and some locations at the west coast of Scotland can qualify.
The ideal mating site for condeep is at the fjord with a relatively narrow inlet but a large water area and deep enough. At the same time, the environment is benign making the operation safer and smooth. No wonder, most of the inshore mating sites for condeeps are along the Norwegian coast [17].

- Secondly, the access and exit of the transportation route should also carefully examined and the transportation analyses need to be carried out for the safety and effectiveness.

Fig. 2.26 Condeep Statfjord B was towed to the integration site at Yrkje Fjord in Vindafjord. (Courtesy of Statoil)

Take condeep Statfjord B as an example, after the GBS hull had been completed at Gands Fjord off Stavanger, it was towed at the draft of 62 m to the mating site at Yrkje Fjord in Vindafjord. The towing weight was 634,000 tonnes and the tow width was 135 m. The minimum water depth along the route is more than the required 70 m, but at the passage near the mouth of the Grands Fjord, the channel width was only 280 m, therefore needs extreme caution of navigation. Towing effectiveness was also a concern. Since the deep draft of the condeep and the short towing lines for the narrow shipping channel, propeller backwash was very strong, which reduced the net towing power drastically. Based on the experience, pushing tugboats were used instead (Fig. 2.26).

For the case of exit towing channel consideration, Chevron's DDS (Deep Draft Semisubmersible) platform Blind Faith is a good example. The hull of Blind Faith platform was fabricated at Verdal in Norway and the topside was constructed at GIF yard at Houma, Louisiana. The integration site was chosen at the integration yard belonging to KOS at Ingleside, Texas, where is not far from the platform's stationing location in Mississippi Canyon Area block 650 in GOM, approximately 140 nm south-east of New Orleans. The hull of the platform was transported to the integration yard being equipped with the cranes capable of lifting the integrated topside by a single lift.

The integrated semisubmersible platform was then wet towed to the offshore field. Because the limited water depth of the transportation route, the inshore towing draft could not go beyond 6.1 m, the transportation stability could not meet the requirement at this transit draft. Fortunately, by closely following the weight control record, this potential issue was identified earlier. There was already a developed plan in place to addressing the issue. The idea was to attach specifically designed portable sponsons temporarily to the platform hull columns to increase the GM value of the platform during the inshore towing. After the platform reached the location where the platform draft could be increased by ballasting, the four sponsons, each of them attached to one of the four columns, were released. The platform was then further ballasted down to the offshore towing draft and towed to the offshore field (Fig. 2.27).

Fig. 2.27 Temporary sponsons for handling inshore towing stability issue. The *left* shows the sponsons are installed at quay; the middle shows the platform under tow with sponsons attached. The *right* shows one of the sponsons was just separated from the hull column (credit to the Blind Faith T&I project)

- During the platform integration, platform's loading and environmental conditions keep changing, though some of them are temporary, checking of safety such as stability of the platform, overloading, etc. as well as the integrity of the structures are necessary for each operation steps.

In the following, several approaches in inshore platform integration are discussed with examples.

2.2.1 Inshore Topsides Integration by Heavy Lifting

The topic of the method of integrating the platform at assembly yard was already touched when discussing the topsides design. Nowadays, for large offshore projects, integration of the separately fabricated topsides and corresponding structure become an important step of platform construction. The completed topsides and substructures built at different construction site will meet at a selected yard with high capacity cranes or a sheltered inshore site with HLCVs to achieve the platform integration by heavy lifting. This approach is not only applicable to floaters such as semisubmersibles and TLP's, but also worked for GBS platforms. The operation can be carried out at the quay of the integration yard or in a carefully selected sheltered waters. The topsides can be modularized or integrated. The results are all the same: the whole platform is fully integrated and ready for transit to the field where the platforms are positioned by either connected to the preset mooring system or being ballasted down and sitting on the seabed followed by the offshore HUC with minimized work scope.

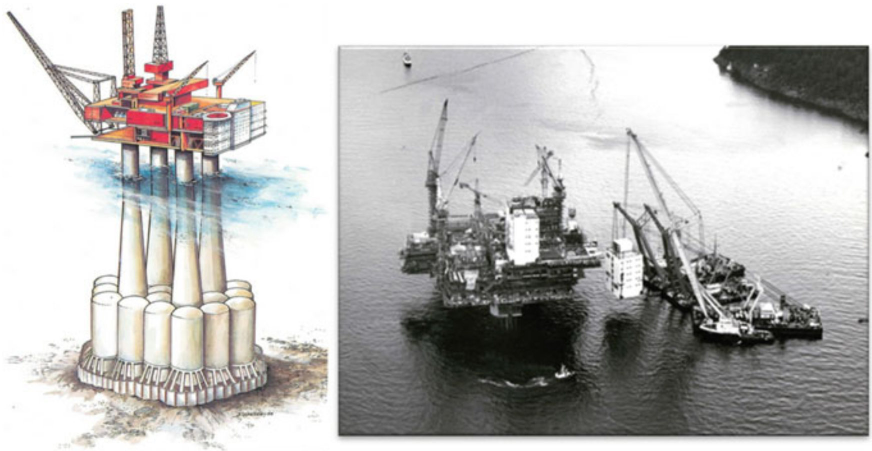

Fig. 2.28 Condeep Statfjord A and the installation of topsides modules (courtesy of Statoil and Norwegian Petroleum Museum)

- GBS platforms

  For deep draft GBS platforms, the preferred option of platform integration is inshore to take the advantage of avoiding impacts of the severe weather, especially in the earlier time before the innovation of floatover technology.

  Statfjord A is one of the condeep built for the North Sea, which belongs to the early generation of GBS. In Fig. 2.28, the left is an effect picture of condeep Statfjord and the right picture shows the installation of the modules on the topsides. When the hull of the condeep was towed to the mating site, it would be ballasted down to have only 5–6 m of the columns above the sea surface and the module support structure (frame) was then installed on the column tops. Following that, the crane vessel lifted the modules and installed them on the topsides. The topsides installation of Statfjord A condeep was in 1977. For condeep Statfjord A, the three (3) living quarter modules were 40 m high and weighed about 1000 ton each. Each module could not be lifted by a single crane but required three (3) crane barges working in concert, not because of the weight but the height and the configuration.

  Following the completion of the modules' installation, as much HUC work as possible can be performed inshore and make the offshore HUC work scope minimized.

- TLPs

  For large TLPs, the platform integration is carried out inshore for the same reasoning. The integration can be at the quay of the integration yard or in the sheltered waters using heavy lifting vessel. As examples, brief discussions of two cases of Shell's TLP platforms are in the following.

  – Mars TLP [18, 19] (Fig. 2.29).

    Shell and BP's Mars TLP was deployed in the Mars field in GOM with water depth about 900 m (2940 ft) in 1995. Total weight of the platform was 36,500 tons. 55% of the total development cost of \$1.2 billion was spent on the fabrication and installation.

    The 15,650-ton hull of the Mars TLP consists of pontoons and four circular steel columns, which was built in Belleli SpA, Taranto, Italy, and delivered on Aug. 31, 1995. It was then "dry-towed" approximately 6500 nautical miles to Aker Gulf Marine's fabrication yard at Ingleside, Texas, riding on

Fig. 2.29 Shell TLP Mars integration. The *left* photo shows the Mars' hull being carried by Mighty Servant 2 of Dockwise; the center shows the installation of modules; on the *right*, the integrated platform was wet-towed to the field (courtesy of Shell)

Dockwise semisubmersible heavy lifting vessel Mighty Servant 2 for platform integration. The journey took 22 days.

Compared with the cost of topsides/hull mating for Auger TLP at open sea, Shell chose to perform the platform integration for Mars inshore at the yard near Corpus Christi.

The yard is equipped with shore-based twin boom heavy lifting facility—SLD (Specialized Lifting Device) which is capable of lifting objects up to 4000 short tons. The topsides of Mars consists of five (5) main modules (process, power, quarters, drilling, and wellbay) and each module was built and commissioned by the corresponding contracted fabricator before being transported to the integration yard. During each lift, the hull need to be so positioned that the module-carrying vessel could be under the SLD to make the lifting safe and smooth.

Then the necessary HUC work was completed at the integration site. Comparing to working offshore, there was no need for extra helicopters, supply boats, and marine equipment. In addition, the possibilities of delays caused by weather were greatly reduced. As discussed earlier, by integrating the platform inshore, the offshore HUC work was minimized and the cost was drastically reduced, even if the topsides was of modularized design.

The integrated platform was then transported to the site by wet-tow using four ocean-going tugboats. It took seven days for travelling the 400 miles to the field.

– Ursa TLP

  Shell's Ursa platform is a third generation design of TLP and was deployed on Mississippi Canyon Block 809 with the water depth being approximately 1158 m (3800 ft). The fabrication started in 1996.

  Similar to Mars, the TLP hull also consists of four circular steel columns connected by a ring pontoon. The hull, weighing 28,600 tons, was built at Belleli Offshore.

  The total weight of Ursa TLP was 97,500 tons and the total steel weight is 63,300 tons. The topsides of Ursa consists of six (6) modules: wellbay, living quarters, power, drilling and two processes. J. Ray McDermott built all the modules. The total weight of the topsides was 22,400 tons (Fig. 2.30).

  The platform integration site was chosen at the Caracas Bay of the Curacao Island, Netherlands Antilles, which was off the coast of Venezuela. The integration site is located off the hurricane zone and the water depth is enough for Ursa TLP module installation. The other favored factor is that Heerema's SSCV Balder was just there for routine maintenance and available for the integration operation.

  The Ursa hull itself was much larger than Ram Powell and twice the size of the Mars TLP. Although there were limited port facilities on the Curacao Island, the staff and equipment needed for the integration project had to be either flown in or shipped across the GOM. With the detailed

Fig. 2.30 The *left* photo shows the Ursa hull being transported from Italy to the integration site offshore Venezuela on barge H-851. On the *right*, the HMS's SSCV was lifting modules during the installation. The sheltered waters were calm (courtesy of HMC)

project execution planning and joined efforts, the integration was completed ahead of time and good preparation led to the big time saving for offshore tendon installation.

From the above discussion, it is convincible that the inshore platform integration is a better choice for conventional TLP platforms, even using heavy lifting of modularized installation.

- Semisubmersibles

  With the introduction of the integrated deck concept, quite a few semisubmersible FPS's (Floating Production Structure) were integrated inshore using floatover method, which will be discussed in later subsection. Here the integration of the hull and topsides of Chevron's DDS production platform Blind Faith is presented as an example of using heavy lifting for inshore integration (Fig. 2.31).

Fig. 2.31 The platform integration of Chevron Blind Faith DDS. The topsides is an integrated topsides. HLD (Heavy Lifting Device) lifted the integrated topsides from the transportation barge (*left*) and put on the hull (*right*) (courtesy of Rigzone and KOS)

As mentioned earlier, Blind Faith platform is a DDS with draft of 100 ft. The total displacement of it was 40,000 tons and the topsides was an integrated topsides fabricated in GIF in Louisiana. The hull was built in Aker's yard in Verdal, Norway. Integration yard of KOS near Corpus Christi, Texas was selected as the site for topsides mating. The crane through one single lift successfully installed the 7000-ton topsides.

For this kind of integrated topsides, there should be no certain preference between inshore and offshore installation. Saving on offshore HUC is the same. Selection of the integration site is decided case-by-case with consideration of multi-factors including availability of lifting equipment, schedule, Mob/Demob cost, environmental condition, etc.

2.2.2 Inshore Platform Integration by Floatover

Floatover technology has been a well-accepted offshore installation option in offshore oil and gas industry and becoming popular. In the offshore industry, floatover installation technology links to open water on-site platform topsides installation. Most of the completed projects using floatover methods were fixed-platforms. However, the first application of floatover technology, an innovation by Larry Farmer and Phil Abbott of Brown & Root in later 1970s, was to the platform integration of steel GBS Maureen platform in the North Sea. Following that floatover technology were widely applied to inshore platform integration for various kinds of offshore platforms including GBS, TLP, and Semisubmersibles. The following are some examples.

- GBS

  Before the first floatover method application on the Maureen steel GBS in the early 1980s, the topsides installation of the condeeps in the North Sea were carried out by modularized operation. At that time, the integrated deck concept was still in the development stage and the floatover technique had not been invented. The matting of the MSF deck with a few modules on the concrete base was carried out by floating the deck over the shafts of the already ballasted down platform base, just as shown in Fig. 2.32 of the mating of Statfjord A platform. Starting in 1980s, concepts of integrated topsides and floatover have been widely used for GBS platforms including condeeps and CGBSs (Concrete GBS). Since all the GBS topsides are huge and very heavy, the floatover operation generally needs multi barges involvement instead a single barge.

  Take Statfjord B platform, which started production in 1982, as an example. It was the first four-shaft condeep and the first platform using inshore floatover method for platform integration. Similar to the mating operation of Statfjord A

Fig. 2.32 Mating operation of Statfjord A. The topsides was not an integrated topsides, a few modules were installed on the MSF which is carried by two tankers and then floated over the shafts of the base which was only a few meters above the water surface (courtesy of Norwegian Petroleum Museum)

platform, the shafts only have 6 m above the surface of the water, but the operation was then a floatover process.
The differences were:

- The topsides was an integrated topsides, not a MSF deck with a few module installed. The topsides comprises of several decks including cellar, module, weather and upper weather decks; altogether 28,900 m^2 space were provided. All the modules made both in Norway or in other countries were already installed on the topsides and connected.
- The completion of the mating was by simultaneously de-ballasting the concrete base and ballasting the barges, which is a typical operation process of floatover platform integration).

Challenges in the operation were obvious: not only the huge topsides weighed more than 40,000 tons, but also the ballasting/de-ballasting performance control was quite complicated. Figure 2.33 shows that four (4) barges with different sizes were involved, a good planning and an accurate execution of the plans on coordination of water pumping for each corresponding tank at any moment was a key for the success (Fig. 2.34).
Another example is the CGBS Hibernia platform, which was deployed in Grand Banks of Newfoundland, 195 miles east southeast of St. John's, Canada

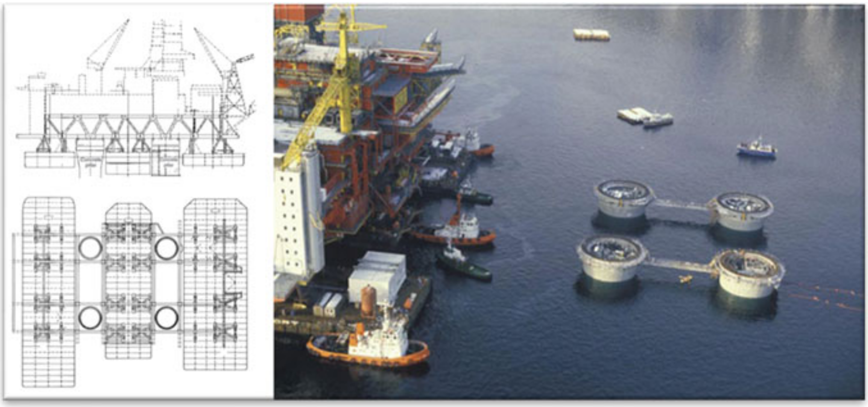

Fig. 2.33 Statfjord B platform integration was the first inshore floatover integration (photo shows the floatover of Statfjord C which has the same design of Statfjord B), this operation used more than two barges (credits of drawing go to Aker Maritime [9], photo courtesy of Statoil)

(Fig. 2.35). The platform is a huge CGBS weighing approximately 1.2 million tons and more than 219 m high after being completed. The topsides consists of five (5) main modules, which were built globally. All the modules were assembled and installed on the topsides in Bull Arm. The integrated topsides weighed 37,000 tonne. The base of the platform weighed 550,000 tonne [20, 21] (Fig. 2.36).

The platform integration was carried out inshore using floatover method. The integration site in the middle of Bull Arm where is near the base construction site. Two giant barges formed a catamaran carrying the huge and heavy

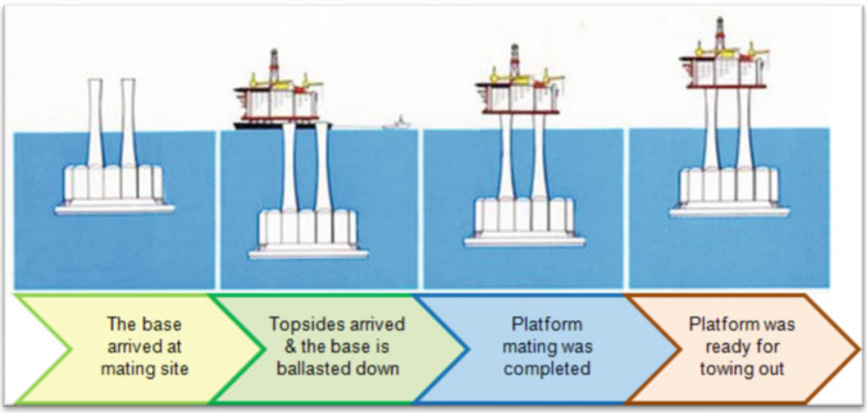

Fig. 2.34 Illustration of the platform integration process of Statfjord B

Fig. 2.35 Hibernia platform (courtesy of HMDC)

Fig. 2.36 Hibernia platform integration. The base structure of Hibernia is shown on the *left* and the *right* shows the topsides was transported by two giant barges to the integration site (courtesy of HMDC)

Fig. 2.37 The topsides of Conoco (UK) Ltd's Hutton TLP was under construction at Ardersier Yard (courtesy of Oilrig-Photos)

topsides. The operation was successful and the experience accumulated will benefit the future same kind of projects.

- TLP
  In the early section, examples of TLP platform inshore integration by heavy lifting were presented. The operations were very successful. Not so many cases of TLP platform integration using floatover can be found. One of the possible reasons might be that the stability of the floating TLP is sensitive to the floating draft before it is anchored by the tendons. The Conoco Hutton TLP was integrated using inshore floatover method [22] (Fig. 2.37).
  The Conoco Hutton TLP was the first production TLP ever built for the Hutton field in the North Sea where the water is not deep—only 148 m. The concept development was by Vickers Offshore since 1974. The topsides and the hull of Hutton TLP were fabricated at separate yards in parallel. The Hutton topsides, an integrated topsides, was designed by Brown & Root and fabricated at the McDermott Ardersier yard in Scotland. The hull was built in the drydock at the nearby Highland Fabricator's Nigg yard in the north of Scotland.
  The 17,600-ton topsides and the 22,000-ton six (6) columned hull were integrated by floatover method in 1984, following the success of Maureen steel GBS platform. The mating site was at the Moray Firth off Findhorn, the east coast of Scotland. The site was close to both fabrication sites and no need for a 1ong distance towing operations. Aker Offshore carried out the floatover

operation at the mating site off the east coast of Scotland. The Moray Firth mating site is exposed to the North Sea, environmental conditions were a challenge for the mating operation. Engineers conducted analyses to simulate the relative motion of the operation and it turned out that the relative motion was much lower than the operation limit.

One thing worth noticing, i.e., although the operation has been called floatover, it was actually a bit different from the original HIDECK floatover concept. It was NOT the same for the Maureen platform floatover in achieving the mating contact between the two parts of the platform. The TLP hull was ballasted down to the designed draft for mating, instead of moving the topsides over the hull; the floating hull was aligned with the topsides and de-ballasted up. After the contact, the rising hull lifted the topsides from the transportation barge and then complete the mating by welding (Fig. 2.38).

The integrated Hutton TLP was towed to the stationing site in July, 1984; the hooking up with tendons only took three days. The first oil was produced twenty-five (25) days after its arriving. The success of the Hutton TLP platform integration fully demonstrated the advantages of integrated deck and inshore platform integration.

- Semisubmersible

  It should be natural to consider integration semisubmersible platform by floatover method. A semisubmersible is stable by design when floating as an integrated platform. The inshore platform integration of Statoil Kristin semisubmersible is a good example (Fig. 2.39).

  Aker Kvaerner and GVA designed Kristin production platform, which is a semisubmersible with four (4) columns. Fabrications of the topsides and the hull were in separate construction yards. Samsung Heavy Industries in South Korea built the 14,450-tonne hull. Fabrication of the integrated topsides weighing no less than 19,000-tonne was at Aker Stord. The mating site was in the Aker Stord's harbor and the completed hull was transported to the mating site by the Dockwise heavy lift vessel Mighty Servant 1. The topsides was on the semisubmersible heavy lifting vessel BOA Barge BB19.

  The integration went smoothly and it took only one hour and forty-two minutes (1:42) to complete the mating of the topsides and the hull. After that, the extensive welding was carried out. The platform integration was quite impressive.

  However, for quite a few semisubmersible platforms including drilling rigs, the topsides is often built in the yard with large drydock facility. The platform hull and topsides are also built separately. The integration of the topsides and the hull happened in the drydock by a method similar to but different from the floatover. See the discussion of this method in the next section.

Fig. 2.38 The Conoco's Hutton production TLP was integrated using floatover method (courtesy of Conoco)

Fig. 2.39 Inshore deck floatover installation of semisubmersible platform Kristin (courtesy of Statoil)

2.2.3 Moving-in-Under [23–25]

This is the method having been applied in the semisubmersible platform integration in the docking facility of the fabrication yards for various kind of platforms. There has not been a unified name for the method, and just name it “Moving-in-under” in this book. In the following, the discussion will be on the platform integration of a semisubmersible.

By applying this method, the topsides, an integrated topsides, will be elevated up to a height mechanically in a drydock to create enough space for the semisubmersible hull to move in beneath the topsides. The topsides and the hull columns will be aligned and then the topsides will be lowered in a controlled manner to complete the mating with the hull. In this section, we will present two different approaches with a few examples.

The first approach is to lift up the topsides with a giant crane capable of handling very heavy topsides, as it happened at the yard of CIMC Raffles, in Yantai, Shandong, China. The second approach is to use gantry-lifting systems to elevate the topsides in the drydock and then make it possible for the hull to move in beneath and aligned with the topsides.

- Approach of using heavy lifting derrick over the dock
  This approach is specifically to the platform integration of floaters with integrated topsides. It should be noticed that there is the limit of the total height of the integrated platform. The advantages are:

  - A single lift operation
  - Making it possible to parallel fabricate the hull and the topsides
  - Shortening project schedule and improve utilization of resources
  - Safe with good quality.

  Obviously, the high capacity crane and related rigging are the key factors. These facilities need a big investment and good maintenance during the service life. The realization of the above-mentioned advantages very depends on the backlog of the fabrication projects.
  The best examples are the platform integration operations performed by Yantai Raffles’ yard using its Taisun Crane with safe lifting capacity of 20,133 tonne (Fig. 2.40).
  The maximum lifting height is 80 m for the Taisun crane, which is enough for semisubmersibles, and FPSO’s to complete the mating operation. Since the performance is in the drydock, the working environment is very favorable. This technology has been recognized by the industry. Its record of topsides installation has been 17,000 tonne up to now.

- Approach of using jacking systems
  The concept is the same in creating mating room by elevating the topsides to a needed height but without using the huge derrick on the drydock walls. The

Fig. 2.40 The 14,000 tonne integrated topsides of the COSL Pioneer drilling semisubmersible had been lifted and the hull was moving in underneath (courtesy of CIMC Raffles)

Fig. 2.41 P-55 platform integration in the drydock of Rio Grande yard (courtesy of Petrobras)

temporarily erected gantry tower lifting system was the key for the integration operation. A few examples are presented for illustration.

– P-55 semisubmersible production platform (2012)

The Petrobras P-55 semisubmersible platform had its topsides and hull constructed separately but simultaneously. The integrated topsides or the deckbox was fabricated in the RIO Grande yard. It weighed 17,000 tonne. The hull was fabricated in the Suap yard (Fig. 2.41).

The drydock of the Rio Grade yard, where the topsides was fabricated, was selected as the integration site. The Mammoet Gantry System was setting up in the dock for the topsides lifting. The gantry system consisted of twelve (12) towers connected to twenty-four (24) hydraulic jacks, each with a capacity of 900 tonnes. When setting up, six (6) towers on each side of the dock will be erected. Twenty-four (24) sets of fifty-four (54) steel wire ropes were used to lift the structure. For P-55 platform integration, the 17,000 tonne topsides would be lifted up to the height of 47.6 m above the drydock bottom (Fig. 2.42).

For this case, the topsides height reached almost 50 m. Theoretically speaking, the jacking height should be able to be adjusted by the gantry system when higher elevation is needed. The topsides lifting and mating site preparation took six (6) days following the procedure below:

Fig. 2.42 The topsides and the hull were aligned and ready for mating (courtesy of Petrobras)

- First, the topsides was lifted up to a height of 20 cm for testing and final weighing.
- Then, it was lifted to the height of 15.4 m above the bottom of the dock. The grillage and fenders for the hull floating in were put in place at the same time.
- The topsides will be lifted further and be ready for the hull to move in.

The hull was then to be floated in with the drydock being flooded to the depth of 13.8 m through the water collection pipeline and the floating gate being opened.

After floating the P-55 hull into the dock, the flooding gate was closed. Then the water depth inside the dock was drained to 7.2 m. The topsides was then lifted to the maximum design height of 47.6 m and the hull was aligned underneath the topsides. After final adjustment, the topsides was lowered down by the jacking system and the mating process was completed. Following that, the entire platform landed on the grillage through draining the dock.

The total integration process only lasted two (2) weeks, which was a better, and cost-effective approach comparing to the conventional construction of semisubmersible. This approach may not be as effective as the directly lifting by the huge crane like happened in the drydock of the Yantai Raffles' yard in both the mating operation and the drydock usage, but there was no need of the large permanent investment on the super crane. Other yards have also chosen similar approach.

– Aker H-6e drilling rig

Aker H-6e drilling rig is the six (6th) generation rig capable of working in Arctic severe environment. The hulls of the first two (2) rigs were built in the yard of the Drydocks World in Dubai, UAE. For each platform, the hull was wet-towed to the Aker Stord yard for integration, where the topsides was fabricated in the drydock.

Fig. 2.43 Aker H6-e semisubmersible drilling rig was integrated at the drydock of Aker Stord yard (courtesy of Aker Solutions)

Fig. 2.44 Both of the topsides and the hull were built in the drydock of the Drydocks World yard at Dubai, the topsides was fabricated in the drydock (courtesy of Drydocks World and ALE)

In Fig. 2.43, the eight (8) SMLTs (Sarens Modular Lifting Tower) were erected in place in the drydock. The topsides was already lifted up by the gantry lifting system. On each of the eight (8) towers, there are four (4) standard strand jacks. The whole lift system is capable of handling the weight of 144,000 tonne and withstanding a full Norwegian winter storm. The 10,700 tonnes topsides of the

Fig. 2.45 The topsides of the Dolwin Beta was lowered on the columns of the semisubmersible look-like GBS hull, the ALE's gantry system can be seen clearly (courtesy of Drydocks World and ALE)

Fig. 2.46 Both the drydocks are open to the sea. On the *left*, it can be seen that three (3) tugs are used to push the hull to move in underneath the elevated topsides (courtesy of Aerophoto.no and Drydocks World separately)

semisubmersible drilling rig "Aker Spitsbergen" was lifted up to 34 m high and the hull was moved in underneath the topsides. The mating was successful.

– Dolwin Beta HVDC (High Voltage Direct Converter)

The Dolwin Beta platform serves as part of the offshore windfarm. The total weight of it is 23,000 tonne. From the structure of the hull and the topsides, it was often taken as a semisubmersible platform, however from the function offshore, it is really a GBS.
The construction of Dolwin Beta was the same as the floating platforms. The topsides and the hull were fabricated separately and then the two were mated at the shipyard.
The 10,000-tonne topsides was built in the drydock of the Drydocks World yard at Dubai. The gantry system used for the topsides jacking up was by the Netherland Company ALE. The system was designed combining several different standard gantry systems. It consisted of six (6) consoles as shown in Fig. 2.44. Three (3) of them forming a row on each side of the dock with two (2) ALE's Laced Tower system at the ends of the row and an A-Frame structure in the middle. Four (4) strand jacks were installed on each tower unit with the minimum lifting capacity of 500 t for each strand jack. All the tower units were sitting on the bottom of the dock and the standing stability was assured (Fig. 2.45).
After the completion of the topsides, it was lifted up to the height of more than 50 m from the bottom of the dock. The final height before the mating reached 52.8 m. The hull was then floated in carefully in between the gantry towers and underneath the topsides. The topsides lowering and mating operation was controlled by the gantry system similar as discussed earlier.

From the three cases presented above, it can be seen that the gantry systems played a vital role in the operation, though their designs were different. Not only the system lifting capacity is critical, but also the standing stability and controlling system of the jacking motion and the safety under the operational environment all create challenges for the execution. It is not difficult to understand that the lifting operation needs the coordinated actions at all the towers during the jacking up process. At the same time, the drydocks as the mating sites in the shipyards are all quite open to the sea; therefore, the weather condition is a factor non-negligible. All the integrated operation efforts are for assuring the accurate alignment between the topsides and the hull (Fig. 2.46).

One point worth noting: behind all the successful inshore mating operation, there were intensive efforts in the concept development as well as careful planning with details. Engineering supports through thorough investigation of technical issues and creating solutions by analysis and design are vital. All the plans, procedures and operation manuals should go through seriously and strictly checking before formally issued and strictly followed during the execution.

2.3 Offshore Integration

For fixed platforms or CGBS in shallow water or compliant towers in relatively deepwater, the substructures are first installed at the stationing location and then the topsides is installed on the substructure at the site. Therefore, the offshore platform integration is inevitable.

For single columned floaters such as Spars or the MinDoc platform, the hull arrives at the offshore field first. Operations of upending, hooking-up with the preinstalled mooring system and the topside installation will follow. This is also a process of offshore integration. As discussed earlier, both minimizing the work scope of the offshore HUC and reducing the duration of the offshore integration process are the key factors contribute to the project cost saving and improvement of the operation safety. The development of integration methods and corresponding equipment including the installation vessels has always been focusing on the same goal.

For the existing installations of offshore platforms, most of them were installed using heavy lifting vessels either by a single lift of integrated topsides or by modules. Floatover method, which includes variations stemming from the initial invention of HIDECK, is the other option and gaining some kind of moment in recent years in certain area such as South East Asia, especially for heavy topsides installation. Brief discussion on these two options will be carried out here and leave more detailed discussion on the floatover technology in the following chapters.

2.3.1 Topsides Installation by HLCV [26, 27]

The topsides of platforms vary in dimension, weight and configuration and the environment such as the water depth, wind/wave/current conditions, neighbor existing structures, etc. at the platform stationing location are project dependent.

Therefore, the selection of the installation vessel and the creation of the installation plan should start very early with the project. It is not so easy to hold a suitable vessel with a very long lead-time. On the other hand, as discussed in Chap. 1, changing the installation method in the later stage of a project is very costly and sometimes is not feasible.

- Single lift operation

  Since the earlier years of the offshore industry, topsides of fixed platforms were installed by crane barges. The ideal situation was to have a crane barge available with the capacity of lifting the topsides in one piece (Fig. 2.47).

  When the topsides becoming larger, heavier, the existing crane vessels could not install the topsides by a single lift. One of the solution is to make a multiple lifting operations by modules. The other is to build large capacity crane vessels. At the same time in the 1970s, the concept of integrated topsides appeared which created the demands for larger capacity HLCVs. Since 1979, several huge SSCV's (Semi-Submersible Crane Vessel) were built and joined the global HLCV fleet. They are Balder and Hermod of HMC (Heerema Marine Contractor), following them in the middle of 1980s, came the largest SSCV Thialf of HMC and the Saipem 7000 of Saipem S.p.A (Fig. 2.48).

  Both giant crane vessels are huge in size: 201.6 m (L) × 88.4 m (B) × 49.5 m (D) of Thialf and 198 m (L) × 87 m (B) × 43.5 m (D) of Saipem 7000. Thialf's displacement is 198,750 t, while Saipem's is 172,000 t. The designed lifting capacity of Thialf is 14,200 tonnes at 42 m and the capacity of Saipem 7000 is 14,000 tonnes at 31.2 m. However, Saipem 7000 when she succeeded the installation of the 12,150 tons Sabratha deck in the Mediterranean Sea created the record of lifting the heaviest objective.

Fig. 2.47 The topsides of a fixed platform was installed by a crane barge (courtesy of CNOOC)

Fig. 2.48 World largest SSCV's. On the *left* is the largest SSCV Thialf (originally DB-102 of McDermott) of HMC. On the *right* is the second largest SSCV Saipem 7000 of Saipem S.p.A (courtesy of HMC and Saipem)

All these large SSCV's are designed multifunctional and most suitable to large deepwater projects. They can handle most of the heaviest structural objects and can perform subsea installation for very deepwater.

However, the offshore operation accomplishment does not only depend on the weight lifting capacity, but also on other factors such as the water depth, structure size and configuration, oil field environment, etc. Therefore, less capacity HLCVs with shallow draft are also important members in the global heavy lifting fleet. They have played important roles in the offshore installation including the single lift topsides installation for both fixed platforms and spars (Fig. 2.49).

In the offshore industry, the designed platform topsides weight and size have been engaged in the development of HLCV's lifting capacity in a spiral cycle. When the heavy lifting side sees the potential or trend of topsides going bigger, higher capacity vessels are designed and built; on the other side, when higher

Fig. 2.49 HLCVs. On the *left* is Blue Whale of COOEC hoisting the largest offshore oil wellhead platform module in Bohai Sea China. On the *right* is the McDermott DB-50 equipped with DP system (courtesy of CNOOC and McDermott)

Fig. 2.50 In early 2009 HMC installed the integrated topsides of the Perdido with a 9773 ton single lift by their SSCV Thialf, a record for the US part of the GOM. The living quarter was then put on the topsides. It took two weeks to complete the installation (courtesy of HMC and Shell)

capacity HLCVs are available or under construction, larger or heavier topsides design will appear. Both sides keep the same focus in mind, i.e., to make the single lift installation of the integrated topsides successful and safe.

Sometimes, limited capacity of the installation vessel may inspire the engineers to make creative efforts in the optimization of the topsides design. The completion of the Shell Perdido spar platform is a good example (Fig. 2.50).

When the project started, the SSCVs were considered as the topsides installation vessel and the integrated topsides design weight was set to be under 10,000 tonnes. The single lifting operation assured the reduction of the platform offshore integration duration and the integrated topsides design minimized the offshore HUC work scope.

- Installation by modules

  When the topsides offshore installation cannot be completed by a single lift operation, the topsides will be fabricated into several installation modules, which can be installed one-by-one using HLCVs.

  Platforms such as fixed platforms and compliant towers and spars with large topsides often perform topsides installation by modules. The module here means the installation modules, which may not be the same as the equipment modules fabricated by the vendors.

  The Chevron TOL (Tombua Landana) compliant tower in West Africa is an example for the modularized topsides installation. The topsides of the compliant tower was an integrated design according to Chevron, but the installation was carried out by SSCV Thialf by modules in the order of the MSF, the CM (Center Module), the WM (West Module, the EM (East Module), the FB (Flare Boom) and the LQ (Living Quarter) (Fig. 2.51).

  Installation of the topsides of spars by multiple lifting happened in most of the spar projects. One of them was the Genesis spar platform.

  The topsides of the Genesis spar was installed by multiple lifting including production deck, east and west drilling/utility modules, a living quarter package,

Fig. 2.51 The Center Module was lifted and put on the MSF of the Chevron TOL (Tombua Landana) compliant tower platform in offshore Angola (courtesy of Chevron)

Fig. 2.52 The McDermott DB-50 was preparing to lift up the lower deck of the Genesis spar topsides (courtesy of McDermott)

Fig. 2.53 Bottom Feeder with lifting capacity of 4000 tons (*left*) and VB 10,000 with lifting capacity of 7500 tons (*right*) (courtesy of Versaba, Inc.)

and a drilling rig. McDermott's DB-50 equipped with DP system was used for the installation (Fig. 2.52).

For multiple lifting operation, to reduce the installation duration without interruption is critical and challenging. Knowledge and information of the weather at the site play an important role and carefully developed installation plan and procedure must be strictly followed.

- "Bottom Feeder" and VB 10,000 (Fig. 2.53)

  A different kind of heavy lifting vessel VB 10,000 by Versaba, Inc. worth mentioning here. The vessel concept started from "Bottom Feeder" in the middle of 2000, which was designed for the platform decommissioning tasks. The rigid frame trusses are mounted on specially designed barges forming a catamaran, which can accommodate the environment at the working site. There is enough space created under the frame trusses and between the barges, therefore the two formed gantry system is capable of removing certain sized topsides of platforms by a single lift.

  VB 10,000 was the further development from the successful Bottom Feeder. Although the vessels were initially designed for platform decommissioning, it has easily to be agreed that they could also be used for platform topsides installation. In fact, VB 10,000 has been proposed for fixed platform topsides installation projects. As pointed out earlier, the challenge of the single lift of the topsides comes not only from its weight and weight distribution, but also from the size and the configuration. Because of the limited space bounded by the frame trusses, sometimes, the lifting height and the weight balance control may cause the capacity reduction.

2.3.2 *Offshore Topsides Installation by Floatover*

When discussing offshore topsides installation by floatover methods, it naturally focuses on the integrated topsides. As mentioned in the above section, integrated topsides single lift operation has been the favored in the platform installation projects. Depending on the size of the platform, an integrated topsides may either be a whole topsides with all the equipment installed on it or the MSF with key production and processing equipment included. So far, the HLCVs still have a majority share of the integrated deck installation market in competition with other options.

However, under either of the following situations, the floatover method will be the first choice:

- Suitable vessel not available or the mob/demob cost too high
  It should be noted that the majority of the medium-to-large capacity HLCV's generally be spotted working or temporarily stationing in areas like the North Sea and GOM where the infrastructures are established and more activities are going on. For projects in remote areas, it's hard to make the planning of the offshore operations based on the needed HLCV's, especially when considering the uncertainties of the development of the projects.
- The topsides design or the field environment make the application impossible
  Sometimes, the platform topsides is too heavy to be lifted by an HLCV. The obvious example is the huge CGBS. In addition, when the topsides may not too heavy, but the water depth prevents the HLCVs with the requested capacity to work at the installation field.

When talking about floatover methods, the most important equipment are the vessels and the rigging designed for a specific project. These vessels play the role of transportation of the topsides for installation and the mating of the topsides and the substructures. There is a larger room for selecting the suitable vessels and the cost will be lower including mob/demob.

Furthermore, as shown in earlier examples in inshore condeep topsides integration, floatover operation can be performed with multi-vessels and can even consider using of piggyback arrangement. In addition, floatover method works in

Fig. 2.54 SHWE platform integration in Bay of Bengal, Myanmar. The weight of the topsides is 26,000 Mt carried by the COOEC barge HYSY 229 (courtesy of Dockwise)

Fig. 2.55 Corocoro CPT (Central Production Facility) project was in the 5 m water depth field (courtesy of ConocoPhillips)

very shallow water environment and one example will be presented for illustration later.

- Fixed platform topsides installation
  In recent years, quite a few of the floatover topsides installations have been very quite successful, most noticeable area is the South Eastern Asia. Projects such as Bayu Undan, Angel, Wheatstone, Malampaya, SHWE, etc. all created some kinds of records at their installation time. The accomplishment of these projects were very impressive especially considering the large integrated topsides, high air-gap request for some project, the long journey in open sea for the topsides transportation, etc. The safe and cost-effective operations sufficiently demonstrated the advantages of floatover technology and the application of the floatover technology to offshore platforms has been gaining momentum, more fixed platform projects are in the list for future floatover operation.
  The SHWE is one typical project in the South Eastern Asia area. The platform had a huge integrated topsides and the floatover topsides installation method was chosen from the beginning of the projects. The transportation/floatover vessel availability is high and the fleet has been growing.
  The floatover operation of SHWE platform topsides integration is illustrated in Fig. 2.54. The water depth at the field is 110 m; the jacket was designed considering the one barge floatover topsides installation operation. HHI fabricated both the 22,000 t jacket and the 26,000 t topsides. In the early December of 2012, the topsides arrived at the site riding on barge HYSY229 provided by COOEC (China Offshore Oil Engineering Co. LTD) after a journey around 4000 n.m. from Ulsan, South Korea. The barge was built for large jacket launch and floatover operation and has a bottle shaped hull. The total weight carried by HYSY229 was about 31,000 t including the DSF (Deck Supporting Frame). The operation had no surprise and was successful.
  There are also successful floatover installation examples in other areas, e.g., Technip have completed more than six (6) floatover projects applying their UNIDECK floatover technology, including four (4) fixed platform topsides

Fig. 2.56 Sakhalin II project PA-B platform floatover topsides installation (courtesy of Posh Terasea Offshore Pte Ltd.)

installation in the West Africa and the weights of the topsides ranging from 9500 to 18,000 t.

It is also notices that it is not difficult to find the vessels suitable for performing floatover operation in the very shallow waters. The example for Venezuelan Corocoro CPF (Central Production Facility) project is a good demonstration. The topsides weighs 7400 Mt and the water depth was only 5 m. BOA barge BB29 was selected as the transportation and floatover vessel (Fig. 2.55).

The above examples are all single vessel floatover operations, which happened with very high percentage in the total real floatover cases. For some platforms, especially the jacket of the platform was not initially designed to suit the single vessel floatover operation, catamaran floatover technique then can be considered to avoid the jacket redesign. An example of spar topsides floatover operation using catamaran floatover technique will be presented later.

- CGBS floatover topsides installation offshore

  In the earlier discussion, the *inshore* floatover platform integration of CGBS platforms was illustrated by the Herbinia platform example. Here is an example of *offshore* CGBS topsides floatover installation. The installation of the topsides of the PA-B (Piltun-Astokhskoye-B) was in the Sea of Okhotsk, northeast of Sakhalin Island, Russia. As shown in Fig. 2.56, the 29,600 Mt topside was built in Koje, Korea by SHI (Samsung Heavy Industries) and was carried by the "T" shaped (or bottle shaped) barge TCB2 and transported to the field where the concrete base was already settled down. The floatover operation was completed

Fig. 2.57 The hull and topsides mating operation for Shell Auger TLP. McDermott's Intermac 650 carried the topsides weighing 24,000-tons. The top of the TLP column was 7 m (23 ft) above the water surface. The two derrick barges were not only standing by, but also assisting the mating operation (courtesy of Shell and McDermott)

with the TCB2 on 5th of July, 2007. It was also a record-breaking success [28, 29].

- Floaters

  When discuss the floating platform integration by offshore floatover, it generally means single columned floaters such as the spar's for which the hull needs to be wet towed to the field and then upended to be ready for the integration with the topsides. TLP and Semisubmersibles would get the floatover integration inshore. Shell's Auger TLP was a special case. The platform integration site was at Galveston Block A206 of GOM, approximately 70 miles south southeast of Freeport, TX. The mating site is not the TLP stationing location. The place was not inshore, but could be considered near shore. The water depth at the mating site is 73 m (240 ft). However, the area is not a sheltered coastal region and the operation was during the hurricane season.

  The Shell Auger TLP was the first TLP platform in the GOM. The TLP platform was to be stationed in the Block 426 of Garden Banks of GOM. The water depth of the station area is 870 m (2860 ft). The 21,500-ton Auger TLP hull was fabricated primarily at Taranto, Italy. After the completion, it was wet-towed to the GOM over a long journey more than 6880 nm. The topsides was built at McDermott's Morgan City yards with the total weight of 24,000 tons. The floatover method was chosen and the operation vessel was McDermott's Intermac 650, which carried the integrated topsides to the mating site and

Fig. 2.58 Murphy's Kikeh truss spar platform integration offshore Malaysia in November, 2006 was the first open water catamaran floatover operation and was successful (courtesy of Technip)

performed the single vessel floatover operation. During the mating, the TLP hull was de-ballasted making the columns rise and attach the topsides' legs. Derrick barges DB-16 and DB-28 were on site to assist the mating operation (Fig. 2.57). The platform integration was successfully completed in October 1993. Then the integrated TLP was towed to Freeport for inshore HUC. After that, the TLP was towed to the stationing area where it was hooked up with the pre-installed LMS (Lateral Mooring System) and the tendons were installed. The Shell Auger TLP is the only TLP with LMS and completing the topsides/hull mating in open water during hurricane season. Actually, the operation arrangement was not as initially planned but took place in dealing with the delay in the schedule. Tremendous efforts were made in the management and planning supported by intensive engineering efforts. In preparation of the topsides/hull integration operation, an Offshore Procedure Manual and a Weather Contingency Manual were developed with very detailed instructions. Although the operation succeeded, the open water floatover hull/platform integration did not become the favored choice for TLP. Inshore integration using heavy lifting equipment have been applied of the other Shell TLPs in the record.

For floaters like Spars, on-site topsides installation is inevitable. Among the proposed methods, catamaran floatover method has been commonly accepted as the favored one. However, there had no completed open water catamaran floatover operation before Murphy's Kikeh truss spar installation. The Hibernia CGBS platform integration with catamaran floatover operation was aforementioned, but that was inshore within the sheltered waters. Kikeh spar was deployed 75 miles northwest of the island of Labuan, offshore Sabah, East Malaysia with the water depth of 1341 m (4400 ft). The truss spar hull and topsides were fabricated at the Malaysian Shipyard and Engineering Sdn Bhd Facilities in Johor Bahru, Malaysia. The topsides was not so heavy—weighing 4000 Mt [30].

The team from Technip conducted the topsides installation. The mating site was the stationing area where the spar hull was upended and hooked up with the pre-installed mooring system. Different from the single vessel floatover operation, the topsides was not directly loaded out from the yard to the floatover vessels, but first onto a transportation vessel. Then the topsides was later transferred to the floatover vessels at a pre-selected location to form a catamaran. The detailed discussion on the catamaran floatover methods will be included in Chap. 6.

For Kikeh project, the chosen transportation barge was UH336 of Uni-Bulk Services with the specified deadweight of 11,000 Mt. Twin barges of Swiber Offshore—Swiber 252 and Swiber 253 were used as the floatover barges with the deadweight of 5332.3 Mt. The site of topsides transferring from UH336 to the twin barges was in the harbor of Labuan. The site was sheltered. After the completion and with the favored environment, the catamaran was towed 59 nm (110 km) to the spar stationing site for the mating. At the site the significant wave height Hs was 0.7 m and the corresponding swell period was seven–eight seconds. The floatover operation went smoothly and was successful (Fig. 2.58).

2.3.3 Challenges and Development

For offshore floatover installation, as previously mentioned, the catamaran method is no doubt an option to supplement the single vessel floatover method, which is considered mature in operation. Comparing to single vessel floatover, more technical and operational challenges exist for the catamaran floatover technique.

First, the selection of the two floatover-barges is not simple, beside the examination each barge for hydrostatic, hydrodynamic and structural properties, the behavior of the catamaran during the transportation and the floatover operation need thorough and seriously engineering analyses to assure the safety of the operation

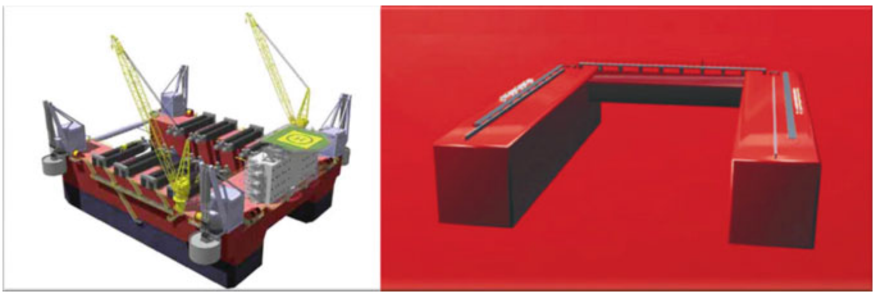

Fig. 2.59 Example of vessel concepts for catamaran. On the *left* is a conceptual design of OCDV (Offshore Construction and Decommissioning Vessel) by Master Marine AS. On the *right* is the catamaran vessel concept from student team of the University of California, Berkeley in 2002 (courtesy of Master Marine AS and UC Berkeley, Ocean Engineering) [31, 32]

Fig. 2.60 The largest vessel in the world so far—Pioneer Spirit of Swiss Company Allseas (courtesy of Allseas and gCaptain)

and the cost-effectiveness. In most cases, the engineering modification of the vessels and the heavy rigging design are necessary.

Secondly, the extra step of topsides transferring brings about more challenges for engineering and operation. In catamaran floatover operation, transferring the topsides from the transportation barge to floatover barges was a critical step. Transferring site selection and engineering simulation of the operation are vital. On the operation side, carefully created procedures and operation manuals with details of systematic instructions based on engineering studies and real practice experiences are the key for success.

The mating process for catamaran floatover is also more complicated because of the involvement of multi-body motions.

In dealing with the aforementioned challenges, one way is to conduct thorough engineering simulations and to optimize the operation procedures with adequately prepared equipment as well as contingency plans. Success can be expected with the accurate execution of the installation plan. The success of Kikeh spar is a good example, which can encourage more applications of the open water catamaran floatover.

At the same time, it should be noted that in offshore industry there have been intensive efforts in develop new method to use one vessel to carry out the catamaran floatover tasks considering both simplicity, safety and cost-effectiveness.

Some of the activities started actually from searching the solution of the platform decommissioning. As estimated, there are more than 80,000 aging platforms waiting for removal. Although the decommissioning process can be thought the reverse of the installation, but it is not practical. Some real decommissioning projects have been carried out and there have been various approaches to make the operation safe, environment friendly and economic, but there is no simple solution. For fixed platform decommission, an ideal solution is to remove the topsides and the jacket by single lift without using huge HLCV's.

Many efforts have been focusing in the development of new type of vessels, which are capable of performing the topsides catamaran floatover operation in the open sea and can perform decommissioning of platforms by a single lift. Examples include cantamaran vessel concept by UC Berkeley, OCDV(Offshore Construction and Decommissioning Vessel) by Master Marine AS (Fig. 2.59), MPU Heavy Lifter by MPU Offshore Lift ASA, DSIV Technip, etc. They will be revisited with detail in later chapters.

The goal of the concept development is straightforward: the vessels based on these concepts can be designed for real isolation and decommissioning projects. Of course, there are other factors having impacts on the investors.

One vessel launched in 2014 drew the attention in the shipbuilding, oil & gas and energy industry. She is the Allseas' new vessel "Spirit Pioneer" which was originally named "Pieter Schelte" and was recognized as the largest vessel built in the world so far. "Spirit Pioneer" is a multi-functioned vessel of 382 m (1252 ft) × 123.75 m (406 ft) × 30 m (98 ft). The vessel was designed to remove and decommission of the topsides of Shell's Brent platforms with weight ranging from 16,000 to 30,000 tons and the Brent Alpha's steel jacket. At the bow of the vessel there is a slot of 122 m (400 ft) × 59 m (194 ft), equipped with eight (8) sets of horizontal lifting beams for a single lift of topsides weighing up to 48,000 tons. Two tilting lift beams at the stern can be used for the installation and decommissioning of jackets weighing up to 25,000 tons. The main construction of Spirit Pioneer was done at Daewoo shipyard, Korea and completion was in the Netherlands (Fig. 2.60).

There is also the large deck space for offshore onboard operation. The stability and motion property are outstanding and she is capable of performing the offshore operation under the condition of Hs = 3.5 m. The decommissioning of Shell Brent platforms will start in the future, and at that time, the experiences of using Spirit Pioneer could affect the direction of the development of platform integration methodology.

2.4 Summary

Bases on the discussion with the examples of offshore installation practice, the following conclusions can be drawn:

- For floaters, if possible, the inshore platform integration is preferred. There are multiple factors in choosing between applying heavy lifting and floatover methods. Modularized lifting operations are still used and the decision will be made by the specific projects.
- Although there have only been about 30 offshore floatover operation completed in the world, the momentum has been building up, especially for heavy topsides weighing more than 10,000 Mt. There is still room for floatover technology development, including new vessel and equipment development.

Detailed discussion on floatover technology is in next chapter.

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Chapter 3
Floatover Technology

Abstract Floatover technology appeared in 1970s together with the invention of the "integrated topsides". This technology was initially aimed for the heavy topsides installation of the fixed platforms, but the first application of the floatover technology was on the steel GBS Maureen. The floatover operation can be performed at inshore sites as well as the offshore sties. Discussions in this chapter cover the floatover concept, the history of the technology development and the advantages of the floatover method comparing to the heavy lifting method. Development and evolution of floatover technology have never been stopped. Brief introduction of several main floatover techniques such as HIDECK, UNIDECK, catamaran floatover, etc. is made in this chapter and leave the detailed discussion in the following chapters.

Floatover technology covers many topics in a wide range. The focus of this book is on the technical connotation of floatover technology and the application in the offshore construction mainly for oil and gas industry. In this chapter, discussion will cover the floatover concept, the history of the technology development and the brief introduction of several main floatover techniques such as HIDECK, UNIDECK, catamaran floatover, etc. Details of the mentioned floatover techniques will be discussed in the following chapters.

3.1 Floatover Concept

Generally speaking, floatover is an operation methodology of offshore platform integration. As the platforms are structurally divided into topsides and substructures, which are generally designed and fabricated separately, the integration of the platform or the mating of the topsides and the corresponding substructure becomes one significant step of the platform construction.

Offshore platforms vary in design, size, weight in response to the field development requests and the specified functions of them by design. The topsides of the platform may also be different from each other greatly. How to choose the best solution for the platform integration of a specific designed topsides and corresponding substructure is a very challenging task. Multi-factors need to be gone

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Fig. 3.1 Smaller and light topsides can be lifted by Derrick Vessels (courtesy of COOEC)

through carefully, such as feasibility of the method, equipment availability, schedule and duration, weather window, total costs, etc. The principle is to make the operation safe and cost-effective.

Optimization starts from the topsides. One of the most effective approaches in attempting to reduce the total installation cost is to design a topsides which minimizes the work scope of offshore HUC. In other words, the HUC of the topsides is almost completed before the topsides is transported to the field for installation. The integrated topsides design meets the requests. The methodology has become popular since the concept appeared in early 1970s. With an integrated topsides constructed, the most important issue becomes how to get the platform integrated safely and in a very short time duration. This depends on the installation methods and installation equipment including vessels.

Naturally, searching for vessels capable of handling the weight and size of the topsides became the efforts of the offshore industry from the very early years. Without the HLCVs, crane barges can install the small and light platform topsides (Fig. 3.1). However, for large and heavy topsides or very heavy modules, the installation needs HLCVs. When the size and the weight of the topsides go beyond

Fig. 3.2 HMC have been planning to build a new SSCV with even higher capacity than SSCV Thialf. The new vessel Sleipnir will be equipped with twin heavy lifting cranes, each of them with lifting capacity of 10,000 Mt at a radius of 48 m (courtesy of HMC)

the capacity of the existing HLCVs, the efforts of building new HLCVs with increased capacity continues. As aforementioned, the platform design followed the spiral path in the size and weight—when higher capacity crane vessel being available, the topsides would be increased to the limit in size and weight and following that the demanding of higher capacity crane vessels would be in place timely. The fleet of the SSCVs are the results of the kind of development efforts mentioned above (Fig. 3.2).

Beside the efforts on the vessel and equipment side, there had been efforts of searching for alternative methods of integrating the platform without using HLCVs aiming at breaking the limit of platform design by the capacity of the existing heavy lifting vessels. The activities of pursuing alternative methods for platform integration began as early as in the 1950s.

The invention efforts in this area might be inspired by the innovative bridge installation method patented by Du Bois [1]. As Shown in Fig. 3.3, in the patent, the whole span of the bridge or part of it could be constructed at a site at the river or water on a “floating foundation” away from the planned bridge settling position. After the completion of construction, the floating foundation with the completed bridge span on it would be towed to the bridge settling position and over the piers and then the bridge span was to be lowered down and to be hooked up with the piers to complete the bridge building. The floating foundation was then further ballasted down and towed away. During the whole process, no lifting crane was involved. The method could also be used for the bridge replacement and removal.

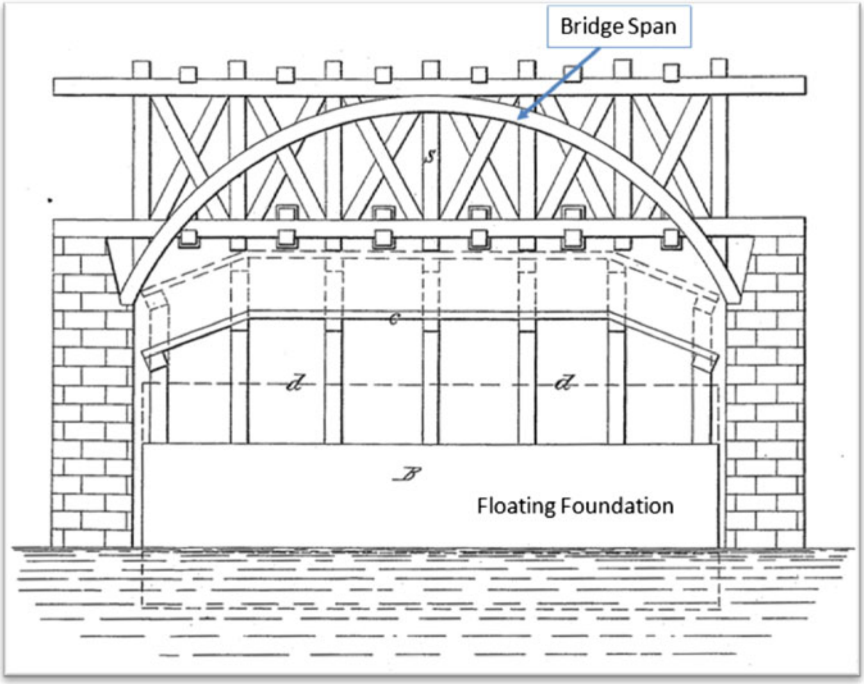

Fig. 3.3 Truss bridge installation by John Du Bois (US Patent 36606)

Comparing to inshore/offshore floatover operation in modern time, it is much simpler, but the fundamentals of the floatover technology was already there. This technology is still applicable to the modern bridge construction.

Since the milestone of offshore industry by Kerr-McGee's tender drilling off the coast of Louisiana, how to safely and cost effectively construct a platform in the open water became the challenging topic. Parallel to the efforts on building up the capacity of HLCVs, trying on inventing a new approach of offshore platform installation without crane vessels had not been stopped. Beside the invention of jack-up, there were patents in topsides installation by barges with special equipment. One of them was the method of constructing offshore drilling platforms invented by Wilfred Crake from Shell and his patent was published on October 6th, 1959. From the sketches shown in Fig. 3.4, the vessel carrying the topsides was quite similar to the concept of specifically designed catamaran vessel or pontoons and the process of the operation is very close to the industrial practices. Of course, the technology has been evolving through offshore practices.

Not so long after, the HIDECK concept floatover technology made public in late 1970s and was patented in early 1980s by engineers of Brown & Root [3]. The first application of the HIDECK floatover technique was on the first and the only steel GBS Maureen in the North Sea, instead of a fixed platform. The operation was a success and demonstrated advantages of the new technology of offshore platform

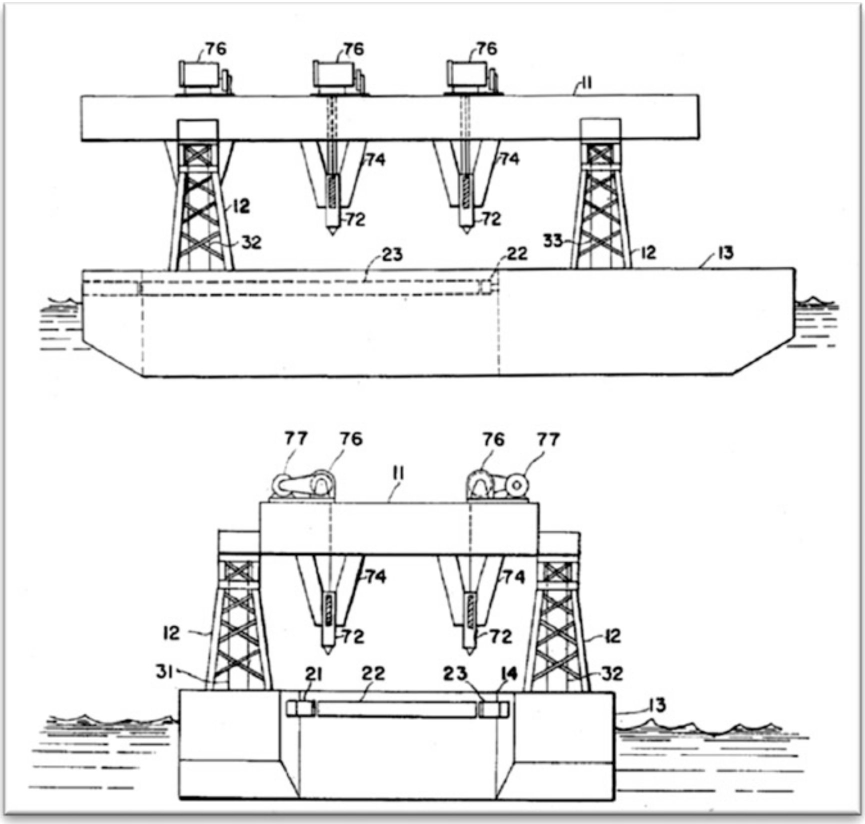

Fig. 3.4 Offshore drilling platform construction. The vessel has a slot wide enough for the substructure when the vessel is moving to it (US Patent 2907172) [2]

integration. Larry Farmer, Graham Blight, Phillip Abbott et al. from Brown & Root have been recognized by the industry as the pioneers in the floatover technology development. Beside HIDECK floatover concept, others such as UNIDECK were also developed in the early 1980s. Floatover concept drew attention in the industry, but did not gain the moment until in the middle of 1990s when several very heavy topsides were installed using floatover method in the South Eastern Asia. Now, the floatover technology developed and evolved to meet various kinds of projects' needs for both inshore and offshore operation. More projects of fixed platforms with increased water depths consider using floatover method for offshore platform integration. The application of the floatover technology is no longer only limited to a few areas and being expanded globally [4–6] (Fig. 3.5).

Since the decommissioning operation can be considered as the reversed process of installation, one-piece lift-off the topsides/platform becomes the favored removal approach. More specifically designed vessels to fulfill the tasks have been delivered and these kinds of vessels can be used for floatover topsides installation.

Fig. 3.5 The floatover installation of Nigeria East Area 1 B GX platform with the topsides weighing 12,381 t. There are more than 27 open water floatover worldwide so far (courtesy of boskalis)

The floatover concept, in brief, means to elevate the topsides of the platform by vessel(s) to a certain height above the top of the substructure at the mating site and then the topsides will be floated over the substructure and aligned. The mating of the topsides and the substructure is fulfilled by the controlled relative motion between the topsides and the hull in the vertical direction. The operation makes the connection between each connection column of the substructure and the corresponding mating leg of the topsides until the whole weight of the topsides being transferred to and to be supported by the substructure. For offshore mating of fixed platforms, compliant towers, GBSs, etc., the integration operation is completed by lowering the topsides. For inshore floater or condeeps, the mating can be performed by lowering the topsides, raising the substructure or the combination.

One topic is brought up here, i.e., the boundary between the platform integration by heavy lifting and by floatover sometime may be a bit blurred. For example, when we discussed in Chap. 2, the integration of platform Statfjord A was identified as by heavy lifting while the integration of platform Statfjord B was taken as the first inshore floatover operation for condeep. Why? Especially considering that the connecting between the topsides and the condeep columns were using vessels for both cases (Fig. 3.6).

The distinguishment between the two methods in this case is whether the topsides is an integrated topsides before the integration operation to be performed. For platform Statfjord A, when the mating operation happened, the topsides assembling was incomplete with part of the modules on the MSF and the HUC was not

Fig. 3.6 Statfjord B and C were of the same design. The topsides of the platform was built at Rosenberg Verft yard in Stavanger, Norway. The photos above show the topsides mating of Statfjord C. Multi-vessel operation was performed (courtesy of exxonmobil/norwegian petroleum museum)

completed. After the mating, HLCVs were called in, lifted other modules, and continued the installation work before the platform being ready for towing out.

Statfjord B was different: before it was leaving the construction site at Moss Rosenberg Verft's Rosenberg Verft yard in Stavanger on March 20, 1981, everything supposed to be on the topsides was then in place except the 120-m-long flare boom. The topsides at that time before the integration operation could be considered as an already commissioned integrated topsides. The mating operation is considered as floatover. This is similar to the Shell Perdido spar case: its topsides is still taken as a single lift integrated topsides although the living quarter module was installed after the platform integration.

Floatover technology seems very straightforward and simple, however, to be successful it needs highly coordinated teamwork, especially when more than one vessel are used. As discussed in Chap. 1, the installation plan development should start at the very early stage of the project, since the method selection will have strong impacts on both topsides and substructure design. Also very intensive engineering efforts are needed in identifying critical loads, structural design, weather window definition, operation procedure and manual development, etc. Problems happened in any link of the whole process chain leads to delay, cost increase and even disaster.

Floatover operation depends on intensive engineering analysis, simulation and rigging design, which vary project by project. Based on the engineering study outputs, comprehensive installation procedure and operation manuals will be developed with systematic operation instruction included. There are challenges and risks at each link of the whole chain of actions, which should be identified in the early stages of the project and correct measures should be taken promptly. In addition, the contingency plans should be in place before the commencement of the operation.

Continuous efforts have been made in floatover technology development through completion of real offshore installation projects. Floatover technology is no longer novel technology today. With good planning supported by engineering analysis and design, projects can be carried out successfully with less risk and saving in time and cost.

3.2 Advantages of Floatover Method [7–10]

When talk about the advantages of floatover method, it generally implies comparing to heavy lifting operation. A comparison list is often drawn quickly based on the intuitive understanding. However, we need to keep the following points in our mind:

- The floatover method is a good alternative to the lifting operation by crane vessels. However, for the entire offshore industry, these two methods are competing but also complementary. HLCVs still have large share in the offshore installation market.
- When talking about cost cutting, one should know that the significant cost reduction part locates at the minimization of offshore HUC work scope. As discussed in earlier chapters, the key to achieve this goal is to have a better-designed integrated deck. Look at the example of Shell Perdido project, the one lift integrated topsides was also cost-effective.
- When making comparison, it is better to look at the project details, e.g., can the topsides be installed by a single vessel? Are there the needs for structural modification and at what level? How about the environmental conditions at the mating site? If use HLCV, what capacity is necessary and what the availability is? and so on.

  Fairly speak, to make an accurate comparison and scientific judgment, project by project including every possible factor's details are necessary. In the following, a general discussion about the advantages of floatover is presented.

- Offshore HUC scope of work is minimized which leads significant cost reduction

  When discussing floatover operation, the presupposition is that the topsides is an integrated topsides although the operation method can also be applied to very heavy module.
  As discussed earlier, the most significant factor to the offshore construction cost reduction is to minimize the offshore HUC work scope. For floatover installation, the topsides has all equipment on board and fully commissioned before the platform integration, most of the HUC work has been completed before the platform integration operation. If the integrated topsides can be handled by an HLCV, then this advantage no longer exists. When compare to the heavy lifting installation by modules, the cost saving is obvious (Fig. 3.7).

- There is almost no limit of the topsides weight for floatover method

  Looking at the HLCVs, even the largest SSCVs such as Heerema's Thiaft and Saipem 7000 still have the capacity limit. However, for very large fixed platforms, the weight of the integrated topsides is easily beyond 20,000 tons, not to mention the huge topsides of the GBS platforms.

Fig. 3.7 Maureen substructure waiting for the mating with the topsides. The Mating operation was the first HIDECK floatover technology application (courtesy of Oil Rig Photos)

Look at the floatover platform integration projects completed in recent years, the weight of the topsides using floatover method by single vessel already beyond 20,000 tons such as Platong Gas II Central Processing Platform of 20,943 ton and SHWE platform of 30,000 ton. HLVs and high capacity barges are available to carry out this kind of operations (Fig. 3.8).

For ultra-heavy topsides, the lifting capacity of floatover method can come from multiple barges, which is doable. Look back at Fig. 2.9 in Chap. 2, during the inshore floatover platform integration, four barges were used. In the middle, the

Fig. 3.8 Very heavy topsides is no longer rare now. On the *left* is the topsides of SHWE A-1 platform weighing about 30,000 tonnes and on the *right* is the under construction Hebron GBS of which the platform integration will use catamaran floatover with the mating load up to 40,000 tonnes (courtesy of shell and warleyparsons) [11, 12]

Fig. 3.9 There are more DTVs and large capacity barges available globally and the MOB/DEMOB is much easier and faster comparing to HLCVs. On the *left* is the loadout of the Bayu Udan topsides on Dockwise's DTV Blue Marlin. On the *right* shows the successful floatover installation of HZ25-8 topsides (courtesy of bayu udan project and CNOOC) [13]

two barges were arranged in the piggyback way. Undoubtedly, to reach the goal of minimizing offshore HUC work for platforms with ultra-heavy topsides, floatover is the method to choose.

- Availability of floatover vessels are higher than HLCVs

Floatover operation uses barges or DTVs (Deck Transportation Vessel) such as vessels from Dockwise and COSCO (China Ocean Shipping Company) which can float on/off and transport objects weighing more than a few dozens of thousand tons. There are more these kinds of barges/DTVs available than HLCVs. Especially for remote areas such as Timor Sea. It may not be practical to depend on the HLCVs for the platform integration.

On the other hand, because of the DTVs and the high capacity semisubmersible heavy lifting barges used for the floatover projects are simple in design and construction with reasonable cost, for large projects, new vessel can even be ordered at the early stage of the project to meet the schedule.

Furthermore, corresponding to the demand of the decommissioning market, specifically designed vessels for decommissioning and removal of existing platforms. Most of these kind of vessels can handle the installation of very heavy integrated topsides by floatover.

Therefore, when a project chooses to use floatover method for its platform integration, it should be relatively easy in finding the right vessel(s).

Information about Bayu Udan project shows that two (2) platforms were installed using floatover methods in two (2) consequent operations by Dockwise's Blue Marlin. The weights of the topsides are 11,500 tons and 13,900 tons and the field was in the Timor Sea. The SSCVs with the required capacity were not available in the area at that time (Fig. 3.9).

At the same time, as previously mentioned, for some projects, multiple vessels may be used to handle the installation of very heavy topsides without limitation in theory.

- Floatover method may benefit project management

  To integrate the platform offshore using crane vessels, no matter by modularized operation or one lift integrated topsides installation, beside the crane vessel, there must be the transportation vessel(s). As for the floatover method, the transportation vessel(s) will be used for the topsides/substructure mating operation. The potential benefits to the project management created are:

  – For floatover method, a single contractor can cover the topsides loadout, transportation and installation. Therefore, there will be no need of the interfaces between the installation and transportation in the project execution plan.
  – At the same time, the schedule alignment between two different kinds of vessels is not needed any more and thus reduces the project execution risk.
  – It creates the possibility of reducing the offshore installation operation hours. With shorter operation duration, it will be easier for the project to catch the installation weather window, in turn to be able to conduce the project schedule handling and further cut the cost.

- Project costs can be expected lower comparing to installation by heavy lifting

  Suppose the integrated topsides is to be installed by both methods. In addition, assume that there is no so much difference in the offshore operation duration. There is still possible large cost difference between the two methods. The cost saving for floatover method comes from fewer vessels involvement and lower charging rate as well as lower MOB/DEMOB cost of the barges and DTVs comparing to the HLCVs.

- Safety

  In the entire process of floatover operation, the topsides is supported by specifically designed structures even during the load transfer. All the installation steps are based on matured operation practices strictly following carefully developed procedure and operation manual/instructions. Any offshore operation is not risk free but the risk rate is minimized during the floatover operation. It is safe to say that floatover method has comparable or less risk against installation by crane lifting.

- Fewer constraints

  – When face very heavy integrated topsides, say more than 7000–10,000 tonnes, the capable HLCVs can only work in deepwater, but the floatover method can handle very shallow water with engineering efforts.
  – To handle mega or ultra large topsides, not only the weight is high but also the size is large especially the height, which adds challenges to HLCVs including Versabar vessel. The topsides height increase can also come from very high air gap requirement such as happened in the Angel platform of

Fig. 3.10 Floatover method can be used in very shallow water with high mating load as shown on the *left* for the COCOCORO project—the water depth is 5 m and the mating load was 7400 tonnes. On the *right* is the Sakhalin LUN-A platform, the topsides weighed 21,800 tonnes (courtesy of conoco and shell respectively)

Woodside in Australia. However, for floatover method there indeed no limitation issues on the height and the size of the topsides when the right DTV are chosen and the stability meet the requirements (Fig. 3.10).

In summary, floatover method has been recognized by the offshore industry as a matured and versatile installation methodology with advantages proven by successful projects in safety and cost-effectiveness for offshore platform integration both inshore and offshore. The statistics also showed the trend of increase of floatover application especially for heavy topsides. According to the results of the study covering offshore platform installation during the period from 2005 to 2012, for topsides weighing over 12,000 t, among the 72 projects, one third of them were completed using floatover method and this trend keeps going the same direction.

Of course, there are still challenges in further development of the floatover technology but there exist new opportunities for the technology to develop and to improve, especially when combining the market demands for both installation and decommissioning [14].

3.3 Category of Floatover Technology

Since the success of the first HIDECK floatover platform integration in 1983, the principles of the floatover methodology concept have been well accepted by the offshore industry and efforts on application accompanied by improvement and development have never been stopped in the past more than 30 years. As the results of the efforts, several variants stemmed from the fundamental principles have been introduced, patented and applied to the real projects. They are UNIDECK of Technip, SMARTLEG of EPTM, MOAB (Mobile Offshore Application Barge) of OVERDICK, FOHAG (Floatover of High Air Gap) of Technip and so on.

All of them are based on the main principle of achieving the integrated topsides installation using DTVs without cranes, but distinguish themselves from each other in equipment/rigging design and usage, vessel usage and selection, operation details, etc.

There have been articles in which these methods are classified into different categories, however, without clearly defined guidelines for grouping. In this book, discussions will be divided into five parts covering HIDECK, UNIDECK, SMARTLEG, Catamaran floatover and other methods, which includes newly appeared methods such as MOAB, FOHAG, etc. The features of each method will be discussed with certain details.

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Chapter 4
HIDECK Floatover Technology

Abstract Floatover technology starts from HIDECK floatover. It is the most successful floatover method for inshore and offshore platform integration. HIDECK floatover was invented for installing heavy integrated topsides on the jackets of the fixed platforms without heavy lifting equipment. A single barge is used to transport the topsides to the installation site. The mating of the topsides and the jacket is accomplished by de-ballasting the barge. The method can also be applied to floaters such as TLP, semi-submersibles. HIDECK floatover method has been widely used for offshore open water topsides installation. It becomes the favored method for integration of platforms with heavy integrated topsides. In this chapter, the concept and the development of HIDECK are discussed in depth with the application examples. The successful accomplished projects presented convincingly show the advantages HIDECK floatover method in safety and cost effectiveness.

The concept of HIDECK was developed in late 1970s after the "Integrated Deck" was conceived in 1973 by the offshore industry in the North Sea area. It was among the efforts to meet the request from the offshore platform installation. In the northern part of the North Sea, the conventional steel fixed platforms were not feasible because of the severe environment, although the water depths are suitable. If a fixed platform is considered, it need to have over large and heavy substructure and the installation of the jackets became very challenging. Furthermore, not only the design and fabrication, but also the installation in operation and the handling of the very narrow weather window encountered great challenges. Faced this kind of demands from the industry, GBS concept emerged as well as the integrated topsides concept.

The main goal for the integrated topsides design, as discussed earlier, is to try to make the modules on the topsides hooked up and commissioned before go offshore so that minimize the HUC work scope in offshore. Then how to handle the integration of the platforms with the integrated topsides became a challenge. Obviously, the integrated topsides would be heavy and large. One option was to optimize the integrated topsides by reducing the module connecting structure weights, condensing the deck space to lower the request on the capacity of the HLCVs. At the same time to design

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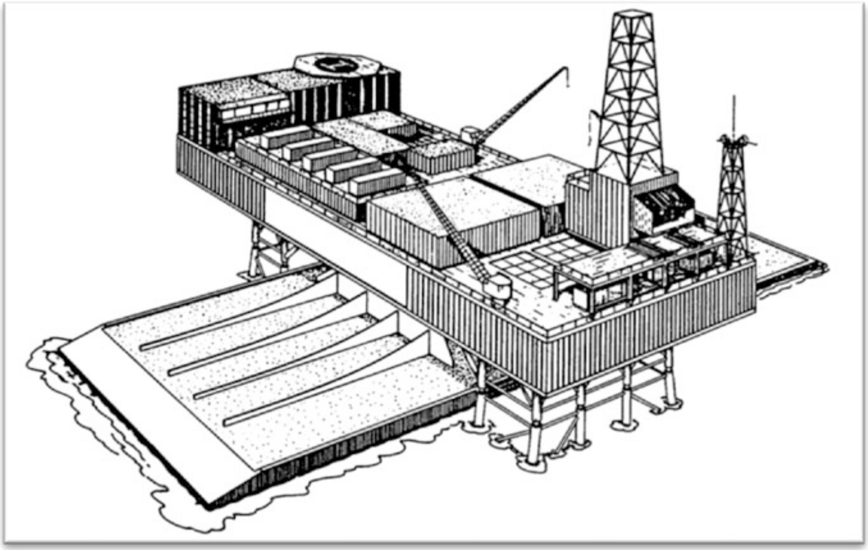

Fig. 4.1 The HIDECK floatover concept presented in OTC3978 by Abbott et al. in 1980 [2]

and construct huge HLCVs with high lifting capacity. Actually, the large SSCVs of the HMC were already available in the late 1970s.

Around the same time, engineers from Brown & Roots made public their new idea—HIDECK. On the surface, HIDECK is a new concept of the integrated topsides, but in fact, it introduced a new platform integration method with an evolved integrated topsides design. HIDECK was to be fabricated, fully equipped, outfitted and tested in a building dock and to provide a complete drilling and production facility. It would be a single piece structure to be transported and installed on the pre-installed steel or concrete substructure inshore or offshore.

It should be noted that HIDECK was different from the existing concept of "integrated deck". In the paper presented by Graham Blight in April 1978, he explained that HIDECK was a "semi-integrated deck" with a very large deck area being provided on two major levels [1]. HIDECK was a versatile concept offering wide scope and possibilities in arrangement with the consideration of easy equipment additions and changes. The hint might be that HIDECK was more emphasizing the integration and more flexible on the topsides weight.

In OTC paper 3978 in 1980, the HIDECK floatover concept was defined clearly and the application details were presented (Fig. 4.1). The original concept contains the following parts:

- HIDECK, a new integrated deck could be transported by a single barge
- A specially designed substructure
- The method of mating a HIDECK to a previously installed substructure offshore.

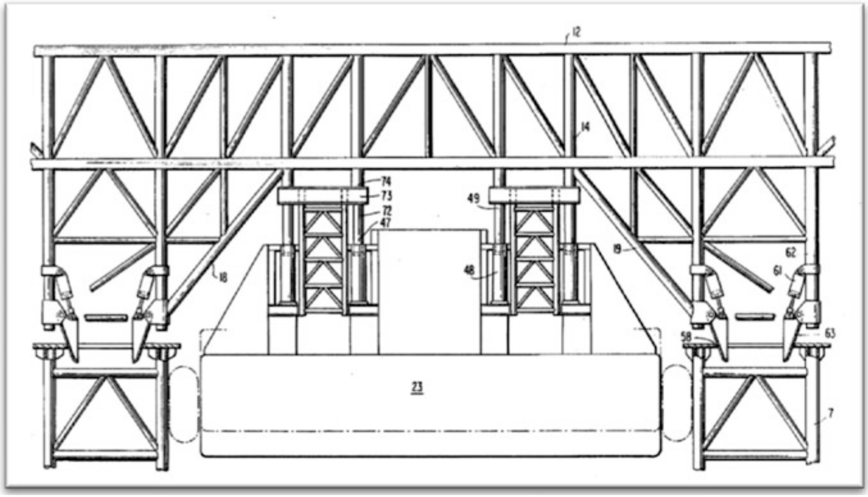

Fig. 4.2 An illustration sketch demonstrating the HIDECK floatover concept in US Patent #4252469 [3]

Although the technology was first applied to the inshore integration of the Maureen steel GBS in 1983, the concept initially was clearly developed for an offshore fixed platform. The technology development seems starting from 1977.

Three patents related to this concept were applied in 1978 and then were granted between 1980 and 1981 (US4242011) [4, 5] (Fig. 4.2). In the patents, the whole concept of single vessel floatover was covered with all the technical details including topsides, substructure, equipment and operation procedure which is a very useful guideline of the floatover operation. The fundamentals of floatover methodology presented in the documents have not been changed after so many years.

In the published articles and the patents, one development goal was emphasized, i.e., the invention would drastically reduce the offshore HUC work scope hence reduce the installation costs. The discussion of the cost reduction using the hypothetical project case in the North Sea project is as follows. Assume that the topsides of a platform consists of eight (8) to twenty (20) modules. It was typical in the North Sea. By modularized installation, the offshore HUC work on average needed one (1) million person-hours at the time and the activities would last for ten (10) months. If the HIDECK technology is applied, the inventors argue, 90–95% of the offshore HUC work will be eliminated. Furthermore, the HIDECK was designed as an open truss structure, which also lowered the onshore construction cost comparing to the modularized method, since it allows more orderly facility layout and straighter piping and cabling runs [6].

Technically, HIDECK floatover methodology established the fundamentals of floatover operation by identifying the main operation phases and entailing the actions at each step. It also covered the device and rigging design and the ideas of their functions related to smoothing load transferring, structural integrity and operation safety, e.g., the alignment between the topsides and the substructure, the shock absorbing, the quick disengagement between the topsides and the barge after the completion of the integration, etc. Although changes and development of equipment and rigging have been made during the applications of decades, these fundamentals are still there. These fundamentals have also been adopted in the development of novel platform integration technology.

HIDECK floatover method was invented with the barge (vessel) as the center for the achievement of the topsides mating. It started on using a single barge. Not only the HIDECK topsides design was directly involved with the vessel selection including capacity, weight distribution, stability, etc., the substructure design is also strongly affected. As an example, the inshore platform integration of Maureen Alpha GBS is discussed. It was the first application of the HIDECK floatover installation method in the industry [7–10].

The Maureen HIDECK weighed 18,600 tons when it was completed. The deck was 225 × 246 ft including a flare-stack towering 389 ft above the bottom of the lower deck. The primary steel frame of HIDECK consisted of five (5) main trusses supported on ten (10) legs (Fig. 4.3).

Maureen Alpha platform was the earliest one among a few steel GBS. The platform was designed to be anchored by its heavy bases, however, from the platform original design concept, it should belong to the group of "submersible". Now, there exist only a very few submersible platforms (rig). The design concept of the submersibles (mainly the offshore drilling rigs) is that the platform would stand on the seabed stably by its weight and ballast during working (drilling), after the work is completed, it is then floated up by deballasting the buoyancy tanks and transferred to a new working site.

Maureen Alpha platform was designed for the field, which was marginal, and the platform was supposed to be re-usable: the three (3) storage tanks can be used to provide buoyancy to float the whole platform up and ready to be towed away. In this sense, Maureen Alpha platform can be taken as a submersible. Actually, it was refloated in 2001 but not for re-use in a new location, but for the decommissioning instead (Fig. 4.4).

According to publications, the initial platform design had the topsides configured as a module support structure sitting on the hexagonal framed tower. After the adoption of HIDECK concept, both the topsides design and the hull design were altered. The topsides was the HIDECK design or the floatover integrated topsides design, which made all the equipment on the topsides and fully commissioned before the integration with the GBS hull—Maureen TSG (Tecnomare Gravity Structure). At the same time, the Maureen TSG design was also changed to be a floatover substructure with the upper part of the hexagonal tower being modified to be a jacket like. After the modification, the upper part of the hull had two rows of columns with an opening wide and deep enough for the floatover barge to move in and out during the topsides mating operation. Each row possessed five (5) supporting columns to be connected to the topsides. The floatover barge H-114 with DWT (Dead Weight) of 39,776 tonne and dimension of 160 m × 42 m × 10.7 m, owned by HMC was specifically built for the integration of the Maureen Alpha platform (Fig. 4.5).

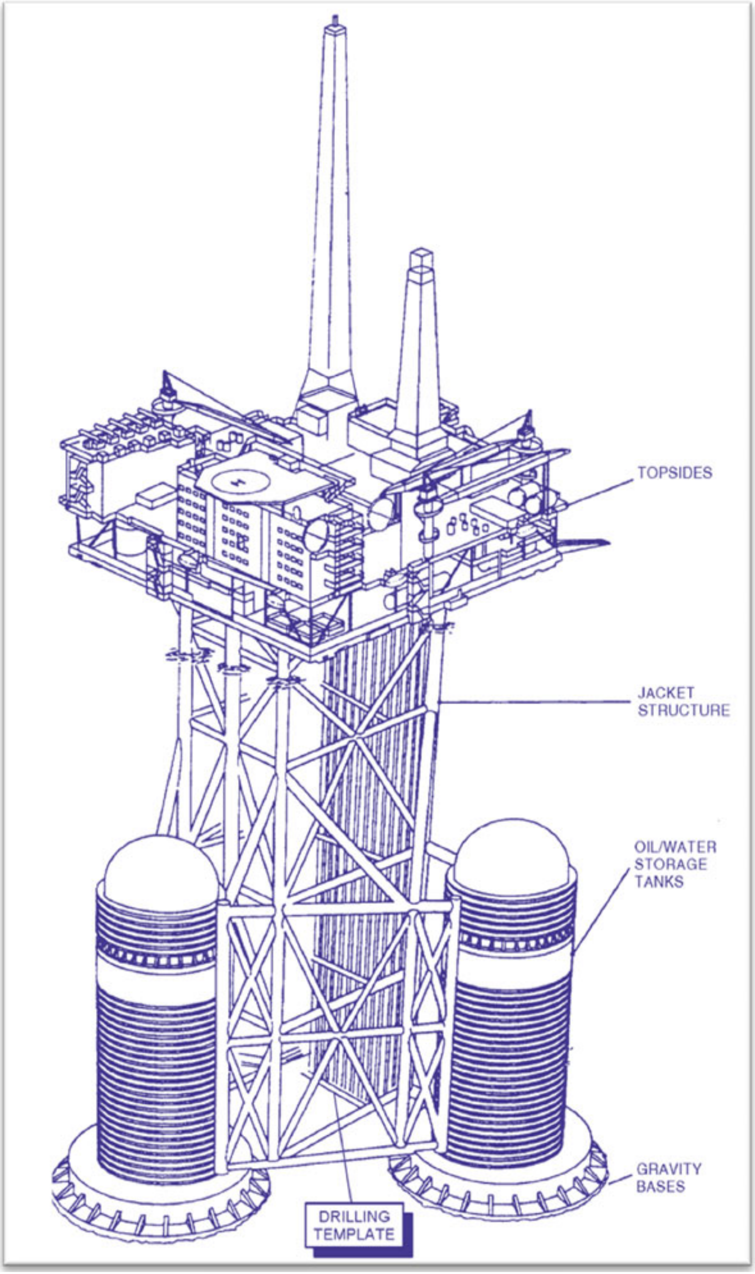

Fig. 4.3 The topsides of the platform sits on the jacket structure in the middle (after Broughton [8])

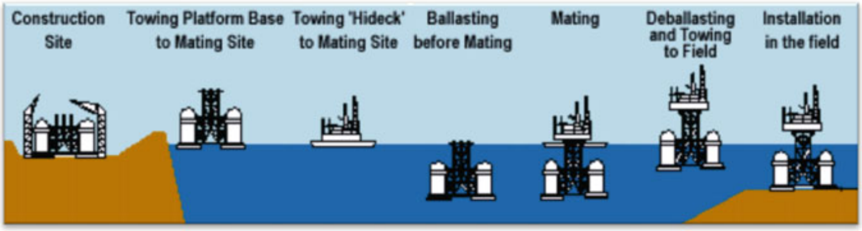

Fig. 4.4 The Maureen Alpha platform was designed to be re-usable

Fig. 4.5 The topsides of Maureen Alpha platform was built over water spanning between the quayside and a row of piled supports; It was carried by H-114 to the mating site (*left*). On the *right* is the Maureen TGS before the mating. It would be ballasted down at the mating site (Courtesy of Fagioli and ConocoPhillips respectively)

The completed HIDECK was towed out from the Howard Doris yard to the mating site at Lock Kishorn in February 1983. The HIDECK design allowed the field to come on stream two (2) weeks ahead of schedule and reduced the offshore HUC work scope to 80,000 person-hours (Fig. 4.6).

The HIDECK floatover method has been classified as a passive floatover technique with its reason. In the initially developed concept, the barge plays the critical role in the whole floatover process from the topsides loadout to the mating operation. The gap between the tip of the mating leg and the top of the substructure mating columns is achieved by the height of the DSS on the barge. This height could not be adjusted as soon as the topsides is loaded out until the mating operation. At the installation site, to integrate the topsides with the pre-installed substructure, say, the jacket or the CGBS hull, the reduction of the mating gap is carried out by increasing the draft of the barge and the process is supposed not

Fig. 4.6 On the *left*, it shows the platform integration operation inshore, the Maureen TGS was ballasted down leaving about 8 m (26.2 ft) of the jacket top emerging above the water. It can be seen on the *right*, after the H-114 withdrawing, the Maureen Alpha platform further deballast and ready for towing off (Courtesy of Oilrig.Hunterston.eu)

reversible. Of course, the gap value during the mating process is impacted by the tidal conditions at the site. The sand jacks, if used, are only designed to help the disengagement between the barge and the already installed topsides. On this aspect, HIDECK is quite different from Technip's UNIDECK and ETPM's (Entrepose GTM Pour les Travaux Petroliers et Maritimes) SMARTLEG.

As we mentioned earlier, the early applications of HIDECK were the inshore platform integrations in the North Sea. Beside the Maureen Alpha steel GBS; the other platform is the first TLP in the world—the Phillip's Hutton TLP. For the inshore floatover operation, it is more "passive" on the floatover vessel. The mating gap reduction is at least not merely by ballasting down the vessel but deballasting the substructure or the combination.

Some information of the platform integration of Hutton TLP might help to see the floatover technique fundamentals and also the differences comparing to the floatover practices in recent years [11–15].

Under the decision of using HIDECK floatover method for the integration of the Hutton TLP, the topsides was designed as an integrated topsides with the goal of strict control of the weight and COG. The following were considered during the topsides design:

- To lower the structure weight by arranging the equipment in the way to keep the function but reduce the connection steel weight and minimize the cable running
- To have the hazardous area separated on the south half of the platform topsides
- To best position the COG, the accommodation modules were cantilevered with controllable value so that to create the needed lever arm to offset the eccentricity caused by certain heavy objects such as drilling derrick, well riser tensioners, etc.

All the above is consistent to the design principles of the integrated topsides, which are still applied in the present practices. The common issue of topsides structural deformation was effectively addressed during the Hutton TLP topsides construction. The topsides was 74 m × 78 m in dimension. When being supported on the columns of the TLP hull, the loading conditions was different from the loading conditions during the fabrication at the yard, since supporting truss were much narrower. Measures were made to successfully handle the effect of the load distribution change. This finding and experiences from practice are beneficial to later floatover projects (Fig. 4.7).

Mating operation phase is one of the most important phases. The operation involves load transferring with the risk of damage of the platform structures. For Hutton TLP, similar to the Maureen Alpha platform, the reduction of the mating gap was also through the de-ballasting of the TLP hull during the whole mating process. There were total sixty-eight (68) ballast tanks equipped in the hull columns and pontoons. The pumps located at the bottom of the central columns performed the ballasting/deballasting. The ballasting/deballasting operation was handled by the temporary control module attached to one of the columns. The topsides was carried by the then McDermott barge Oceanic 93 which was very "passive" during the mating procedure—the change of the relative position vertically between the topsides and the TLP hull was by deballasting the hull ballasting tanks of the TLP following the ballasting plan. The load transferring from the barge to the TLP hull induced the change of Oceanic 93's draft.

Fig. 4.7 The topsides of the Hutton TLP was a HIDECK design and fully commissioned before the inshore mating with the Hull (Courtesy of ConocoPhillips)

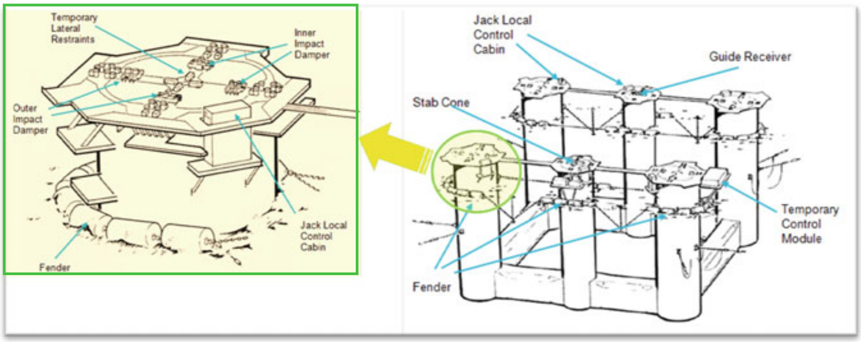

Fig. 4.8 Hutton TLP Mating equipment (after [10])

Safety is always a big concern for any operation and as one of the earliest application of a novel technology at that time, extraordinary attention was paid to the measures of prevention of operation interruption and damage to the structures and equipment of mating assistance. Beside the fenders and temporary mooring system for safe barge moving in and the alignment of the topsides and the TLP hull, bumper pads were also used to prevent any damage to the topsides.

The most important issue for every floatover operation is the safe transfer of the topsides loads to the substructure under the relative motions caused by the environment. Not only the carefully developed ballasting/de-ballasting plan is necessarily in place, the equipment capable of guiding the connecting motion and absorbing impact loads in both vertical and horizontal directions are vital. Because of the Hutton TLP platform integration was the second application of HIDECK floatover technique in the history, the installation was still considered as some kind of pioneering work in floatover operation area. The system designed for absorbing the mating impact loads was more complicated than the LMUs (Leg Mating Unit) being designed for the floatover projects completed in recent years (Fig. 4.8).

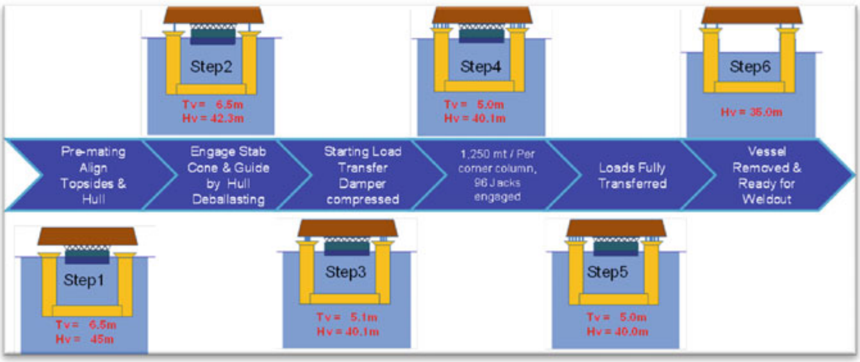

Fig. 4.9 Six (6) steps of the mating process for Hutton TLP

The Hutton TLP hull consisted of six (6) columns, which will share the topsides load of 18,000 tonnes. The mating process was further sub-divided into six (6) steps as demonstrated in Fig. 4.9. The devices assisting the mating operation were functioned into the following groups and allocated at the designed locations.

- Contact guiding and impact load absorbing
  Two sets of equipment were designed:
  - **Stab pin and cone receiver** with the latter was located on the top of one of the center column and the stab bin was located at the corresponding position under the topsides. This group would be the first contact spot during the mating and the cone receiver was facilitated with two (2) kinds of shock cells to absorb initial vertical dynamic load and also to provide lateral constraints to the relative motion between the topsides and the hull as soon as the stab pin and the cone receiver being hooked-up.
  - **Guide and guide receiver** which was located on the top of the opposite center column which would work as the second contact spot. After the hook up of the stab pin and the cone receiver, the topsides and the hull as two (2) rigid bodies had a single contact. In the horizontal plan, the relative rotational motion had not been blocked. Then the guide pin and the guide receiver would be connected to make the relative motion between the topsides and the hull fully constrained. This pair was also equipped with two kinds of shock cells.
    These two (2) sets of equipment only provide the initial aligned contacting between the two (2) mating parts, no real load transfer happened. However, the deballasting of the hull reduced the gap between the topsides and the TLP hull.

- Impact dampers absorbing vertical compressing load
  This group consists of sixteen (16) individual impact dampers functioning as a soft spring when the load transferring commenced. They are located on the top of the four (4) corner columns with four (4) on each column. When the deformation of the dampers occurred, the load transfer was underway and the draft of the mating barge would be reduced correspondingly by the reduction of the load on it.
- Jacking system to even distribute vertical loads
  To make the topsides load evenly distributed at each column when the weight wholly transferred to the hull, each of the six (6) columns was equipped with sixteen (16) hydraulic jacks. The jacking system also work together with the dampers in handling the impact loads. When about 25% of the topsides load had been transferred, the jacks would start to take loads by adjusting the height in order to avoid overloading to the dampers and related part of structures. According to the design, the center column carried twice as much as the load carried by the corner columns; the jack capacity on the center column was also more than twice as the capacity of the corner jacks.

At the end of the mating, the entire topsides load was on the ninety-six (96) jacks and well distributed. The jacks would be at the height so that the infill steels would be fitted in for the weld-out.

The jacks would be removed after the completion of the weld-out.

- TLR (Temporary Lateral Restraints) to keep the mating completion status before the weld-out.

  After the completion of the load transfer, the entire weight of the topsides was supported by the hull. However, before the infill steel was in place and welded, there was no lateral constraints. The TLR units were designed to be temporarily engaged in providing safe lateral restraints when all the sixteen jacks on each column were assured to be the only load path providers.

As shown in Fig. 4.9, each step followed the plan with extraordinary details backed up by engineering study and experiment. During the whole process, the ballasting system equipped on the hull played critical role in controlling the mating gap change and the load transfer. One thing need to mention here is that the ballasting of the barge was also involved in a supporting role, i.e., when 60% topsides weight was transferred, the barge ballasting system was used to keep the heel and trim angle minimum. When dealing with the fixed platform, the situation will be completely different and the capacity of the barge's ballast system will be critical.

The advantage of the floatover technology was shown by the simplicity of the de-mating of the Hutton TLP topsides. The operation was carried out by a single vessel S600 owned by Saipem at that time. The 18,000 tonne topsides was separated with the hull and carried by the barge to the Sevmash fabrication yard at Severodvinsk, in Russia. There, it was refurbished and reinstalled onto a new hull structure of the Prirazlomnaya platform (Fig. 4.10).

The integration of the Hutton TLP platform went smoothly and the installation project carried out by Aker Offshore in 1984 was successful. Although the mating process and the equipment used are more complicated comparing to the later

Fig. 4.10 The de-mating of Hutton topsides was carried out by Saipem barge S600 (Courtesy of ConocoPhillips)

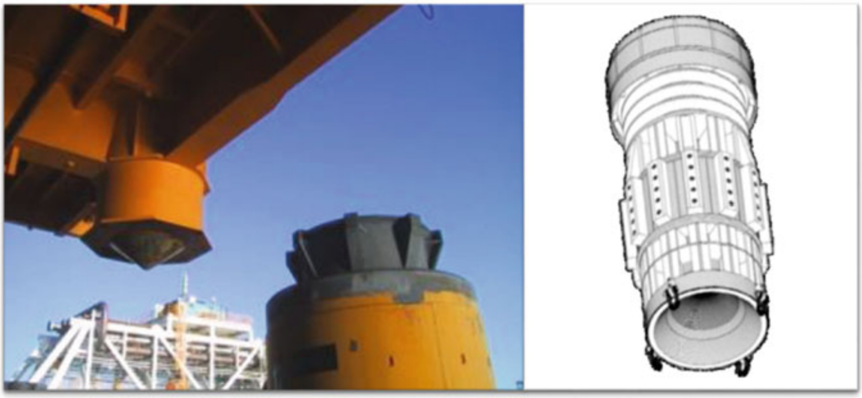

Fig. 4.11 LMU is widely used in conventional floatover. Here is one of the LMU design and used in the floatover projects (Based on Hutchinson's brochure)

projects, undoubtedly, the fundamentals of the mating procedure and the principles of the handling of load transferring are still the same. A lot of the new technology development such as the LMU has benefitted from the earlier success of the HIDECK floatover technology application (Fig. 4.11).

The inshore platform integration operation applied to condeeps and semisubmersibles can be considered as the success of the HIDECK floatover technology based on the same fundamentals and the passive approach of the mating operations. The Auger TLP topsides installation in the open water can also be considered belonging to this category although the operation was not as initially planned. However, keep in mind, the technology was originally developed targeting at the offshore open water fixed platform integration and it was doable in the North Sea but not the favored choice of the operators in that region.

Fig. 4.12 Examples of floatover installation. On the *left* is the Shell's Malampaya platform with the weight of the topsides being 11,600 tons, installed in 2001. On the *right* is the Liwan 3-1 topsides with the weight of 32,000 tonnes installed in 2013 (Courtesy of Shell and CNOOC respectively) [16]

Fig. 4.13 ACG Topsides Floatover Installation in Caspian Sea [17]

The door was opened by the successful installation of the topsides for Shell's M1 and M3 platforms offshore Malaysia by KBR in 1995. The successful fixed platform integration with the topsides weighing more than 7000 tons were followed by the much heavier topsides floatover installation, e.g. the Malampaya platform with the weight of the topsides being 11,600 tons (Fig. 4.12).

More companies joined the trend and more installations of heavy topsides have been carried out. As mentioned earlier the SHWE topsides weighed about 30,000 tonnes and was successfully integrated with the pre-installed jacket offshore Myanmar in December of 2012.

With accumulated experiences, the technology become mature in application and the operation procedure has almost been standardized, although tailored equipment design and specific details of the operation planning are still needed. HIDECK floatover method becomes a favored selection of the newly designed fixed platforms in the Asia Pacific region. The applications have also been made in other areas such as the Caspian and recently in GOM (Fig. 4.13).

With the efforts on the improvement of the equipment design, vessel selection and outfitting as well as engineering analysis, the floatover operation can be carried out with a very smooth load transferring and quite short mating period.

The biggest challenge to HIDECK floatover technique comes from the large air gap requirement to some platforms. Since the topsides' height over the transportation vessel deck is fixed after the loadout and before the mating operation, higher elevation of the topsides not only requests super large topsides supporting structure and may lead to low stability for transportation and the mating operation. Projects such as Angel with high air gap were accomplished using floatover. However, sometimes, the vessel selection and outfitting as well as the large supporting structures came to eat off the benefits of the method. Some innovations are needed for special cases.

In summary, HIDECK floatover technology is the most successful floatover method for inshore and offshore platform integration. It has been widely used for offshore open water topsides installation. With the integrated topsides design and a single vessel for transportation and mating operation, the method has shown by successful accomplished projects the advantages in safety and cost effectiveness. The experiences gained during the project execution by HIDECK floatover technique helps its maturation. At the same time, the fundamentals and technical details also benefits the development of other floatover technologies.

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Chapter 5
UNIDECK and SMARTLEG

Abstract One of the operation challenges to single barge floatover is to handle the heave motion of the installation vessel induced by the environment during the floatover operation. The natural period values of the vessel carrying the topsides fall in the period range of long waves such as ocean swell. In the region like West Africa, swell is often the dominant environment factor, HIDECK method is not suitable for the direct application. Two single vessel floatover methods are capable of handling the swell induced motion by specially designed equipment and operation procedures. They are the UNIDECK method and the Smartleg method. The UNIDECK method is an "active" floatover method. The UNIDECK transportation/floatover vessel is equipped with a specially designed jacking system which makes possible for the mating process to be reversible during the operation. The same vessel/barge can do both HIDECK floatover and UNIDECK floatover depending on what installation equipment put onboard. A vessel with UNIDECK equipment can carry out the floatover operation by only using the ballasting system as the HIDECK method. The UNIDECK method has been quite successful in offshore open water platform integration. The SMARTLEG technology is also capable of handling the swell environment. Different from UNIDECK, SMARTLEG system is designed to avoid the taking place of the impact during the mating process, hence it was also called "shockless floatation method". However, this technology has not gone very far with only one offshore application. Discussion in this chapter covers the technical details of these two methodology through the presentation of real projects.

5.1 UNIDECK Floatover

According to published information, UNIDECK technology as an alternative option to the heavy lifting method of platform topsides was developed by the subsidiary TPG (Technip-Geoproduction) of Technip. Therefore, it was also called UNIDECK-TPG. UNIDECK has been Technip's proprietary technology for platform floatover operation in open water [1–3]. This technology has been used more

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than a dozen's times globally including West Africa where the severe swell condition is very challenging for fixed platform integration operation.

In simple description, the UNIDECK procedure works as follows [4]:

- The topsides to be installed is first loaded out onto the supporting structure with specially designed jacking system on the installation vessel and transported to the installation site of the offshore field.
- The vessel together with the topsides is inserted between the legs of the pre-installed jacket via a specially designed guiding system and the use of fenders. When entering the jacket, the air gap is controlled to 1.5 m by the barge ballasting system.
- The topsides is then lowered onto the jacket through the jacking system with control or by the combination of the jacking and the ballasting of the barge. (Note: the installation can be completed by using only the ballasting system as the HIDECK method for some cases.)
- UNIDECK method is considered an "active" floatover method capable of handling the prevalent sea swell by using the controlled jacking system. It is hence the favored choice for projects in West Africa.
- After the topsides loads are fully transferred to the jacket, the barge would be removed as planned.
- The duration of the installation process takes 12 h under the permitting weather conditions.

5.2 Comparison UNIDECK to HIDECK

UNIDECK method in many aspects are quite similar to HIDECK floatover method:

- Both methods avoid heavy lifting operations in performing the offshore platform integration.
- Both methods use integrated topsides design.
- Both methods use a single vessel (barge) to carry the topsides covering the transportation and the platform integration.
- Both methods use LMU to handle the impact loads and the topsides weight transferring during the mating process.
- They have the same advantage of safe and cost-effective comparing to the installation using heavy lifting vessel, especially the minimizing of the work scope of the offshore HUC.

The major difference between UNIDECK and HIDECK methods is the approach of the mating operation. As aforementioned, the HIDECK floatover method was sometimes categorized as "passive" floatover method. The UNIDECK on the opposite is an "active" floatover method. When applying the UNIDECK floatover method, the selected vessel is equipped with a specially designed jacking system

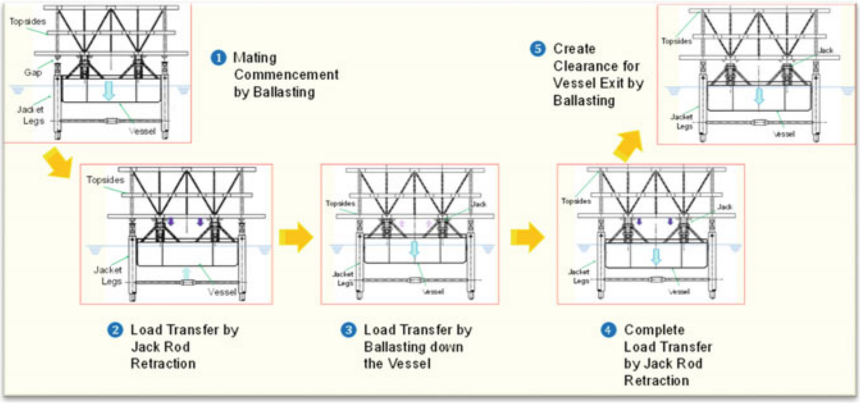

Fig. 5.1 Illustration of the mating phase operations for UNIDECK method

beside the required ballast system, which may sometimes be used during the mating operation. The jacking system consisting of hydraulic jacks and a control center makes possible for the mating process to be reversible during the operation. As well known, in HIDECK floatover operation, as soon as the mating activity starts, there will be a no-return point for the operation. The same vessel/barge can do both HIDECK floatover and UNIDECK floatover depends what installation equipment are put onboard during the outfitting.

Very often, the mating process is accomplished through jacking down the topsides at the site instead of ballasting down the vessel. By "active", it means that each of the steps of the jacking system actions is reversible, therefore the mating process can be "actively" controlled, which cannot be done when using HIDECK method. In Fig. 5.1, the schematic diagram gives some details for the mating and load transfer activities in a typical UNIDECK floatover operation. In the five steps shown in the figure,

- Step ❶ is the starting point of the mating process with the sketch shows the status of the end of pre-mating with the required gap between the stabbing cone and the jacket LMU. The blue arrow indicate the action being ballasting the vessel down and narrowing the gap.
- Step ❷ represents the action of partial load transfer by retraction of the jack rods. At the end of last step, the stabbing cone and the LMU are aligned and the gap is reduced to the distance of touching but not hooking up. The small purple arrows show the action of the jack rods retraction of the whole stroke with a fast speed and achieving the transfer of part of the topsides load to the jacket. Then the topsides and the jacket is fully engaged. The light blue arrow shows that the vessel is moving up because of the loads on it suddenly reduced by a large portion.
- Step ❸, is the continuation of load transfer by vessel ballasting. By controlled actions, the vessel's draft is increased accompanied by the gradual extension of the jack rods shown by the light purple arrows pointing upwards. The ballasting

operation also handles the tide compensation. Another part of topsides weight is passed to the jacket as the results of the activities.

- Step ❹ starts with the jack rods extended to the required stroke and the retraction of the jack rods again completes the transfer of 100% topsides weight to the jacket. The whole mating process is completed and there is a clearance large enough to avoid the contact of the vessel grillages with the underside of the topside.
- Step ❺ is the action of the vessel draft adjustment for vessel exiting the jacket slot.

After the completion of the weight transportation from the vessel to the platform substructure, the vessel's ballast system will start to ballast the vessel down so that the vessel is separated from the topsides and then removed.

5.3 UNIDECK Equipment and Operation

In the following, UNIDECK floatover method related details are illustrated through a West Africa project—Exxon Nigeria East Area GN platform floatover installation. During the discussion, the method is also to be compared with the HIDECK method.

- Equipment:
  - Vessel

  When applying UNIDECK method, the key element for the operation is still the installation vessel, which is capable of carrying out the transportation of the topsides to the installation site and accompanying the mating operation.

The vessel to be selected can be DTV, barges or HLVs such as the vessels in the fleet of Dockwise. For example, for CPOC project in Thailand, Southeastern Asia in 2009, the HLV "Black Marlin" of Dockwise was used for the transportation of the topsides of the MDPP platform and the integration of the topsides and the platform by HIDECK floatover. The same vessel was also used for the Exxon East Area GN platform integration by applying UNIDECK floatover method in Nigeria, West Africa in 2005. For both cases, the journeys were long, but the floatover operation was short and successful. The skid beam and the grillage design should be the same for the two projects because of the topsides weights were very close.

- Supporting system

The big differences were in the topsides supporting design. For the MDPP platform the DSS were used, while for the GN platform the Technip proprietary jacking system as shown in Fig. 5.2. As mentioned earlier, the jacking system is the special characteristics of the UNIDECK floatover method. According to Technip, because of the jacking system, every step of the floatover operation is reversible and it also makes the mating process and the load transfer very fast, therefore it can

Fig. 5.2 The skid beam and grillage design for the two projects should be basically the same. On the *left* is the topsides of GN platform to be loaded out to the installation vessel; on the *right* is the installation vessel for the integration of the MDPP platform of CPOC (courtesy of Technip and Sembcorp respectively)

handle the harsh installation environment such as severe swell environment condition much better than the HIDECK floatover method.

Following the concept design, the system consists of sixteen (16) hydraulic jacks divided into eight (8) pairs with each pair being mounted on a substructure forming a jacking unit as shown in Fig. 5.3. Two (2) jacking units form a group being

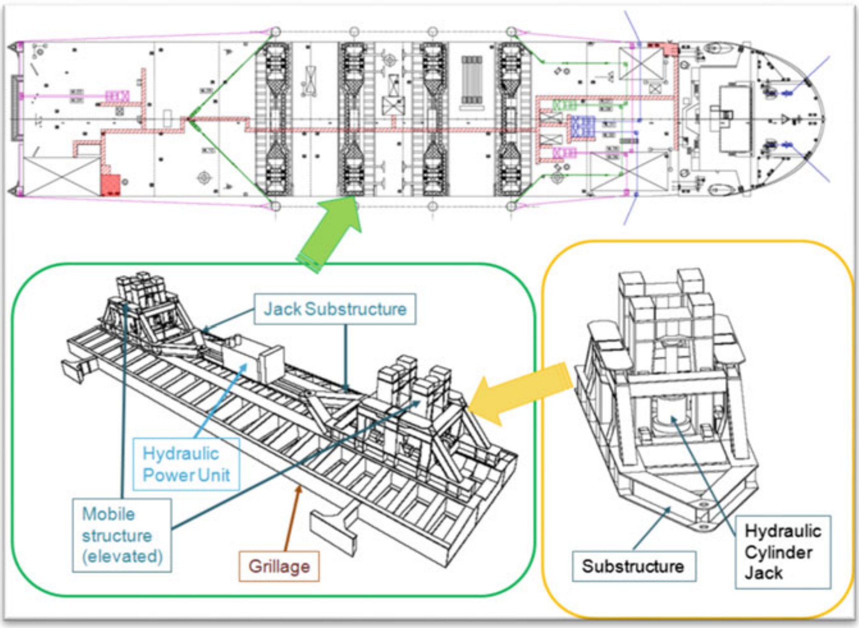

Fig. 5.3 The arrangement of the jacking system on the grillages (based on [1])

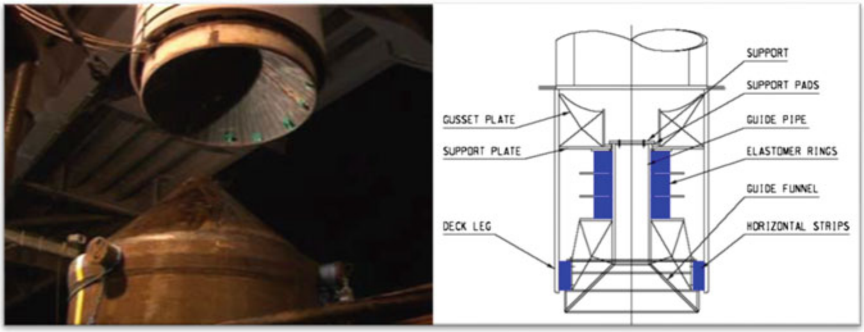

Fig. 5.4 The arrangement of the jacking system on the grillages ([1])

mounted on one (1) row of the skid beam and grillages. There is a hydraulic power unit within each group. The entire system was controlled by a main cabinet in the control room. The system was designed with redundancy to enable the operation being safe and continued in case of equipment failure and dysfunction. Furthermore, there are also two (2) degraded operation modes for emergency handling: the "manual mode" and the "ultimate mode". Therefore, the safety of the jacking system operation is assured by the comprehensive design.

The capacity of the jacking system is an important design index, which depends on the project's need. The set of the jacking system used for Exxon East Area GN platform integration possesses the maximum capacity of 22,500 tonnes. The system is re-usable.

The jacking system, on the other hands, may be uninvolved during the mating operation for some projects as mentioned earlier.

The other function of the jacking system is to help improving the transportation stability for certain cases. When the COG of the topsides is high because of the elevation requirement for the floatover operation, the transportation stability might be jeopardized. Then to keep the COG low, the topsides jacking up operation can be waited until the vessel arrives at the mating site. However, the amount of adjustment is limited and all these adjustments before being made need thorough investigation for the feasibility and safety. Technical challenges might not be realized at preliminary study phase.

– LMU

Another essential mating device is the LMU for the mating operation. Some detailed discussion is included in the Chap. 8. Looking at Fig. 5.4, it can be found that the LMU technology are the same as used for the HIDECK floatover method, though for each project the device design needs to be tailored to meet the project requests.

– Fenders, etc.

Fenders and mooring system to be used follow the same definition of functions and the same design philosophy used in HIDECK floatover.

- Operation procedure

It is safe to say that comparing to the HIDECK floatover method, the UNIDECK method is the same in the phase division of the whole operation process starting from loadout. Here, the discussion will cover the following operation phases from the topsides loadout to the vessel withdrawing after the completion of the platform integration.

– Topsides loadout at the quay
– Transportation of the topsides
– Docking
– Pre-mating
– Mating
– Vessel withdraw—undocking.

Only a few phases are covered with certain details in the following discussion and the main focus is on how the combination of jacking and ballasting to work during the mating process using the GN platform case as the example.

- Project execution

The project execution from the loadout to the docking phase is the same for both methods including the skid beam and grillage design, sea-fastening, vessel outfitting, stability checking, etc. The only obvious difference is the installation of jacking system including the hydraulic power units and control system for the UNIDECK method (Fig. 5.5). Also with the jacking system the topsides elevation can be adjusted.

– Pre-docking and docking stages

When the vessel arrives at the mating site, she will be moored outside the already installed substructure, which can be achieved by the same design and operation for

Fig. 5.5 Except the capability of topsides elevation adjustment by the jacking system for UNIDECK method, no big difference in project execution for the two methods. On the *left* is the GN platform integration using UNIDECK method and on the *right* is the SHWE platform integration using HIDECK method (courtesy of Dockwise)

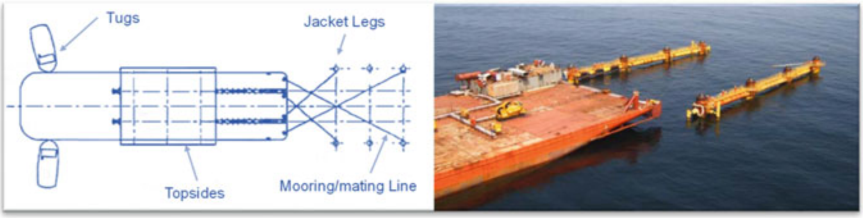

Fig. 5.6 Operation of the pre-docking. The entry of the floatover vessel is achieved by mooring/mating lines and tug boats (photo [1])

both HIDECK and UNIDECK. This step sometimes is called the pre-docking stage (Fig. 5.6).

Following the pre-docking stage is the docking phase during which the vessel is moved into the space in-between the two rows of the jacket legs. There can be the difference during the docking operation in the sense that there is no topsides elevation operation if applying HIDECK method.

However, when using UNIDECK method in the GN platform case, as the vessel started to move into the slot between the two jacket leg rows and before the topsides mating legs reach the front jacket legs, the topsides was elevated 1.75 m. Followed that the vessel moving in was continued until the topsides was aligned with the jacket.

- Pre-mating stage

At the pre-mating stage, the mating cones and LMUs which are separately mounted beneath the topsides and on top of the jacket legs will be aligned and the required gap between the two will be reached by the operation of the ballast system of the vessels. Environment impact including tidal conditions need to be carefully considered to make sure there is no contact between the mating cone and the LMU. It is almost the same for two methods. For the GN platform integration, the Black Marlin was ballasted down to have the gap kept around 0.7 m in calm water, while the maximum vertical motion of the mating legs was ±0.6 m (Fig. 5.7).

Fig. 5.7 Pre-mating stage. On the *left* is the GN platform integration using UNIDECK method in West Africa with 18,000 tonne topsides and on the *right* is the MDPP platform integration using HIDECK method in Southeastern Asia with 19,000 tonne topsides. Both projects used Dockwise's HLV Black Marlin (courtesy of Dockwise)

- Mating operation

The mating completion for HIDECK is carried out by ballasting following the developed and approved ballasting plan. The GN Platform mating was through the combination of the jacking operation and the vessel ballasting. It started by topsides jacking down by retraction of the jack rods over the complete stroke of 1.8 m accompanied by the reduction of the vessel's draft caused by the topsides weight being transferred to the jacket. At the end of this first jacking down, around 50% of the topsides weight was transferred to the jacket and the topsides supported by the vessel was hooked up with the jacket. This process was completed within one minute and was not supposed being interrupted. At the end the operation, the topsides and the jacket were connected through the steel-by-steel contact.

Then the vessel ballast system will work together with the jacking system to transfer another 20% of topsides load to the jacket in the following way:

During the vessel ballasting down, the jacking system was working coherently with each of the sixteen jack rods extending by a corresponding amount so that:

– The topsides and the vessel had no relative motion;
– The COG location change was under control;
– The bending status of the vessel hull during the load transferring was compensated.

When the above operation was completed, each jack rod extended to the required stroke correspondingly and the vessel ballasting condition should be as planned.

- De-docking

Then as the final step of the transferring of the left topsides weight, the jack rods retracted for the second time and the whole weight of the topsides was transferred to the jacket and a gap between the topsides and the vessel was created which was the end of the mating process.

The de-docking process are the same for the two methods. The vessel for the two methods face the same situation for moving out.

5.4 Advantages of UNIDECK Method Comparing to the HIDECK Method

HIDECK method has been the most used method for floatover installations and will still be widely chosen. However, in comparison, UNIDECK method possesses some advantages, which are listed below:

- Since the mating process can be stopped at any step of the operation and the situation can be reversed, it will be much safer to use the method in the environment, such as in West Africa, where large un-favorite motion of the vessel may be induced during the operation.

There was successful topsides integration example of applying HIDECK floatover method, but very few operators will be comfortable to use it.

- With the jacking system, the quick retract of the jack rods after the topsides weight being fully transferred to the jackets makes the separation of the installed platform much faster, therefore to reduce the opportunity of the topsides underneath to be damaged by the vessel from the environment induced motions.
- The jacking system can make adjustment of the elevation of the topsides not only during the mating process, but also during the transportation. Therefore, when needed, the topsides can be lowered down during the transportation in order to improve the stability and later to be jacked up to the sufficient height for the commencement of the mating process.

As announced by Technip, when using the UNIDECK floatover method, there is the option to accomplish the mating process by merely using the vessel's ballast system without the involvement of the jacking system. However, in such cases, the UNIDECK method most likely will lose the competitive edge to the HIDECK method, because of the cost of the equipment. Considering to add the jacking system to the vessel, not only the hydraulic system is very expensive, but it also need the accompanied power system, control system and vessel outfitting work.

In a short summary, UNIDECK method has been quite successful in offshore open water platform integration. The use of the equipped jacking system makes this method capable of operating in the environment with severe swell conditions.

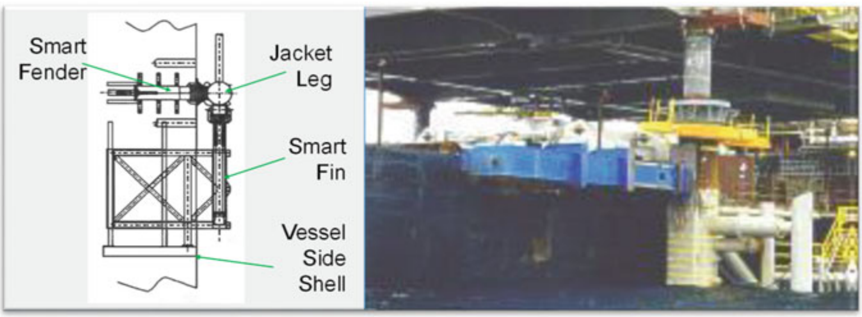

Fig. 5.8 Smart fins and Smart fenders for SMARTLEG topsides floatover installation method (courtesy of ETPM)

5.5 SMARTLEG Installation Method

SMARTLEG floatover technology was developed and patented by French company ETPM in 1993. The technology development was also targeted at handling unfriendly weather with long period swell, which induces extreme vertical motions of the floatover installation vessel. In the following four (4) years, intensive engineering work including analysis, equipment design and tests were carried out for application to platform installation in West Africa [5–8].

For both HIDECK and UNIDECK, the approach of handling impact load is to allow a certain amount impact loads to happen and use equipment such as LMU to absorb the shock during the operation. Different from the previously mentioned approach, the SMARTLEG equipment are designed to avoid the taking place of the impact during the mating process. Therefore, it was also called "*shockless floatation method*".

The principal idea is to engage the topsides with the substructure at the moment when the heave motion of the vessel reaches the peak and the vertical motion is zero hence the kinematic energy is zero. It can be seen that at the conceptual level, the SMARTLEG method is more focusing on the acting corresponding to the vessel heave motion.

Comparing to the conventional floatover methods including both HIDECK and UNIDECK, SMARTLEG method is relatively more complicated. To achieve the goal of shockless mating, special equipment are designed and installed on both the topsides and on the vessel. These equipment consists of four "Smarts": Smart legs, Smart fins, Smart fenders and Smart shoes. Among them, the key elements are Smart legs and Smart shoes. Smart fins and Smart fenders (See Fig. 5.8) function similarly to the fender systems in conventional floatover. The Smart fins are located

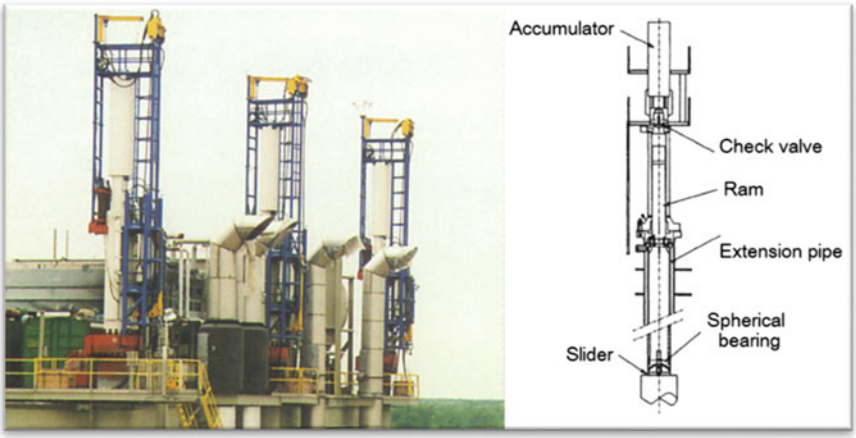

Fig. 5.9 The smart leg. On the *left* is the three smart legs on one side of the EPKE gas compression platform. On the *right* is the illustration of the smart leg (courtesy of ETPM)

at all corners of the substructure. Smart Fins are equipped with hydraulic shock absorber and can manage the yaw and surge motions of the vessel loaded with the topsides. Smart fenders function as the sway fenders in the conventional floatover to eliminate the motion of the vessel in the sway direction.

Smart legs are the most important equipment for the mating operation. They are installed on the topsides (Fig. 5.9).

The capacity of the Smart legs should be designed to meet the project's need. Also since the whole Smart leg assembly will be installed inside a topside mating leg, the topsides mating leg should be a hollow tube by design. Therefore, the decision of selecting the SMARTLEG method should be made in the very early stage of the project, otherwise important modification of the topsides structure is necessary. The main components of a Smart leg assembly are:

- A hydraulic cylinder
- A pilot check valve
- A low pressure accumulator
- An extension pipe of the ram.

Similar to the docking stage of the conventional floatover operation, as the floatover vessel with the topsides onboard being positioned inside the jacket slot and the topsides being aligned with the jacket legs, the Smart legs start to work with

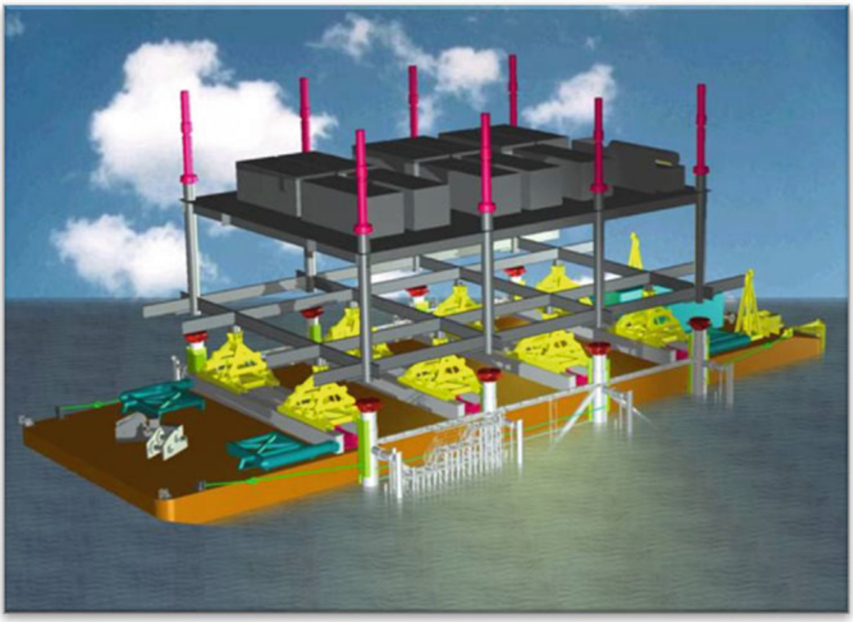

Fig. 5.10 Illustration of the topsides installation using SMARTLEG method, all the important equipment are shown in the schematic diagram (courtesy of ETPM)

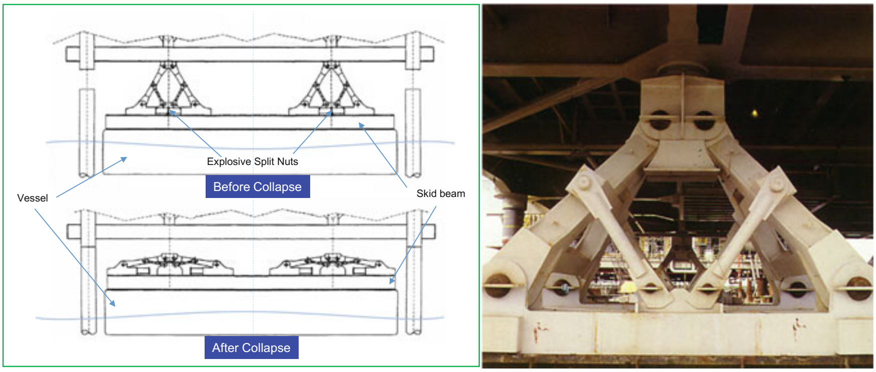

Fig. 5.11 Smart shoe and its working mechanism (courtesy of ETPM)

the jacks to be activated to deploy extension pipes to establish contact with the top of jacket legs. The mating happens between the Smart legs and corresponding jacket legs. The vessel is motion free only in the heave direction since the surge, sway and yaw are limited by the Smart fins and Smart fenders. A non-return check-valve was located between each jack and accumulator. It makes the jack extend or lock into place if the vessel is made to fall by the swell. As the vessel's heave motion reaches the peak, the check-valve will close and lock the topsides with the Smart legs. The velocity of the vessel and the kinetic energy are zero at the moment and the locking action takes place very fast—only a few seconds, no impact load will be induced. Then, the topsides and vessel are totally immobilized since the jacket and the vessel now share the topsides load.

The final load transfer is achieved by ballasting the barge and collapsing the Smart-Shoes. From Fig. 5.10, it can be easily seen that the topsides is sitting on several supporting structures in yellow color just like the DSS in the HIDECK floatover method. These supporting structures are the specifically designed Smart shoes. A Smart shoe consists of two (2) A-frames, with sliding bearing pads adapted to fit onto skid rails. As shown in Fig. 5.11, there are special explosive split nuts in the Smart shoes when they are actuated the frame will collapse and leave a clear gap between the topsides and the vessel. This near-instantaneous collapse of all Smart shoes allowed for the final 50% topsides load to be transferred to the jacket.

5.6 Application of SMARTLEG Technology [9, 10]

There have been two applications of SMARTLEG technology in the records, one was the project of positioning the heavy bridge spans (192 m long and weighing 8000 tonnes) for the bridge crossing the strait between Prince Edward Island and

Fig. 5.12 The EKPE gas compression platform after the completion of floatover operation using ETPM's SMARTLEG technology. The vessel preparation took three days, but the floatover operation only last three hours (courtesy of ETPM)

New Brunswick in Canada in November 1996. The other is the floatover topsides installation of the EKPE gas compression platform offshore Nigeria in June 1997, by McDermott-ETPM offshore Nigeria (Fig. 5.12). The EKPE gas compression platform was designed with the jacket of six (6) legs and the topsides weighed 4100 tonnes. The water depth at the installation site was 50 m. The environment conditions for the installation was dominated by the long period swell with maximum incidence of ±20° relative to the jacket longitudinal axis. The installation limit is $H_{\max} \leq 2.8\,\mathrm{m}(H_s \leq 1.5\,\mathrm{m})$, and the corresponding T_p value can be up to 15 s. Besides, the maximum tide was 2 m and wind, current as well as wind wave need to be considered. According to the publicized information, the project was successful. The vessel preparation took three (3) days and the operation of the floatover was completed in less than six (6) hours.

The SMARTLEG technology won the Offshore Northern Seas Innovation Award in Stavanger in August 1994. According to the developer of the technology, the method can handle the installation of topsides weighing from 3000 to 40,000 tonnes. In addition, the EKPE project showed that the method is able to handle the swell environment well. However, this technology has not gone very far.

Obviously, the main reason should not be from technical side. It worth to go through a lessons learned session to identify the factors influencing success in technology development which will benefit the whole industry.

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Chapter 6
Catamaran Floatover

Abstract When the platform substructures do not have openings wide enough for installation vessels to move in, catamaran floatover method is the choice of platform integration. Two floatover vessels and the topsides form a catamaran. The mating operation procedure are the same as the HIDECK, except the involvement with two vessels. Catamaran floatover methodology has been successfully applied in both inshore and offshore platform integration. In general, the catamaran is formed at the location near the mating site, therefore the topsides will be transported from the yard to the selected location by a third vessel and then the topsides is transferred to the floatover vessels. This extra step operation need to be well prepared through intensive engineering efforts. Discussion in this chapter covers the operation details with the examples of CGBS inshore integration and the spar offshore integration. For these operations, floatover vessels do not need specially designed equipment besides grillages and sea-fastenings. Two other catamaran floatover methods using special equipment: the Versatruss and TML methods are also presented in this chapter.

6.1 Multi-vessel Floatover

As mentioned in the history of floatover technology development, it started very early to use multiple vessels in the platform integration, especially when the topsides' weights were far beyond the capacity of the heavy lifting vessels at the offshore installation time. To use multiple vessels in the floatover operation the following technical challenges can be met successfully:

- To handle the heavy topsides which cannot be carried by a single existing vessel during transportation and platform integration operation

In the years of 1990s and before, there were no single barge being capable of taking few dozens of thousands tonne objects and sailing away. These kinds of heavy topsides or some MSFs could not be handled by any heavy lifting vessels.

- To handle the topsides mating with the substructure without opening large enough for a single vessel to slide in

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Fig. 6.1 Gullfaks C platform integration using multi-vessel floatover (courtesy of Statoil)

This kind situation can happen to single columned floater, compliant tower, GBS or the fixed platforms originally designed for platform integration using heavy lifting but the installation method changed at the later stage of the project. For these cases, more than two (2) vessels need to be used simultaneously during the floatover operation.

One good example of platform integration using multi-vessel floatover is the condeep platform Gullfaks C as shown in Fig. 6.1. Gullfaks C platform is of the PDQ-type, containing Process and Drilling installations as well as living Quarters capable of accommodating up to 300 people. The weight of the topsides being towed to the mating site was approximately 43,000 tonne (49,000 tons) and the topside weight during production is 54,000 tonne (55,000 tons) [1].

Gullfaks C was built in late 1980s as a fast track project. The topsides was integrated with the GBS substructure inshore and the integrated platform was towed to the offshore site with water depth of 217 m in 1989. The total platform height reaches 370 m measuring from the sea bed and the concrete GBS has four (4) shafts which rise more than 160 m above the caisson. As can be seen from the picture that four (4) barges were used during the mating operation with the arrangement of distributing the total topsides weight to the barges which floating the topsides over the top of the corresponding GBS shaft [2, 3].

The multi-vessel floatover operation was applied to the large condeep at almost the same time as the HIDECK floatover technology appeared. How many vessels to be used and the arrangement of the vessels were case by case. Among these applications, the catamaran floatover operation using two (2) vessels became a specific floatover methodology drawing attention in the industry. The main reason is that this method can be applied to the fixed platform or floater topsides/substructure integration without the special design requirement of the substructure.

6.2 "Catamaran Floatover" Origination

In the floatover operations, catamaran floatover implies that the two (2) vessels form an opening large enough to contain the platform substructure in between and to position the topsides over the substructure for the mating. In this sense, if the arrangement of the two (2) vessels do not create an opening to contain the platform substructure during the floatover operation but only for the purpose of adding buoyancy, improving stability during transportation/mating or both, the platform integration could not be considered as a catamaran floatover.

The word "catamaran" used here to mean that during mating of the topsides and the substructure, the topsides and the two (2) vessels (pontoons) form a catamaran entity and it looks like a catamaran vessel carrying a cargo. In the operation practice, the two (2) vessels are often bounded by the topsides structure to each other through the onboard topside supporting structures. The use of the word "catamaran" might be started by the operations personnel working on the Draugen condeep in 1993 or the Hibernia GBS in 1997, because of the twin hull distinction from the dozens of GBS multi-vessel floatover completed before. Although the catamaran floatover application started in the sheltered waters, the methodology can be applied to the open water for both fixed and floating platform integration.

The substructure of the Draugen has only one shaft and the mating operation is similar to the integration of a single columned floater. Nevertheless, the Hibernia GBS possesses four (4) shafts and the space between each two (2) shafts next to each other is less than 10 m, which makes the floatover using two (2) barges the only choice. Some details of the platform integration of Hibernia is presented

Fig. 6.2 The Hibernia GBS platform after integration [courtesy of Hibernia Management and Development Company Ltd. (HMDC)]

here. The Hibernia platform was Canada's first offshore production installation off the coast of Newfoundland and the platform integration is the first time to apply the catamaran floatover method. The mating of the topsides and the substructure took place at the inshore mating site [4, 5].

The Hibernia platform is a drilling and production platform. As shown in Fig. 6.2, it is one of the largest oil platform globally in terms of weight: at a total of 1.2 million tonnes which include the 37,000 tonne integrated topsides facility mounted on the 600,000 tonne GBS along with 450,000 tonnes of solid ballast being added to secure it at the field site.

For Hibernia and Hebron that is under construction, the construction work was carried out at Bull Arm construction site in Bull Arm, Newfoundland Canada. The same construction process is followed:

- The topsides and the GBS were constructed at separate sites not far from each other in the Bull Arm area of Newfoundland.
- The topsides was built on a pier at the Great Mosquito Cove, Newfoundland.
- The construction of the GBS went through two (2) stages: the base slat and the lower part of structure total height of 27.5 m was built in the drydock at the shore of the Great Mosquito Cove and then to be floated and towed out of the cove to the nearby DCS (Deepwater Construction Site) where the GBS is constructed to the full height (see Fig. 6.3).

Hibernia platform topsides is a typical integrated topsides with five (5) super-modules recommended by Aker Engineering, Oslo, Norway. There was no MSF but the five (5) super-modules (process, wellhead, mud, utilities and

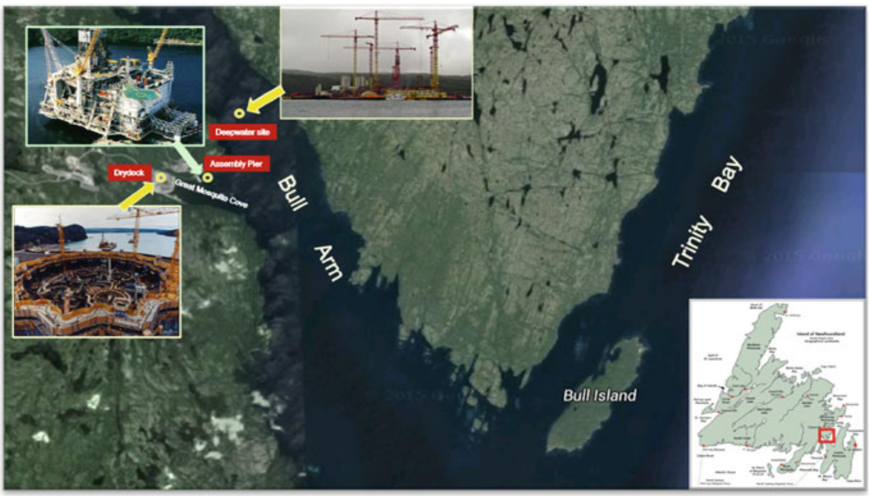

Fig. 6.3 Construction of Hibernia topsides and GBS (based on public information of Hibernia project from website)

accommodations for up to 280 people). The individual modules are joined side by side. The dimensions of the modules decided the full height and width of the topsides. Together with the five (5) super-modules, there were also other seven (7) topside mounted structures including helideck, flare-boom, pipe rack, main and auxiliary lifeboat stations and two (2) drilling modules. All the facilities and structures were integrated at the assembly pier and the total weigh of the topsides reached 37,000 tonne. The length of the integrated topsides is 80 m and the width of it is 34 m.

The GBS base is of the round shape as shown in Fig. 6.2 with the diameter of 105.5 m. Above the base slot, there are the storage caisson of 85 m high with the capacity of storing 1.3 million barrel crude oil and four (4) shafts (utility shaft, riser shaft and two drill shafts) protruding the top of the caisson. The diameter of the shafts is 17 m. The total height of the completed GBS is 111 m. It was designed to be capable of withstanding the impact of a 5.5 million tonne iceberg, a ten thousand (10,000) year return event. Its ice wall consists of a 50-foot thick concrete belt with sixteen (16) ice teeth. The total weight of the GBS after the completion of construction at the deepwater site was 550,000 tonne.

The construction of the GBS began in 1991. The lower portion of the GBS was completed in 1994 and then floated and towed to the DCS with water depth of 180 m, not far away. At the DCS, it was completed in 1996. During the construction at the DCS, six (6) chain lines in three (3) groups moored the floating GBS. When the construction is complete, the draft of the GBS was 75 m with the freeboard being 36 m.

The water depth at the Hibernia site is 80 m, while to perform the floatover operation, the four (4) shafts could only protrude the water surface a few meters, therefore the GBS hull need to be descended by using the equipped ballast system before the floatover operation in order to inspect leaks and verify the ballast/deballast system. These tests were performed two (2) weeks before the scheduled floatover operation. During the tests, the draught of the GBS hull changed through several different values from the mooring draught of 75 m down to the mating draught of 105 m and then back to the draught of 95 m waiting for the topsides to move in.

As the GBS was ready for mating operation, the topsides was lifted up from the assembly pier by two (2) massive barges: Barge Goliat 10 (later BOA barge BB16 and now Hamriyan Pride) and AMT Transporter. The two (2) barges were modified for the lifting up/transportation of the Hibernia topsides as well as the floatover operation. The sizes of two (2) barges after the modification are 150 m long and 32 m wide with DWT more than 20,000 tonnes each.

The topsides lifting-up operation began five (5) days before the platform integration operation at the DCS. The outfitted two (2) barges were positioned one at a time under the topsides. They were on each side of the assembly pier and moved to the position under the main support beams of the topsides. As the barges were snugly in place, the load transfer of the topsides to the barges was conducted gradually and carefully. The process could be divided into steps by percentage of total weight transferred—25, 50, 75 and 100%. The topsides lifting-up operation

Fig. 6.4 Hibernia topsides was towed to the inshore mating site (courtesy of HMDC) [6]

was completed after approximate 24 h with the topsides fully supported by the two (2) barges and ready to be towed to the mating site. At this point, the topsides and the two (2) barges formed a “catamaran”.

After disconnection of the moorings and as the favored weather conditions arrived, the catamaran was towed out of the Great Mosquito Dove to the DCS. A flotilla of seven (7) tugboats were involved in the transportation—two (2) tied alongside each barge of the catamaran; one (1) was in front to tow forward and the other two (2) being kept at stand-by status for the needs caught by unexpected change of weather conditions during the transportation (see Fig. 6.4). The short journey of 1.5 km took six (6) hours.

The platform integration no doubt was one of the most challenging operation campaign for the project. The operation was carried out on February 1997. Before the commencement of the platform integration process, the GBS was ballasted down to the mating draft with six (6) meter of the top part of the four (4) shafts protruding above the water surface. The catamaran was then maneuvered by the steering barges to make the topsides directly over the GBS. As understandable, the mating of the topsides and the GBS can be achieved through the descending of the topsides or raising the GBS or the combination. For the Hibernia platform integration, the practice was to raise the GBS by deballasting. After the accurate alignment of the topsides and the GBS was achieved, the platform integration process became the load transfer efforts. The early stage of load transfer up to 10%

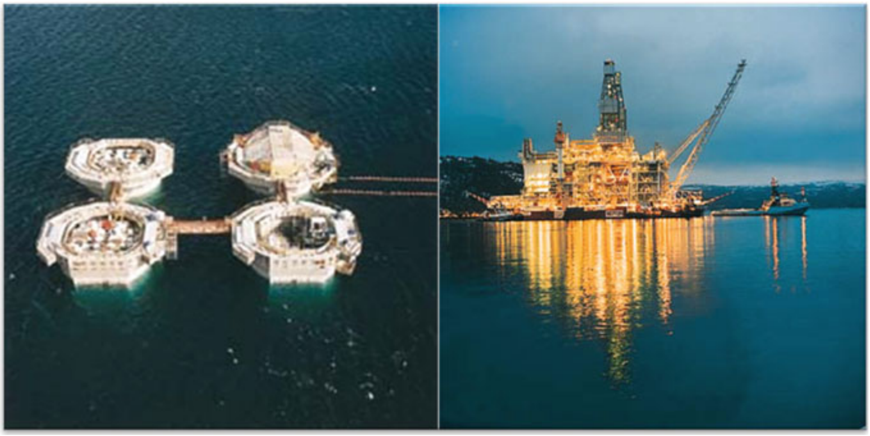

Fig. 6.5 On the *left*, the GBS was ballasted to the mating draught of 105 m with 6 m of the GBS top part being above the ocean surface; On the *right*, the integrated topsides was at the mating site (courtesy of HMDC)

of the total topsides weight was critical. The whole mating operation, which means the 100% topsides were fully passed to the GBS, was completed in about six (6) hours. After that, the deballasting of GBS continued and approximately twenty-four (24) hours later, the two (2) floatover barges were cleared (Fig. 6.5).

The floatover operation for Hibernia platform integration was a success and it was the first inshore catamaran floatover operation. The other massive GBS platform Hebron, which is under construction at the same construction sites in Bull Arm, is expected to be integrated using the same catamaran floatover technology at the same mating site in 2017.

6.3 Catamaran Floatover Technology

6.3.1 General Discussion

As mentioned above, the catamaran floatover started as one of the multi-vessel floatover technologies during inshore integration of platforms of which many were CGBS. The integrations were carried out with the substructures in a controlled floating status. What makes the catamaran floatover distinguish from other approach is not the number of vessels being used in the operation, but the potential opportunities of applying it to the integration of platforms in the open water, for both the fixed platforms and the floating structures. The catamaran floatover technology comparing to the heavy lifting methods in most of cases still possesses the advantages of being feasible in the remote regions as well as cost-effective. At

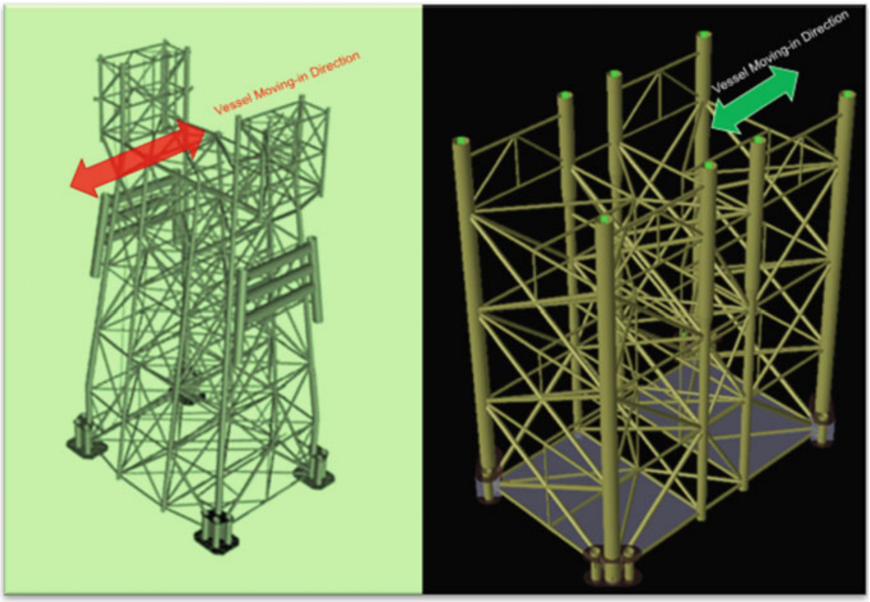

Fig. 6.6 Jacket design considered for floatover installation

the same time, it can work on some cases, which could not be conveniently handled by single barge floatover approach as discussed below:

- For fixed platform without opening wide enough at the top of jacket for barge to float in

Single barge floatover including HIDECK floatover and UNIDECK floatover methods have been successfully applied in offshore open water platform integration. Most of the cases are fixed platform topsides installation. Among them, quite a few platforms were designed for the floatover installation with an opening wide enough for the installation vessel to move in and deep enough for the withdrawal of the vessel after the completion of mating operation (see Fig. 6.6).

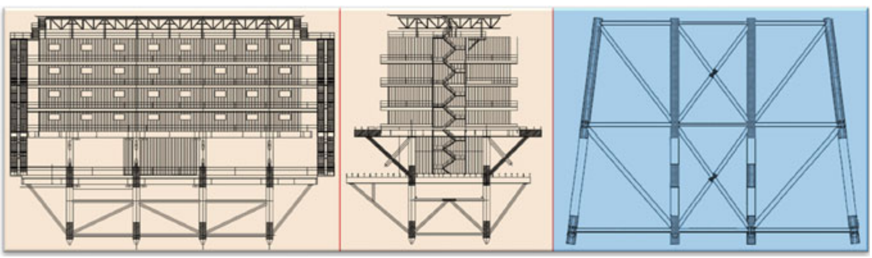

Fig. 6.7 Jacket design not considered for single vessel floatover installation

However, there are cases such as the fixed platform with the original design shown in Fig. 6.7. The original design was for the topsides to be installed by heavy lifting operation. In the late stage of the project with the completed design of topsides and jacket, decision was made to carry out the installation using floatover technique. To do so, the options are between the single barge floatover requiring structural design modification of both the jacket and the topsides and the two (2) barge catamaran floatover which generally needs three barges in the operation.

If choose the single barge floatover method, then major structural modification on the jacket is inevitable to make an opening for the floatover barge to move in. For the jacket design shown in Fig. 6.7, one re-design option is shown in Fig. 6.7. The modified design removes the top part of the middle four (4) legs and makes the corresponding structural strengthening at various location of the jacket. The re-design goal is to best re-distribute the topsides loads on the whole jacket structure after the eight (8) supporting spots being reduced to four (4) and at the same time to optimize the design making the fabrication effective and lowering the cost. Needlessly to say, intensive engineering/design efforts are necessary for keeping the integrity of the structure, meeting the schedule requirement and achieving cost-effectiveness.

On the topsides side, corresponding adjustment on the structural design is also necessary because of the supporting spots reduction. In addition to the obvious needs on the beam bending moment control in dealing with the big increase of the span between the loading support points, topsides design also needs adjustment to accommodate the change of loading conditions during the installation. Choosing the location of the DSU (Deck Support Unit) contacting spots and making proper local structural strengthening are generally necessary (Fig. 6.8).

On the other hand, if catamaran floatover method is considered, one possible plan may be as the one shown in Fig. 6.9, the two barges will lift up the topsides and form a catamaran. The catamaran will move along the longitudinal direction of the jacket and position the topsides over the eight (8) legs of the installed jacket. There is no need for the modification of the original jacket design [7–9].

Some structural work on the topsides for the floatover supporting barges are needed, while the eight (8) supporting columns of the topsides can directly sit on the DSU during the transportation.

The operation of transfer the topsides from the transportation barge to the two (2) floatover barges is one of the most challenging part in the catamaran floatover. Intensive multibody motion simulation and loading calculation need to be carried out using engineering software such as SIMO developed by Marintek. For projects similar to the one discussed above, whether catamaran floatover or the single vessel floatover is the better choice will be project dependent, because there are many factors in the equation. But a couple of things are obvious. One is the much more intensive platform design modification can be avoided if catamaran floatover being selected. The other is that if the decision of changing installation to floatover at the very late stage of the project, there should be less pressure from meeting schedule for both engineering and fabrication if catamaran floatover method is chosen.

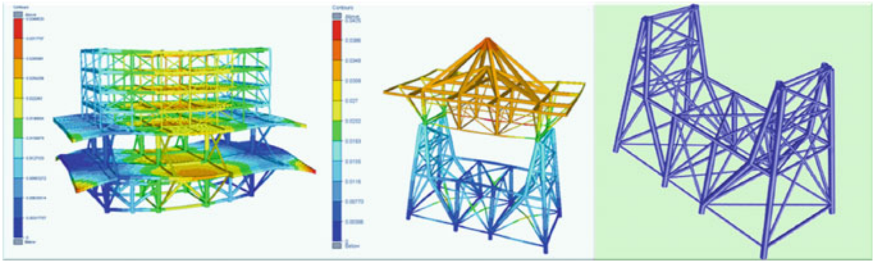

Fig. 6.8 Structural modifications for both the jacket and the topside are necessary

- Floating platform substructure without opening large enough for barge to move in

The situation includes single columned floater such as classic/truss spar, single shaft GBS floating during mating such as Draugen in the North Sea/Hebron in the North Atlantic; or multi-columned substructures such as cell-spar, GBS as Hibernia. For these substructures, it is out of the question to consider the substructure modification of creating an opening, catamaran floatover is the only choice.

The first open water catamaran floatover was successfully carried out for spar Kikeh in Southeast Asia. The second catamaran floatover of spar platform integration may happen to Aasta Hansteen spar project in the future.

As aforementioned, different from fixed platform floatover operation, the mating process for floating structure floatover can be performed by ballasting down the floatover vessels, deballasting the substructures, or the combination. No matter choosing which approach, it involves multiple vessel maneuvering and needs highly synergized actions in the process. It is hence extremely challenging in the planning and the offshore operation.

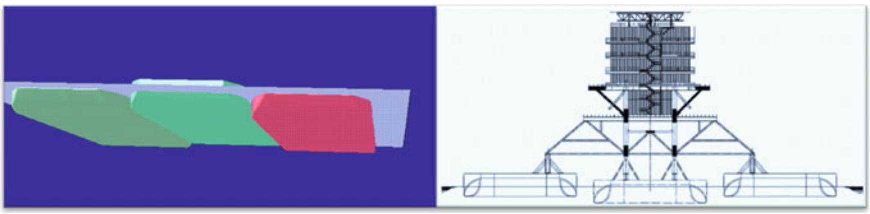

Fig. 6.9 The catamaran floatover generally needs three (3) barges—one for transportation and the other two for floatover operation

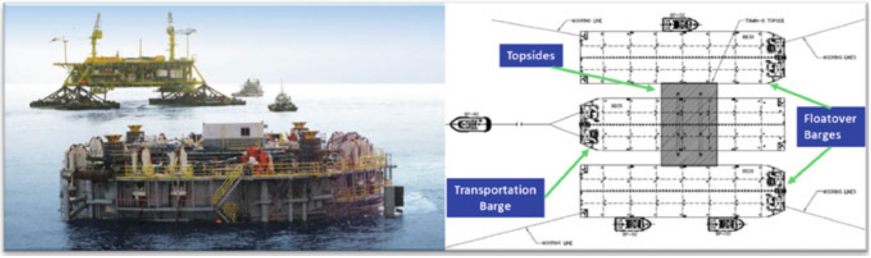

Fig. 6.10 On the *left*, the Kikeh topsides catamaran was moving to the spar hull for floatover operation (courtesy of Technip); on the *right* is a drawing illustrating the topsides being transferred from the transportation vessel to two floatover vessels to form a catamaran

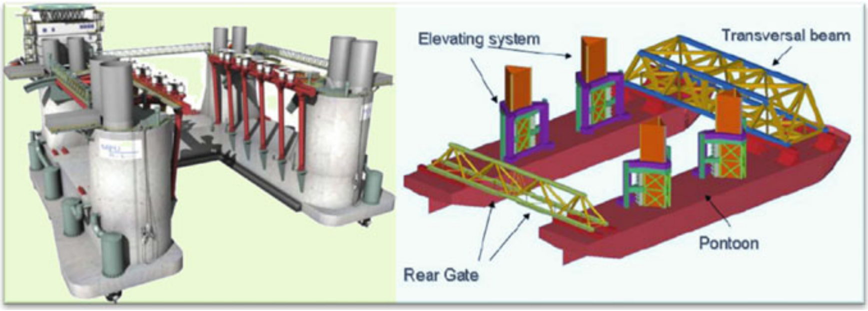

Fig. 6.11 Examples of operation vessels with catamaran shape hull. The *left* is the MPU Heavy Lifter concept and the *right* is the Technip's DSIV (Decommisioning, Salvage & Installation Vessel) concept (courtesy of MPU Offshore Lift ASA and Technip respectively)

6.3.2 Catamaran Floatover Categories

In this book, from the offshore operation point of view, the catamaran floatover method is limited to the definition of using two (2) individual vessels to form a catamaran with the topsides to be installed during the platform integration. It means that platform integration uses the specially designed vessels with the catamaran shaped hull such as the examples shown in Fig. 6.10, as well as the construction vessel Pioneer Spirit and the UC Berkeley's catamaran conceptual vessel introduced earlier, is not considered catamaran floatover method, rather novel one vessel floatover approaches [10] (Fig. 6.11).

All these vessel concepts are focusing on the topsides installation/decommissioning by one single lifting operation without using onboard cranes. Most of the inventions were stimulated by the demand from the huge platform decommissioning market as well as the offshore wind turbine installation worldwide in addition to the offshore platform integration. The topsides installation using these vessels is still floatover, but the process is one vessel operation, which is

Fig. 6.12 The two barges being used in the Hibernia catamaran floatover. On the *left* is Neptun's Goliat 10 and on the *right* is AMT Transporter. The two are not sister vessels with the same size and design (courtesy of HMDC)

much similar to single vessel floatover in operation planning and engineering preparation. Some more discussion on these vessels will be covered in a later chapter.

The catamaran floatover operation as defined above can categorized into two groups:

- Using conventionally designed transportation vessels as the floatover vessels
  The Hibernia installation discussed earlier and the Murphy Kikeh spar topsides installation belong to this group. The floatover vessels are selected by the needs of the specific projects. Sometimes, modification of the vessels are necessary especially the two (2) vessels might not be of the same design. Take the Hibernia project as an example; the two (2) vessels are Neptun's Goliat 10 (the name later changed to Hamriyah Pride) at that time and the Anchor Marine Transportation's AMT Transporter as shown in Fig. 6.12.
  As can be seen that the two vessels were not of the same design/size, to make the two vessels working as a pair to form a catamaran configuration, vessel modification was necessary. Neptun's Goliat 10 was lengthened by 16.6 m and a new 900-t deck structure was installed with grillage and support structure on its top. After that the outfitting of the winching, ballast and electrical lighting system were performed. At the same time, the vessel modification work was also performed on Anchor Marine Transportation's AMT Transporter barge. The hull of it was shortened and on its original deck a new 1400-t deck structure was placed with additional deck tanks put on it. Even when the vessels are twin with the same design such as the two barges chosen for Murphy Kikeh spar, since they were not specifically design for the floatover operation, structural enhancement and ballasting system adding/improvement, etc. were needed.
  In addition, the DSU, grillage, sea-fastening elements need to be designed and fabricated often start from the scratch. The efforts in general are not trivial. Back to the Hibernia case, the modification and outfitting of the two (2) barges to

make them ready, 3300 tonne steel were used. The work was performed at Remontowa, Gdansk, Poland.
Comparing to the specially designed vessels equipped with specific apparatus, which is to be discussed in the next section, it needs more time and engineering efforts on the floatover vessel preparation. Early involvement of floatover operation planning and engineering at the project level is vital.

- Using specially designed vessel(s) with specific apparatus
The two (2) vessels used in this approach are specifically design for floatover/decommissioning operation. In addition, there are specifically designed apparatus in handling the topsides weight by forming the catamaran and performing transportation and mating operation. Two (2) concepts are introduced below.

  – Versatruss offshore lifting system
  The Versatruss heavy-lift system of the Versatruss International, LLC in Louisiana Limited is an impressive invention in handling weight lifting for multiple kinds of offshore operations without using heavy lifting crane. The inventor of the system is Jon Khachaturian, President of rigging specialist Versabar of Belle Chasse, Louisiana. The first Versatruss patent was issued in 1987, and a working model demonstrating the system function in a test tank was completed in early 1995 [11–13].

The system consists of a matched pair of barges, equipped with a few pairs of lifting booms, winches and cables, and standard marine equipment. During the weight lifting such as the fixed platform topsides installation/removal, the two (2) equipped barges will hook up the loading subjects to form a catamaran configuration as shown in Fig. 6.13.

Fig. 6.13 The Versatruss heavy-lift system. On the *left* shows the floatover topsides installation using the Versatruss heavy-lift system in Lake Maracaibo, Venezuela, in 1999. Three platform integration operations were successfully carried out. On the *right*, it recorded the long journey of the system to Saudi-Arabia for two topsides installation in 2010 (courtesy of Versabar Inc.)

Different form the specially designed multi-purpose offshore construction vessels, the Versatruss system is not a conventional single hull vessel/platform in the sense that the system needs to be assembled with the specially designed equipment on a project basis and disassembled following the completion of the work. Comparing to the conventional catamaran floatover discussed earlier, they are the same that the two (2) floatover vessels form the catamaran through the topsides being carried and there is no directly connection between the two (2) vessels. The preparation and operation process are also similar.

The big difference between them is the way to handle the topsides elevation raising/lowering. As discussed in the earlier chapters, for the conventional catamaran floatover, after the topsides sitting on the two floatover vessels and forming a catamaran configuration, the whole acts as a rigid body which will keep unchanged until the completion of the mating operation. Then the vessels are disconnected with the topsides and to be moved away. Elevation adjustment of the topsides is achieved by the ballasting/deballasting of the floatover vessels during the mating operation.

However, for the Versatruss system, as shown in Fig. 6.14, the catamaran configuration keeps varying as the elevation of the topsides being adjusted. The lower end of each lifting booms are installed on the barge deck at the centerline of the corresponding barge with the pinned connection. The lifting booms are rotatable in a certain range around the pin shaft. The onboard main hoist winches, which have the cables tied horizontally to the topsides lower blocks, control the distance between the two (2) barges.

Different from the conventional catamaran floatover, during the mating process, the drafts of the barges keep unchanged, but the distance between the two barges can be adjusted through the winches. By synchronous pay-in/pay-out of the main hoist winches the distance between the two (2) barges reduces/increases, which is followed by the topsides to be raised or lowered. With proper control, the topsides COG moves strictly along the vertical direction. Obviously, this working concept makes the Versatruss heavy-lift system work with shallow

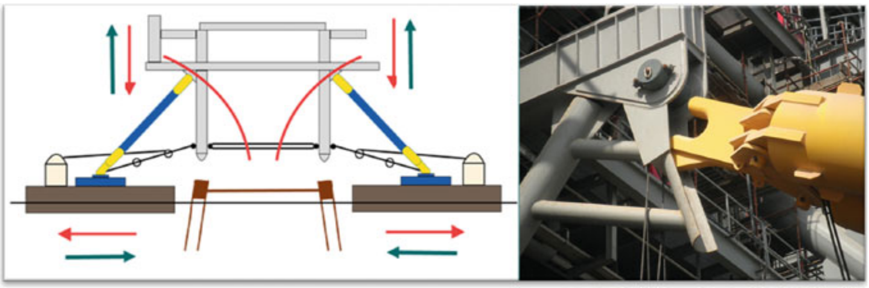

Fig. 6.14 The mechanism of topsides elevation adjustment by using the Versatruss heavy-lift system. The sketch in the *left* illustrating the topsides elevation to be changed when the distance between the two barges changes: the *red arrow* direction leads to the lowering of the topsides and the *green arrow* direction brings the topsides upward. The *right* photo shows how the *top* end of the steel lifting booms to connect the topsides structure (courtesy of Versabar Inc.)

vessel draft and lower the constraint of the operation site for forming catamaran configuration and mating.

In 1999, Three (3) topsides were successfully installed by catamaran floatover using the Versatruss system in Lake Maracaibo, Venezuela, In each case, the system hooked up to the topside at the port forming a catamaran which was towed to the mating site, and then complete the platform integration. The water depth at the port and the installation site are very shallow.

The Versatruss heavy-lift system was first accepted by the industry in 1996 for the decommissioning of Mobil's West Cameron 77 four-pile deck in the GOM. The 200-ton deck was successfully lifted and set onto a transport barge. Before the project, in the fall of 1995, a full scale test of using the Versatruss system with two (2) 140 ft by 40 ft barges to move a 200-ton, four-pile deck was conducted in Belle Chase, Louisiana and was completed successfully.

Theoretically, with the proper size of the barges and corresponding onboard equipment, there is no real limit on the topsides weight. There is no limit on the topsides size and the elevation during the floatover/removal operation, because of the open space in both horizontal and vertical direction. Some Versatruss system were designed to handle the topsides weighing up to 20,000 tons and it has been used for topsides lifting up to 6500 tons in real projects.

The Versatruss heavy-lift system can be conveniently mobbed, assembled to meet the requirement of a specific floatover project. Procedure of the floatover operation is quite similar to conventional catamaran floatover.

– TML (Twin Marine Lifter)

  The TML developed by SMI (SeaMetric International) is another example of specially designed heavy-lift system consisting of two (2) vessels. The TML system is capable of performing catamaran floatover. As shown in Fig. 6.15, the system of one version consists of two (2) vessels with specifically designed lifting arms. Each TML vessel is designed for a lifting capacity of 2500 tonnes and equipped with four (4) lifting arms on the deck. On the outer side of the lifting arms, there are ballast tanks. On the side near the topsides, buoyancy tanks are equipped. For lifting operation, the lifting points of the arms fit into the

Fig. 6.15 The TML system. On the *left*, the two TML vessels equipped with lift arms are approaching to the transportation vessel for the topsides transfer; on the *right* it shows the topsides has been successfully transferred to the two TML vessels and the transportation vessel sails away (courtesy of SeaMetric)

docking station on the topsides and the elevation of the topsides is controlled by adjusting the ballast water amount in buoyancy and ballast tanks. The TML system is also a multi-functional heavy lifting system, which can handle both floatover and removal of integrated topsides. By design, the TML system can manage heavy lifts up to 34,000 tonnes [14].

During the development, the TML system concept went through careful analyses and model testing on both stability and dynamic properties. The first system was tried to be built and supposed to be delivered at the end of August 2009. However, the contract was cancelled because the shipyard could not deliver on time and no TML system has been built since. In 2014, Twin Marine Heavylift formed a joint venture with China's Shandong Shipping, named Shandong Twin Marine. The new entity intends to start construction the first TML system that is due to be operational by 2017.

It can be seen that TML system is aimed to the heavy topsides floatover/removal. When carry out the catamaran floatover, the procedure is similar to the conventional catamaran floatover. By the design with the high capacity vessels, it is more weather robust. However, obviously, it is not suitable the operation in very shallow water.

In brief summary, from the operation point of view, the catamaran floatover process includes the same phases for all different approaches discussed above. Using the systems with specially designed vessel and equipment as represented by Versatruss heavy-lift system and TML system can make the equipment assembling and vessel preparation simpler and faster. They may also be able to make the platform integration project more cost-effective. With limited market demand of the catamaran floatover operation, these systems are all developed multi-functional in the heavy lifting sector. They can be used in the platform decommissioning for both topsides and jackets and carry out other offshore construction tasks such as wind form equipment installation.

6.4 Technical Challenges

Comparing to single vessel floatover method, there are extra technical challenges coming from the motion simulation and loading calculation of the topsides transfer as well as related structural and mechanical design for topsides/vessel enhancement and installation equipment.

6.4.1 One Extra Operation Phase

It worth mentioning that there exists one extra phase: the topsides transfer from the transportation vessel to the floatover vessels in order to form a catamaran configuration in the operation process comparing to the single barge floatover. The offshore catamaran floatover operations are different from the inshore mating operation like the Hibernia project with the two barges lifting the topsides directly at the quay. Generally, the integrated topsides is loaded out onto a transportation vessel after the completion of fabrication. The vessel will then sail to an offshore site not far from the installation site where the topsides is transferred to the floatover vessels to form the catamaran configuration [15–17]. This is because of two reasons:

- The fabrication of the topsides especially the very heavy integrated topsides is often in a yards far from the platform integration site. To transport the topsides by a single vessel should be safer and cost-effective comparing to towing the catamaran through a long distant journey.

Take the Murphy Kikeh spar installation as an example, the integrated topsides was fabricated in the MMHE (Malaysia Marine and Heavy Engineering Sdn Bhd) yard located at Johor Bahru, Malaysia near Singapore. The completed topsides was then loaded out to a transportation barge (Barge UH336 of Uni-Bulk Services) at the fabrication yard. The vessel loaded with the topsides was then towed to the installation operations base at Labuan, East Malaysia where the two floatover-barges were already arrived and ready for topsides transfer. The operation of transferring the topsides to the two (2) floatover-barges to form a catamaran was

Fig. 6.16 Illustration of the process of catamaran floatover preparation of Kikeh spar. The topsides was transported by a single barge UH336 from the fabrication yard at MMHE's yard at Johor Bahru, Malaysia to the installation operation base at Labuan, East Malaysia, as indicated by the *yellow dash line*. The topsides and the two floatover-barges then formed a catamaran which is towed to the mating site of Kikeh spar (courtesy of Murphy Oil Corporation and Technip)

performed at the quay in a sheltered water. After the topsides was sea-fastened, the catamaran was towed to the Kikeh offshore site for the platform integration. The towing distance was 110 km (see Fig. 6.16 for illustration).

- The fabrication yard facility may not be suitable for the topsides to be directly loaded out to the two (2) floatover-vessels.

Different from the construction of the GBS topsides, which were fabricated on the assemble quay or artificial GBS shafts with enough space and water depth for the floatover vessels to move underneath the topsides hanging-off parts, the topsides of the steel fixed platforms and floaters are generally constructed on the land of the fabrication yard. The completed topsides is then moved to the transportation vessel along the skidway or by the loadout trailers. Theoretically speaking, at the quay of the construction site if the water is deep enough and the loading space is large enough, the topsides can be either loaded out to the two (2) floatover-vessels parallel moored at the quay as shown in Fig. 6.17 to form the catamaran configuration directly, or to be loaded out transversely to the floatover vessels using one of the approaches shown in Fig. 6.18 to form the catamaran at the fabrication yard. However, in reality these ideal situation is quite slim near the topsides fabrication site, especially for very heavy integrated topsides with large dimensions.

Adding the phase of transferring the topsides to the two (2) floatover-vessels itself creates challenges in both operations and engineering, which in turn affects the project planning and management (Fig. 6.19).

On the project management side, to safely and effectively transfer the integrated topsides from the transportation vessel and then to form a catamaran as the next step, an offshore site or a suitable harbor need to be selected first. The environment of the selected location should have enough space and water depth as well as favorable weather conditions, so that the operation activities can be arranged and the WOW (Waiting on Weather) for the transfer operation to be minimized. In

Fig. 6.17 Demonstration of loading out the topsides longitudinally on the parallel moored two vessels to form a catamaran for floatover operation

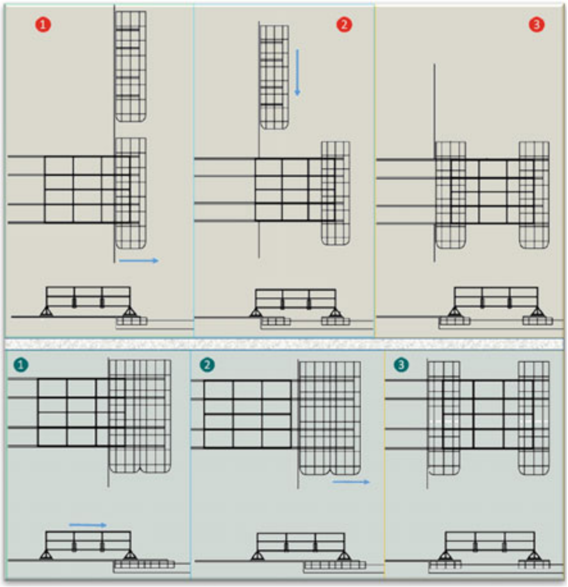

Fig. 6.18 Two (2) different approaches of loading out the topsides transversely and form a catamaran. On the *top*, first the topsides is loaded out on one vessel and then the loaded vessel moves away from the quay and the second vessel moves in; on the bottom, the topsides is loaded out on the two vessels moored side-by-size and outer vessel moves further away from the quay after the on the *right* spot and being sea-fastened (based on Luo's Patent)

Fig. 6.19 The operation of transfer the Kikeh topsides from the transportation barge to the floatover barges was carried out at harbor of Labuan, East Malaysia. The floatover barges were hooked up with the topsides one by one with the first one approached from the starboard of the transportation barge (courtesy of Murphy Oil Corporation and Technip) [18]

addition, the location generally should be not far from the mating site so that the catamaran towing distance is minimized.

When forming the catamaran, the topsides weight are not supported by the mating legs, which sit on the DSU of the transportation vessel. In the project planning, not only the outfitting of the three (3) vessels but also the outfitting of the topsides need to be included. Even for the specially designed catamaran floatover systems such as the Versatruss heavy-lift system and the TML system, the selection of the weight supporting spots on the topsides and the corresponding local structural enhancement have to be performed and all related engineering and outfitting work need to be planned in the early stage of the project.

The operation also involves special equipment and assistant vessels, therefore, a carefully developed operation procedure and on-site operation manual have to be developed and granted by the project management. In addition, a contingent plan for emergency handling need to be developed.

On the operation side, the operation of making the hook-up between the topsides with the floatover vessels and gradually passing the weight of the topsides to the floatover vessels takes time and need to follow the established procedure strictly on site. Vessel mooring, maneuvering, ballasting steps, hooking-up of topsides and the supporting structure, weight transferring percentage control, etc. all need to be looked into in details. Any unsure factor should be eliminated. At the same time, the operation is the coherent team efforts, therefore an efficient and robust communication system need to be established under the guidance of the project management.

The entire project plan and the operation procedure are developed based on the results of intensive engineering study. The project engineering team normally designs the apparatus needed for the operation.

Related important engineering tasks include:

- Simulation of the motion of the topsides and related vessels during the topsides transfer operation for defined environmental conditions
- Based on the loading results from the motion analysis:
  - Check the structural integrity of the vessels and the topsides
  - Perform local structural strengthening if necessary
  - Design grillage and sea-fastening for the floatover vessels.
- Based on the analysis results and the operation needs, identify the operation weather window at the selected operation site.

Technical challenges are obvious, since there are more than one floating bodies involved and to identify the critical loading cases, multi-body coupled analysis is needed. It can be seen that at least three (3) floating bodies are involved: the transportation vessel with the topsides, the two (2) floatover-vessels. It is more complicated for the topsides weight transfer after the topsides is contacted with the floatover vessels. The motion responses and the corresponding loads are nonlinear. If the TML system is under consideration, there are many more bodies should be included since, the operation ballast/buoyancy tanks and the impacts have to be considered with various kinds of combinations.

The engineering efforts should start in the very early stage and will be going through the whole installation project to support the handling of unexpected changes and emergencies during the offshore construction. More details on engineering involvement in floatover project will be discussed later in Chap. 9.

Fig. 6.20 Catamaran floatover mating operation. On the *left* is Kikeh spar floatover; on the *right* shows catamaran floatover used for a fixed platform integration (photo Courtesy of Technip) [18]

6.4.2 Mating Operation

The process of the mating operation in catamaran floatover is similar to single vessel floatover in steps, but facing more challenge in operation and engineering preparation. As mentioned earlier, the catamaran entity formed by the topsides and two (2) floatover vessels. The catamaran entity formed by floatover-barges differs from a rigid body by design like the specially designed OCV such as the Pioneer Spirit or DSIV (Fig. 6.20).

Comparing to the single vessel floatover, catamaran towing, docking stage mooring, premating maneuvering, etc. to some extent are more complicated, but the most challenging part is the mating operation. No matter for the fixed platform mating through the ballasting of the two (2) floatover-vessels, or to deballast the floater hull as in the Kikeh topsides installation, multiple bodies' simultaneous motions need to be controlled in a synchronized way. The correct weather window identification and the accuracy of the simulation of the motion of multi-bodies and the load transferring control are also critical for the success of the operation and needs the supports from intensive engineering efforts.

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Chapter 7
Project Management and Planning

Abstract Commonly, an engineer is more interested in the technical details and the development journey of a new technology. However, if he/she has the opportunities to be assigned to a real project for the float over operation, his/her knowledge in the project management will be a very important factor for him/her to effectively fit in the project team. Project management plays the vital role in the success of the project. If the reader is only interested in the technique aspect of the float over technology, he/she can skip this chapter. The discussions in this chapter touch several important issues for offshore installation project management. Through the materials presented, it is emphasized how the integrated efforts can be realized through well-established management systems. Details of project team framework, project QMS, PEP, communication network, document control system, etc. are also covered in the discussion.

7.1 Offshore Installation Projects

An offshore oil and gas project aims to achieve the goal of bringing the oil and gas from the reservoir under ocean to shore by means of designing, fabricating and installing platforms, subsea modules, flowlines and other facilities in the offshore field. The SOW (Scope of Work) of this kind of project typically consists of engineering (E), procurement (P), construction (C) and installation (I) and they are called EPCI (Engineering, Procurement, Construction and Installation) projects. The owners of the oil field are oil and gas companies often joint as partners with one of them as the operator to perform the management of the oil field development and production. The EPCI projects are contracted out either to a single company to carry out the whole scope or to a few contractors who will split the whole EPCI project by individual contracts. Quite often, for large EPCI projects, EPC and I or T&I (Transportation & Installation) are contacted separately to two (2) individual contractors. The platform topsides installation is included in the T&I project SOW of work. In this chapter, the discussion is focused on the T&I project management. Since projects vary and at the same time, different contractors may handle the same

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project differently through applying their own approach, the discussion here is a bit "general" [1].

7.1.1 Features of T&I Projects

- As a part of the offshore installation efforts, the T&I projects are crucial for the success of the oil field development and can have strong impacts on the overall economy of the oil and gas companies. Unexpected delay, incident and budget overrun can happen under poor project management and the consequence is disastrous. For example, a failed platform installation at the site may easily to postpone the first oil by several months even a year and the economic damage to the oil and gas company is tremendous. There have been cases like this happened globally in the past.
- Because of the huge financial impact as well as the high risk, instead of letting the contractor to handle the project by themselves, the operators are often directly involved with the offshore installation project by joining the project team at various levels in fulfilling specific tasks. How to integrate the efforts from multiple parties becomes a challenge to the project management.
- The execution of platform installation is always in the last phase of the EPCI project before the completion of the offshore HUC for being ready for the first oil and gas production. The operation duration is limited and the installation activities are very intensive and quite sensitive to the environmental conditions. The involvement of personnel and equipment such as OCVs, transportation vessels are quite heavy. Therefore, to be successful and effective, organized teamwork with high synergy is a must, and there is the need of a capable management team.
- Although a T&I project is only a part of the EPCI project as alluded earlier, it is also an EPCI itself in a different scale. The project activities also cover the whole spectrum of Engineering, Procurement, Construction/fabrication and Installation. Therefore, the SOW of the project management is not narrow.

Table 7.1 Federal statutes and the statutory authorities in the United States Waters

Regulatory authority	Federal statute	Offshore installation
BOEM/BSEE	OCSLA, NEPA, NFEA, CAA, NHPA	√
USCG	OPA	√
EPA	CWA, CAA	√
MARAD	Jones Act	√

Note In certain region of GOM, the EPA's role is carried out by BOEM/BSEE
In Table 7.1, the abbreviations are defined as: *CAA* Clean Air Act; *NEPA* National Environmental Policy Act; *CWA* Clean Water Act; *NHPA* National Historic Preservation Act; *HMTA* Hazardous Material Transportation Act; *OCSLA* Outer Continental Shelf Lands Act; *NFEA* National Fishing Enhancement Act; *OPA* Oil Pollution Act

Beside the superintendent and crews, other disciplinary personnel of engineering and management are required to form a functioning project team.

- Dealing with statutory authorities [2]
  Offshore operations must pursuant to the national and/or state statutes where the construction field is located. Every offshore construction operation plan needs to be approved by the national/state statutory authority and the project is supposed to team up with the client to carry out the communication. T&I projects should not be exceptional. However, a T&I project generally does not need to handle this kind of activities—the operators or the parent EPCI project often takes care of the direct communication with the statutory authorities, in GOM, the BEOM/BSEE, USCG.
- Working with MWS (Marine Warranty Surveyor)
  As the common practice in the industry, to manage the huge risk of the offshore field development, the projects are always commercially insured or sometimes using self-insurance when the commercial insurance is not available. The insurant warranty survey is required by the project insurance for construction and installation. In the case of an offshore installation project, the MWS is always necessary.
  The MWS's role is to provide the supervision of marine operations on behalf of a client and according to the insurer's interests. Some insurers request an MWS in their warranty clauses. An MWS is assigned to the project to ensure safety, reliability, and compliance of their installations with applicable standards. Although the MWS practitioners are supposed to work for the underwriters, but are generally welcome by the assured. Sometimes, when the oil companies are self-insured, the oil companies hire the MWS. There are rare cases of two (2) MWS contractors working on the same project—one hired by the assured and the other by the underwriter [3, 4].
  Organizationally, the MWS provider such as Noble Denton, Lloyd, is independent to the Class regulatory organization such as DNV, which is delegated by the statutory authorities in statute enforcement as aforementioned. The nature of the activities in the project by the two kinds of entities is separate and

Table 7.2 Risk probability matrix

Likelihood	Severity				
	Critical (Multiple Fatalities)	Major (Single Fatality)	Moderate (Severe Injusry No Fatality)	Minor (Lost Time / Injury)	Negligible (Effects Not Significant)
Many (at least five times per phase of a project)	Red	Red	Red	Red	Yellow
Multiple (at leat once per phase of a project)	Red	Red	Red	Red	Yellow
Likely (once happened in involved similar projects)	Red	Red	Yellow	Yellow	Green
Unlikely (happened in similar projects but not involved before)	Red	Yellow	Yellow	Yellow	Green
Remote (slim chance to happen on similar projects)	Yellow	Yellow	Green	Green	Green
Extremely Remote (not happened but theorectically possible on similar projects)	Yellow	Green	Green	Green	Green

Red	Unacceptable Risk
Yellow	ALARP (As Low As Reasonable Practicable) Risk
Green	Tolerable Risk

discrete. Interface between them usually involves transfer of documentation. The MWS is primarily concerned with the conduct of critical marine operations during the construction, installation or other key activities of a project. Class are concerned with the long term quality of construction using established rules to ensure the risk during normal operation is minimal and that these standards are maintained through periodic inspections for the life of the vessel or installation. It may be confusing after the organization merging as it can be seen that the both Noble Denton and Lloyd are under the DNV umbrella. However, the separation of the two kinds of businesses still exist.

In offshore construction, there are various kinds of risks and the risk probability matrix shown in Table 7.2 is a tool for risk assessment and risk control. The function for MWS is to disapprove any operation stepping in the "intolerable risk zone" (red). The Warranty Surveyor is sometimes called a "loss prevention engineer". His/her role is to reduce the probability of losses to an acceptably low level, by

- Checking designs and procedures to ensure that they comply with rules and guidelines
- Inspecting the readiness of equipment for a specific operation
- Monitoring the suitability of actual and forecast weather conditions.

The industrial MWS rules and guidelines are different from the Class rules and guidelines. The MWS rules and guidelines issued by large MWS organizations cover recommendations on operation details based on the offshore construction experiences. In the past, the guidelines of marine operations issued by Noble Denton and Lloyd are widely used in the industry and nowadays the DNV VMO (Veritas Marine Operation) rules are often applied in maritime and offshore construction projects.

Involvement of MWS in the T&I project is wide and in detailed levels of offshore operation campaigns covering operation plan checking, QA/QC (Quality Assurance/Quality Control) as well as on-site observation and monitoring. Obviously timely, clear and accurate information exchange between MWS and corresponding project personnel is extremely important and need to be carefully handled by the project management team.

Based on the features discussed above, it is not difficult to see that a strong project management team is essential for the T&I projects including floatover projects.

7.1.2 Project Team and Its Main Functions [5]

A T&I project team consists of the managerial staffs, coordinator/liaisons, engineers, marine and offshore operation crews, office and on-site supporting personnel. The project team framework varies depending on the scale of the projects, the feature of the tasks and the working experience and culture of the client and the contractor. However, the main function of the project team is the same, i.e. to accomplish the offshore installation tasks safely, meeting all the requirements by the rules and guidelines and on time.

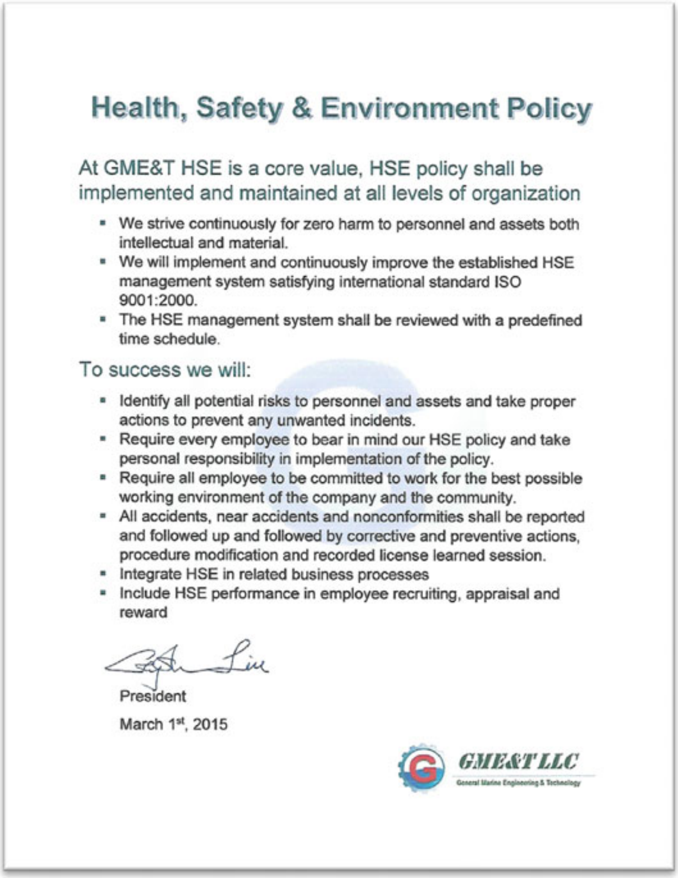
The involvement of the project team covers the early methodology development and operationability study, establishment of the PEP (Project Execution Plan), setup of management team and communication channels, development of procedure and operation manuals, QA/QC activities, preparation of operation campaign, execution of offshore operation plans, post installation activities as well as lessons learned sections during the project.

To make the execution of the project safe and effective, the project personnel including those from the subcontractors are fitted in the framework of the project with clearly defined authority and obligations, which will be discussed in details in later sections. The change of personnel is inevitable during the project development, especially for the large project with long time span. However, the fundamental systems supporting the project framework generally keep the least change during the whole project duration. Among these systems, the following four (4) are the most important.

7.1.2.1 HSE (Health, Safety and Environment) Management System

In fact, every marine operation company/contractor shall have a well-established HSE management system with publicly announced HSE policy at the company level. In the HSE policy, all the HSE laws, regulations applicable to the company's services are identified and the policy clauses discuss in details of how to comply with the HSE laws and regulations. The HSE policy also identifies the HSE behaviors and responsibilities for Managers, Supervisors, and individual employees. The HSE policy is a document approved by the company management team and is audited regularly internally as well as externally [6, 7].

For a T&I project, an HSE Plan (or HSE and Risk Management Plan) stemmed from company's HSE policy shall be developed and issued, which should also be consistent to the specific project work scope. In general, the company's policy document is included as one of the reference documents. The HSE Plan establishes an HSE management system for the project execution by a prevention-based approach building on experience transferred from previous operations and project risk assessment. Behind it is the Zero Mindset Philosophy:



Health, Safety & Environment Policy

At GME&T HSE is a core value, HSE policy shall be implemented and maintained at all levels of organization

- We strive continuously for zero harm to personnel and assets both intellectual and material.
- We will implement and continuously improve the established HSE management system satisfying international standard ISO 9001:2000.
- The HSE management system shall be reviewed with a predefined time schedule.

To success we will:

- Identify all potential risks to personnel and assets and take proper actions to prevent any unwanted incidents.
- Require every employee to bear in mind our HSE policy and take personal responsibility in implementation of the policy.
- Require all employee to be committed to work for the best possible working environment of the company and the community.
- All accidents, near accidents and nonconformities shall be reported and followed up and followed by corrective and preventive actions, procedure modification and recorded license learned session.
- Integrate HSE in related business processes
- Include HSE performance in employee recruiting, appraisal and reward

President

March 1st, 2015

GME&T LLC

General Marine Engineering & Technology

Fig. 7.1 An example of HSE policy (courtesy of GME&T LLC)

- All incidents can be prevented.
- Strive continuously for ZERO accidents to personnel, material, and non-material assets.
- Focus on employee health and continuously improving the work environment.
- Conduct the operations through effective use of materials and energy with minimum waste and damage to the environment.
- Design products and services to have no undue environmental impact to be safe and effective in consuming energy and natural resources.
- Take personal responsibility for HSE (Fig. 7.1).

Obviously, the implementation of the HSE Plan is the joint efforts from the whole project team instead of a small group of managers and leads. As the common practice, responsibility of each team member in related operation activities shall be clearly defined. With the HSE Plan in place, personal responsibility holds all team members accountable for the safety of themselves and anyone who may be at risk from our actions.

7.1.2.2 QMS

The industrial consensus on getting products/services to meet quality requirement is to have a well-established QMS in place and fully implemented in all operation processes, instead of depending merely on personal skills and experiences. Therefore, the QMS is critical for both project awarding and project execution.

When a client chooses one qualified contractor, the candidate must have an established and certified QMS system, which has been implemented in company's operations by both management team and staffs. The company QMS are presented by the company's Quality Policy, Quality Manual and related procedures/work instructions. These documents shall be available for all operation activities and every employee must follow them when carrying out assigned tasks. It is mandatory for all employees to go through the trainings by orientation, workshop and internal communication such as lessons learned sessions. The QMS is completely in line with other company's policies and has especially close relation with HSE management. In some companies, a HSEQ (HSE and Quality) department is formed to handle both HSE and QMS issues. The QMS is directly linked to the industrial practice development and kept being updated timely (Table 7.1).

After a project is awarded, the contractor project management team will work with the client to develop a Quality Plan to meet all the project specific quality requirements. The Quality Plan is developed based on the contractor QMS and includes Quality Plans of subcontractors and vendors. When the Quality plan is granted, it will be implanted project-wide by all involved parties. In the following, discussions on QMS, Quality Manual and Quality Plan are presented.

- Company QMS
  With no exception, the main project contractor, involved subcontractors and vendors all should have an established company level QMS conforming to the requirements of the industrial standards, such as ISO 9001:2008/ISO-9001:2015, API Specification Q1. The company QMS consists of the Quality Policy approved by the top management team, a formally issued Quality Manual providing the overall framework and organization for quality management for their product and service, and underpinning procedures and work instructions as shown in Fig. 7.2.
  The quality policy of a company/organization is in general a concise single page document proclaiming the company commitment to the requirements of its QMS. The developed QMS is evolving along with the development of the corresponding industry and the organization itself. The QMS is signed by the top manager of the organization and shall be certified by regulatory organization regularly. All employees are required to be knowledgeable of the contents of the

Fig. 7.2 Illustration of QMS

quality policy and to go through serious formal trainings on the QSM to assure the high quality of their services/products.

- Quality Manual
  This manual is developed to provide the overall framework and organization for the QMS of the company. At the company/organization level, the quality manual should define their scope of business clearly and establish measurable standards of their products/services, executable measures and tools for QA/QC. Typically, a quality manual in contents will cover the following:
  - Quality Policy
    The company/organization Quality Policy shall be included in the quality manual, no exception. Similar to the HSE policy mentioned earlier, the Quality Policy of a company is typically a one-page concise document approved by the company top management team. It pronounces the commitment of the organization to the QA/QC of its products/services to conform to all the industrial standards.
  - Company business scope and processes
    A clear and accurate definition of the company's business scope should be included in the early part of the quality manual. For example, an EPCI company can make "platform, floater, subsea system design, fabrication, and installation" as their products and service to meet the needs of the oil companies; an offshore installation contractor can focus on T&I service and main processes/activities will be correspondingly defined along their business scope.
    Along the company's development, the business scope may change, e.g. a T&I offshore installation contractor may add a business sector such as SURF (Structure Umbilical Riser Flowline). When it happens, the prompt update of this part in the quality manual is necessary.

– Quality objectives
Quality objectives need to be explicitly written down in the document. The quality objectives should be measurable and consistent with the quality policy. The following are some provisions, which can be found in the "quality objectives" section of the manual:

> To establish a QMS that prevents the occurrence and recurrence of nonconformance in our services provided to our clients. The company's success is measured in customer satisfaction, not solely by profits.
> All services and operations shall be executed in accordance with customer requirements as documented in the contract, and in compliance with relevant mandatory rules and regulations.
> All employees are empowered to place quality of services as their first priority and are dedicated to satisfy for our customer. There shall be no complaints from the clients caused by the conduct of the company or any of its employees
> The company's greatest assets are the employees. The company provide each staff a positive work environment, the tools and training to perform tasks and the support and encouragement to achieve and excel his/her full potential.
> The marketing and development strategies shall be based on a continuou monitoring of the markets, and the organization and resources shall be developed accordingly.

The quality objectives can be logged in a computerized system available for review and modification. The evaluation of the success of achieving the objectives and goals is based on the feedback from the clients, inputs from project "lessons and learned" sessions, special reports, etc.

– Overview of company QMS
The QMS overview provides the information of the company's intention of meeting certain industry quality standards, the philosophy of quality management, the main processes involved, the organization chart of quality management, and the quality management tools developed in the company. The following discussion items contain related information as examples:

△ QMS requirement
The company has established a process oriented QMS, which intended to meet customer specifications, and complies with the requirements of ISO 9001:2015 "Quality management systems Requirements", as well as the quality policy included above in this manual.
Accordingly, the needed processes for the QMS are identified and their application will be applied throughout the whole organization.

△ Process-based QMS
The concept and working mechanism of the process-based QMS are illustrated in Fig. 7.3.

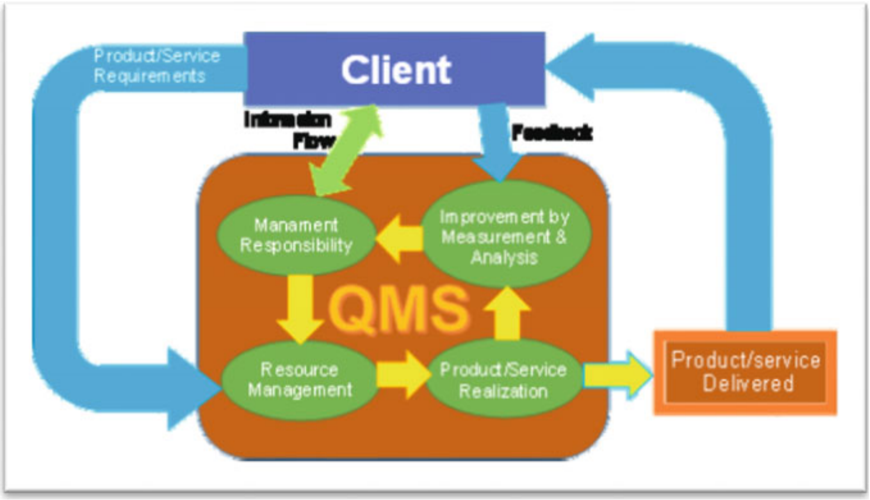


Fig. 7.3 Illustration of the process-based QMS

The offshore construction companies quite often select the process-based QMS. The scope of corresponding activities is listed in the following:

Identifying related processes matching the company's business scope and determining the sequence and interaction of these processes.
Identifying the criteria and methods necessary to ensure that both the process operation and control are effective.
Identifying and implementing necessary actions to achieve results by plan.
Monitoring, measuring and analyzing these processes with assigned resources and assuring availability of necessary information.
Client feedback handling is one important part of client focus in addition to the close communication between the management team with the client during tendering, project execution.
Keeping efforts in continuous improvement of the QMS to closely follow the development of the industrial standards such as ISO 9001:2015.

– Organization and management frame work
Commonly, the Quality Manual contains the organization chart at the level to show the work groups, work disciplines and the hierarch. This chart is used as the reference for definition of processes, description of the interaction between the processes and the relative positions and corresponding functions
The information provided by this kind of chart includes:

Assignment of each working group its function
Definition with details of the authority and responsibility of each involved individual, so that the performance of related him/her is measurable in comparison to the related standards

Description of interactions among various groups and the communication channel within the company's QMS

If there is any possible exclusion, then contents containing its details and the justification shall be included.
Generally, the definition of the function of a QMR (Quality Management Representative) is also included. A QMR is assigned for the QA/Project services, whose main task is to monitor conformity of the workings of the QMS. The work scope includes:

Processes reviews
Identification of performance trends and improvement needs
Communication with clients and authority representatives concerning the QMS
Promotion of client requirements awareness

– Document and record control

The QMS identifies all the required documents for the company operation. The documents will be issued internally or to certain external organization by request. An established documented procedure is linked in the Quality Manual to define the proper actions to

Approve the documents for adequacy prior to issue
Review and update as necessary and re-approve the documents
Ensure the identification of changes and the current revision status of documents
Ensure the availability of reversions of applicable documents at points of use
Ensure documents remaining legible and readily identifiable
Ensure the identification and distribution control of the documents of external origin but determined by the organization to be necessary for the planning and operation of the QMS
Control the obsolete documents to prevent unintended use, retained obsolete files by approval must be suitably identified.

As a special type of documents, records may not be formally issued but often used in providing evidence and information relative to the conformity to QMS requirements and the QMS operation effectiveness. A documented procedure of record control is linked to define the controls needed for the identification, storage, protection, retrieval, retention and disposition of records.

– Nonconformity handling

A documented procedure is established and linked to the Quality Manual for the identification and handling of nonconformities. The procedure includes disposition of nonconformity, corrective action and deviation permit requests to the clients. Provisions for requirements of corrective actions and preventive actions are also defined in the same procedure respectively.

- Quality management audit
  Audit activities of quality management or QA activities are an important part in the Quality Manual. The assigned team will perform the audits internally as well as on the related contractors and vendors in order to

  Verify the adherence to the procedures and contractual requirements
  Determine the adequacy of the QMS and referred procedures/guidelines/work instructions
  Verify implementation of recommended corrective actions
  Identify areas with potential improvements for QMS or referred procedures/guidelines/work instructions

- Referred procedures
  All the referred procedures/guidelines/work instructions related to the actions required by the QMS shall be listed in the manual. The documented procedure/guidelines/work instructions should be reviewed and granted by the corresponding managers and formally issued and readily available at points of use. The owner of the documents has the responsibility for their correction and update.
  The discussion above on the Quality Manual is still quite general; the Quality Manual of each company possesses its own special features fitting into the corresponding business sectors. However, the core of the quality management principles included will not change. The Quality Manual is one of the key documents which can be used by the client in the judgement on whether a company to be capable of handling a specific project.

• Quality Plan
  For an established project, Quality Plan (sometimes referred to as Inspection or Test and Inspection Plans) is a project quality control (QC) plan. The Quality Plan is developed based on the perennial QMS and very project specific. Depending on the scope of the project, the Quality Plan documents vary in its size and structure, however, its function won't change, i.e. to summarize the inspection, testing and verification activities for each process of the project and allow the client and third parties to express their involvement. A Quality Plan shall take into account the criticality of the corresponding products.
  Before the commencement of the project, the Quality Plan document shall be submitted to the client for review and approval by the time specified in the contract. The document itself shall show:

  - Document title
  - Issuing organization
  - Revision
  - Planned date for issue for project review
  - Planned date for project management approved for issue
  - Actual date when issued to the client for review

– Actual date when project management approved for issue. After the finalized reversion of the Quality Plan document, any change requires the approval by the project dedicated quality control manager.
– The distribution/control authority assignment is demonstrated in Table 7.3.

A Quality Plan describes or gives references to the project specific organization, resources, plans, procedures, tools and controls required for a successful project execution throughout all phases. When subcontractors and vendors are involved, specific Quality Plans will be required from the involved sub-contractors and vendors such as equipment/materials suppliers.

One of the examples of the project execution tools is the Project Execution Model, which supports:

– Management focusing on critical activities and emphasizing on the project objectives
– Use of milestone and gate reviews to ensure all activities to be on schedule and coordinated
– Strict specification of quality requirements for each milestone
– Transparency and effective transfer of information to all project participants
– Focus on interface management to ensure quality in all parts of the project
– A standardized regime for project execution and project discipline coordination.

For offshore installation project such as T&I, the main activities involve construction, installation and engineering supporting work. The Quality Plans often detail the activities including fabrication, assembly, examination, inspection, verification and testing processes in a tabulated format (see Table 7.4).

All personnel performing inspection and testing activities shall be suitably qualified. The following quality records generated by the project, either hardcopy or electronic, should be registered in the project document control system for retention:

– Inspection and Test Reports
– Quality Plans and/or Inspection and Test Plans
– Audit Reports
– Non-conformance Reports

Table 7.3 Quality plan document distribution/control matrix

Function/organisation	Prepare	Revise	Approve	Information	Implement
QA/QC Manager	X	X	X		
Project Manager			X		X
Project Engineering Manager		X			X
Department Managers				X	X

Table 7.4 Quality Plan document activity table

Activity Description	ISO9001-2000 Ref.	Procedure for activity execution	Activity deliverable	Responsibility	QA check/surveillance method	Remarks
Procurement coordination	§x x	XXXX-XXXX-XX-XX-000X	Procurement procedure	Procurement	QA Audit	
Supplier evaluation	§x.x.x	Bidders list	RFQ packages	Procurement Lead	QA Audit	
		XXXX-XXXX-XX-XX-000X	Bid evaluation	Eng Mgr's/Leads		
		XXXX-XXXX-XX-XX-000X		Project Mgr.		
Purchasing data and review	§x.x.x		Contract/PO	Procurement	QA Audit	
		XXXX-XXXX-XX-XX-000X		Eng Mgr's/Leads		
				Contracts Mgr		
Monitoring and measuring of product	§x.x.x	Supplier Inspection & Test Plans (ITP)	Certificate of compliance	Project Mgr.	TPI Surveillance	
Verification of purchased product	§x.x	0001-AMC-BA-YI-0002		Construction Mgr.	QA Audit	
	§y.y.y			QA Mgr.		
Project QMS	§z	PMT Quality Systems;	Review record	Project Mgr.	QA Audit	
		Supplier Quality Systems	Audit reports	QA Mgr.		
		XXXX-XXXX-XX-XX-000X				

(continued)

Table 7.4 (continued)

Activity Description	ISO9001-2000 Ref.	Procedure for activity execution	Activity deliverable	Responsibility	QA check/surveillance method	Remarks
Monitoring and measurement of processes	§y.y.y	XXXX-XXXX-XX-XX-000X	Audit schedule	Project Mgr.	QA Audit	
Audits	§y.y.y		Audit reports	QA Mgr.		
Analysis of data	§y.y					
Preventative actions	§y.y.y	Project HSE Plan	Corrective Action Requests (CAR)	Project Mgr.	QA Audit	
		XXXX-XXXX-XX-XX-000X	Concern Reports (CR)	QA Mgr.		
			Audit reports	HSE Mgr.		
			Lessons learned			

– Corrective and Preventative Action Reports
– Welding and NDE Matrices and Records
– Welder Qualification Records
– Material Test Reports
– Documents generated by subcontractors/vendors (as applicable).
  Records may be either hard copy or electronic and shall be forwarded to Document Control for retention.

7.1.2.3 Communication System

To be successful for project, it is vital to be able to share accurate information of the project timely and safely among all the involved parties, or in other words, all the stakeholders through an effective communication system. Stakeholders can either be the persons in the project team such as PM (Project Manager), engineer/operation manager, superintendent, or teams/individuals outside the project, e.g. management team of the cooperation of the project contractor, the representatives from the client, regulatory organizations. It is especially true for the T&I project at the offshore operation phase, when look at the facts of the communicating involvement of the OIM (Offshore Installation Manager) with the client and the inspectors on the site.

The importance of the project communication lies in the directed, conscious efforts in order to get people especially stakeholders to share concepts, thoughts, feelings, and information in a manner that achieves a common vision and makes correct decisions. The information to be conveyed among the project team is often backed by various kinds of data reflecting the project status, development trend, potential challenges, etc. but not the same as data and documents. Of course, the accuracy, comprehensiveness and consistency are the most important for information to be exchanged. At the same time, information possesses the characteristics of temporality and should not be shared with delays or through too many layers. Information should contain important data but should be concise at the same time. Information overloaded with data may lead to the attention deficit to the recipient and the information can become incomprehensible.

Information exchange through communication happens between specific sender/recipient pairs, therefore the information focus varies each time and the contents should be tailored to fit in the interests of the recipient. It is especially important for T&I projects with global involvement—how to convey and interpret the information is critical for correct decision making.

Project information often is sensitive to the client and the contractor cooperation, confidentiality is hence important. So how to keep the information to be distributed with security while make the information flow effective is a challenge for the project management.

Based on the above discussion, it is not difficult to understand that at the commencement of the project or even before it, the effort of establishing an effective project communication system should start. The effort should be an integrated one led by the PM or the dedicated interface manager who typically spend more than 80% their time on the project communication. The quality of the communication system remains one of the major differentiators between project success and failure. The communication system is set up for ensuring the good communication occurs throughout the life cycle of the project. In many respects, the quality of all output on a project depends on the effectiveness of communications system.

The project communication system is built based on the communication strategy developed by the project management team with the involvement of the client representatives and corresponding personnel from subcontractors and vendors when needed. For a sizable project, the project communication system is described in the issued formal document of CMP (Communication Management Plan) (or CP (Communication Plan)). A CMP is developed to:

- Collect accurate timely information and pass it to the right people in the proper form.
- Ensure the communication process occur and sustain itself throughout the whole project life.

A CMP is comprehensive providing adequate coverage of information necessary for achieving the overall vision of the project. At the same time a CMP is concise with contents containing only what is necessary to define, plan, execute, control, and close a project from a communications perspective. The CMP should be accessible by all the parties who need to reference it.

Essentially, the following important elements are included:

- Stakeholders identification and management

  In practice, for an offshore installation project including the T&I projects, the analysis on the documents available from the tender work starts as early as the project is awarded. The purpose of the analysis is to identify the main stakeholders relevant to the project and to find out their weight of influence and what kind information they need and of interest. The communication strategy is then developed based on the analysis results and Stakeholder Management is an important part of it.

  A successful stakeholder management bring the following benefits to the project:

  - Active communication between the project management and the identified main stakeholders can effectively acquire valuable inputs from them for development of PEP and operation procedures.
  - Close communication with powerful stakeholders such as client representatives and the management team of the cooperation can help gaining support in resources and cooperation enhancement.
  - By the identification of the conflicting or competing objectives among stakeholders early, a strategy can be developed to resolve the related issues.

  - Based on the identification of individuals and groups within the project team and the cooperation who will contribute to certain activities in corresponding project phases, directed active communication with them promotes the synergy during the integrated efforts.
  - Timely and frequently communicating with stakeholders help the project management team to be able to more effectively anticipate likely reactions to project progress, therefore can take measures necessary to capitalize on positive reaction and to avoid any negative reactions.

  As mentioned before, the offshore installation project team keeps changing during the project life cycle. Stakeholder are different at each phase of the project and the function and the involvement of a stakeholder vary. Therefore, this part of the communication management efforts last through the whole project life.

- Information flow and communication channels

  One of the measurement of the success and effectiveness of a CMP is the information flow and sharing. For an established project, an infrastructure of communications to support the overall project is a must, especially for a sizable project.

  From the point of view of communications, every stakeholder identified is both a sender and a recipient of information/message. However, for project related communication, it is not needed to have one stakeholder to be connected to every other stakeholder and unnecessary communication activities are not encouraged for any project. Therefore, the communication channels and the information flowing through each channel are under the coordination and control of the CMP.

  According to the results of study, for a project involving N stakeholders, then the possible number of communication channels can reach $\frac{N(N-1)}{2}$, which clearly shows the complexity of the communication structure. One of the powerful tool helping project management to deal with this kind of complexity is to develop a communications diagram. In a communication diagram, a line drawn between a pair of information sender/recipient represents each communication channel. With the communication diagram, not only the "major players" on a project are shown, but also the areas of effective communications and the opportunities for improvement are clearly indicated.

  In Fig. 7.4, the Communication Diagram of a hypothesis offshore installation project is shown. The whole project team is shown in the zone colored light blue and the special topsides installation task team is shown in the yellow zone. The following is a brief discussion about the information flow.

  - The diagram is a simplified one without all the details of the project but only more focus on the specific topsides installation task. Obviously, the crane vessel is not used in the operation. From the figure, the light blue zone includes all the important element of the offshore installation project. Parties

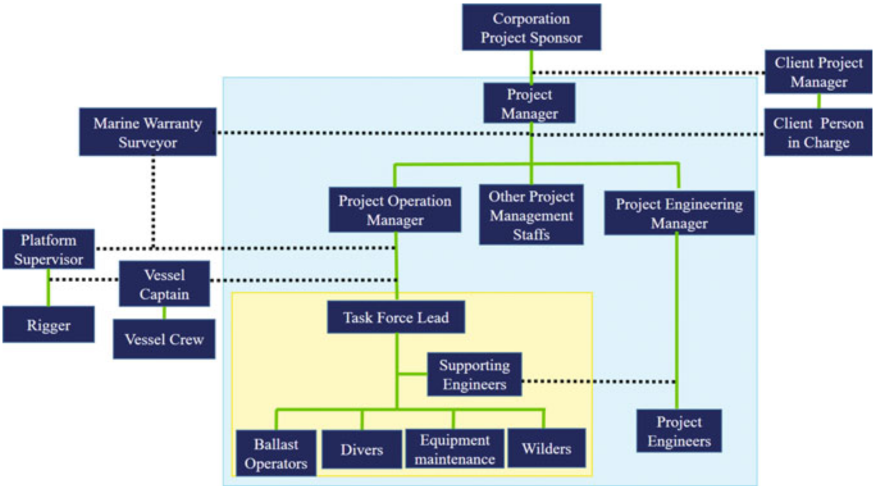


Fig. 7.4 Communication diagram

outside the zone are external stakeholders to the project and they are still important individuals/groups participating the communication activities.

– Inside the yellow zone is the specific task team focusing on the topsides installation. The internal stakeholders are fewer and some part of the project team becomes external. It can be seen that for a large project and last for a long period, there can be several communication diagrams at different development stages of the project or for emphasizing on different tasks.
– The communication diagram is different from the organization chart. A project organization chart, which will be discussed with more details later, is a diagram showing how is the project internally structured and the hierarchies with the depiction of the outlines the roles, responsibilities and “formal relationship” between positions: supervising vs. reporting. The diagram implies the communication flow between the directly connected positions either top-down or bottom-up.

As shown in Fig. 7.4, in the communication diagram, information channels go beyond the project structure. The diagram no longer functions on depicting the hierarchy structure but a network with lateral communication paths. The dashed lines indicate the established communication links. At the same time, the lateral communication among the same level project personnel is implied, e.g. communication between the ballast operator and the equipment maintenance person.

Communication diagram is a living document and to be updated during the project life cycle.

- Communication medium and application guidelines

  There are many ways to communicate, from face-to-face meeting, telephone conversation, to e-mail and teleconference. For different situations, one of the communication tool is more suitable for safe, accurate, timely and consistent information exchange.

  As for the offshore installation projects, offshore operations are risky, intensive often with very tight schedule, therefore, the client and the cooperation of the project owner became the most important and most involved stakeholders. Communication with the client and the corresponding groups in the cooperation accounts for an important portion of the communication load. Another special aspect is the offshore communication between vessels during the operation. Then the communications process requires different equipment arrangement. In the following discussion, a few communication arrangements and the corresponding guidelines are covered.

  – E-mail is a widely used tool for both internal and external communication. Also the information/data amount is huge going through the channels. To make the information shared safe, accurate and consistent, there must be a policy/guideline in place at the project level. Every project member shall follow the established rules. One of the example is:

    A PMB (Project Mail-Box) is set up. All the incoming e-mails for the project need to send to this mailbox and be processed by PM or management team member delegated by him/her. In case, when project personnel e.g. an engineer, received project related e-mail, it must be forwarded to the PMB without any modification.

    Any attachments with the e-mail shall be detached to the project folder and reviewed by the PM or assigned manager/lead.

    If needs action, the PM will make action comments, assign the actions to selected project personnel and forward the related information. The activities of the e-mail processing are recorded.

    All outgoing e-mails need to be reviewed by proper project authority, e.g. e-mails go to the client representatives shall be reviewed by the PM.

    Outgoing e-mails should be sent from the PMB or to be forwarded to the PMB when it is sent out.

    When an e-mail has been actioned, the project personnel responsible for the action will move the e-mail to a corresponding dedicated sub-folder in the project folder ready for archiving.

  – Meetings and reporting

    For offshore installation projects, guidelines on meetings with important external stakeholders need to be included in the CMP. These meetings are typically with the clients on a regular basis to discuss project progress, technical matters and to resolve issues arose during the execution of the contract. The meetings are called by the PM or the project interface manager. The following are the meetings typically to be considered:

△ Bi-weekly project progress meeting

Reviewing action register;
Discussing weekly and overall project progress status vs. planned;
Discussing issues encountered and actions taken;
Highlighting potential risks and corresponding mitigation measures

△ Monthly project progress meeting

Reviewing monthly and overall project progress, especially schedule and budgets;
Discussing remedial and recovery measures to correct progress shortfall;
Discussing critical issues during the project execution and the corresponding actions taken;
Highlighting potential risks and preventive measures

Meetings called by project or by the client

△ Addressing specific project related issues

These kind of meetings are handled very formally. In the invitation of the meeting, the following should be listed clearly:

Purpose of the meeting
Chairman of the meeting
Agenda in which the following up of the requested actions at last meeting are put in the listed items
Necessary basis for the meeting should be referred.

At each meeting, every attendee shall sign the signing sheet as a proof of the attendance. For each meeting there should be a dedicated person to take notes and produce a meeting minute document. The meeting minutes will be reviewed and approved by the meeting chairman for record and issuing to all involved parties.
Beside the face-to-face communication through meetings, reporting is arranged to the client on a regular basis and/or timely to keep the client fully informed of the project progress. Examples of these kind of reports are:

△ Weekly progress report

Reporting weekly project progress with details, generally a spreadsheet with performance indices covering listed items in group, e.g.

Items completed last week
Items to be completed next week
Issue that need to be addressed to preserve schedule
Interface issues that need to be resolved

△ Monthly progress report

A formal report with management summary to report:
Current month progress and activities;
Next month planned activities;
Important issues and concerns;
Vessel & equipment status
The summary is supported by the attachment of statistics, progress analysis, related project reports, photos, etc.

△ Daily site progress report during offshore operation

Take the transportation operation as example, the report can cover:
Location of the transportation vessel loaded with the facility;
Weather conditions;
Updated estimate of arrival time;
Mitigation measures needed;
Activities planned for the next day

△ Accident report

Project management will report all accidents including near misses/dangerous occurrences to the client as soon as it occurred.
All the reports mentioned above need to be reviewed by the project management and approved by the PM before issued to the client and then have a copy in document control system as record.

– On-site communication

When carry out an offshore operation, say, the installation of platform jacket or topsides, vessels such as barges, tug boat, AHT/OCV are involved, and the communication environment is special and a CMP is needed for the safety and effectiveness of operation.
Available communication equipment includes satellite telephone, VHF (Very High Frequency) radio, telex/facsimile machine, e-mail facility, etc. Here, the discussion is on the communication by VHF radio. Following the international agreement, the frequency range is from 156.000 to 162.025 MHz. This range is labeled by ITU (International Telecommunications Union) as the "VHF Maritime Mobile Band". ITU adopts international regulations and treaties governing all terrestrial and space uses of the radio frequency spectrum. Individual countries may adopt their own national legislation within these international regulations to provide a group of standard frequencies that are known to all mariners and can be used worldwide. A good example is that sixty-eight (68) channels are made available by international agreement for the US, but the U.S. only makes use of fifty-one (51).
Before the offshore installation commencement, the project should get the communication plan of using VHF radio equipment ready for all involved parties, e.g. captains/masters of tugs, barges, and AHT/OCV's to fully

understand the guidelines and to follow them strictly on site during the entire operation spree. The following is the brief depiction of the VHF radio communication plan of a near shore transportation of the topsides, which involves the tugs and the transportation vessel (barge).

The primary means of communications between the tugs in the tow spread will be VHF radio.

Communication between all personnel and vessels shall be via VHF (International) Marine CH 74 (156.725 MHz), or CH 69 (156.457 MHz) as a backup. The tugs will also, monitor CH 16 (156.80 MHz) at all times. Each vessel will have at least two working units.

Prior to departing the fabrication yard, the lead tug will make an "all channel security call" alerting the area of the imminent departure of the vessel with the topsides. This security message will be repeated at 30-minute intervals while the tow is negotiating the inland waterways and every 60 min throughout the offshore leg of the tow or as necessary.

Once satisfactory communication has been established between all units on the tow spread, a strict radio silence will be observed unless communications are relevant to the job at hand.

In summary, communication system is essential for integrating the team efforts and successfully carrying out the project. The important factors for a good communication system are:

- The communication network and the persons at each network node
- The proper medium and the guidelines on the information distribution
- Message exchange including the details such as the message composition and review

Among all these factors, the communication participates are the most important, their attitudes and capability of following the guidelines and rules and the congruousness within the pairs of sender and recipient. Therefore, trainings on comprehension of guideline/rule details and familiarization with communication medium as well as teambuilding activities play a vital role in communication improvement.

7.1.2.4 Documentation System

During the whole life cycle of an offshore installation, there are tons of documents such as reports, tech-notes, meeting minutes/memos, drawings, data records, etc. coming from outside the project or generated through the project activities. The information contained in these documents belong to various kinds of categories and need to be grouped, reviewed and timely distributed to the right project personnel and safely stored. During the project life cycle, along the development of the project, documents need to be continuously updated to ensure all the relative information to be fresh and accurate. All the documents to be sent out must be checked and approved by the corresponding leads/managers, while all the documents from the client, subcontractors, vendors need to be distributed to right project authorities then reach the project personnel who need to use the information. An efficient document management system is essential to the success of the project.

In a project, the responsibility of establishing a document management system falls on the shoulder of the PM. The basic considerations of the document management system are:

- Use the cooperation's document management system as the base. Every company has a well established document management system to handle all the documents, both electronic files and printed hardcopies, related to the company activities. The framework of the system, the procedure guidelines as well as the tools including hardware and software are in place and in use. All of these do not need to start from the scratch.
- Nowadays, the vast majority project files are electronic, even the older published materials and signed document sheet can be scanned to become electronic. The center of the project document management system is the specifically set up network folder, e.g. P:\XXXXXXXX with assigned accesses to project personnel. The files in the database are divided into two large groups: the working files and the documentation, some of which will be delivered to the client. The latter will be managed by the project's document control system.
- In line with the communication management system and the quality management system, the document control function is responsible for expediting, logging, distributing and filing of all project documentation, both internal and external. Rigorous filing and documentation tracking procedures are used in conjunction with the disciplinary design/analysis and reporting procedures to provide a consistent and ultimately seamless document handling.
- PDCS (Project Document Control System) also needs flawless connection with the client's corresponding document control system, especially the details on documentation registering, approval and document standards in numbering, format, etc. The contractor's PDCS has to be accepted before it starts to be used in the project.
- The PDCS is managed by a dedicated person who is assigned by the PM. The PM is the center contact point between the project and the client, subcontractors and the vendors.

In Fig. 7.5, the illustration is made to show the concept of the project document system. The project database on the right lower corner contains all the project related files and the access to the specific part is assigned to the related project team members through the combination of user ID and the password. All the documents to be issued including reports, drawing, tech-notes, etc. are created following the strict procedures/guidelines. When it is ready, the documents will be forwarded to the document control unit with the checking list signed by the responsible project member. The document will be registered and sent to the client's document control department for approval. If the document is approved by the client, then it will be

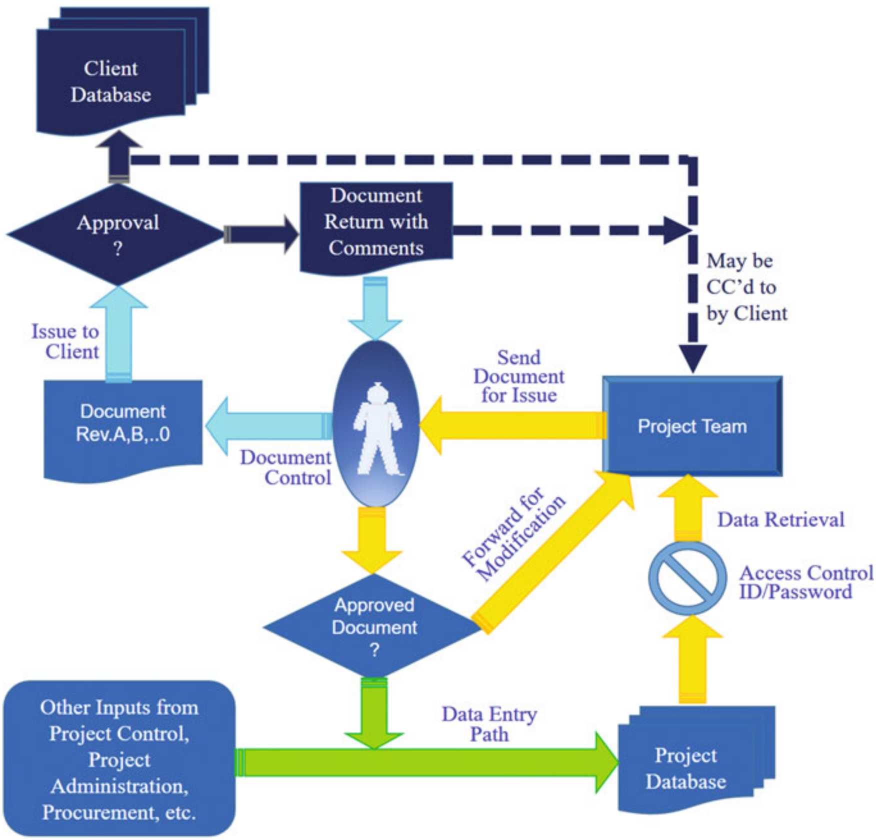


Fig. 7.5 Illustration of document issuing through document control

registered and stored in the project database. If not, the document with client's comments will be registered and forwarded to the responsible person(s) for further action. In a real project, the process is more complicated.

7.2 Project Management and Project Organizations

7.2.1 Project Management

An offshore installation project delivers services through carrying out a series of defined processes and tasks. The deliverable, the tasks to be fulfilled, the working environment and the approaches in problem solving are typically unique. Both the client and the contractor cooperation, especially for sizable project with heavy investment, nowadays regard project management as the very high priority. The function of the project management on the macro level is to lead the project team to complete the offshore installation and meet all the contract requirements within the restrictions of budget, time and resources, at the same time leaves no harm to the environment and safely with zero accidents. On the micro level, the project management needs to satisfy the stakeholders in the day-to-day performance by:

- Clearly define the workscope and project phases with details of the processes and tasks
- Develop the methodology and the PEP
- Provide project progress information on a real-time basis
- Ensure that project team members aware and monitor project risks and share accurate and meaningful project information timely

The project management function is fulfilled by project management team consists of several managers/leads lead by the PM. The main duties of the members of the overall management team are as follows:

- Project quality management through the implementation of the Project Quality Plan with the engineering/operation procedures, audit procedure.
- Project risk management through the implementation of the Risk Management procedures to ensure all project team member being visibly committed to the risk management. Review of the risk management issues is carried out periodically at management meeting.
- Project schedule management through careful handling of the WBS (Work Breakdown Structure) in the planning stage and close monitoring the project progress.
- Project cost control through project control system implementation led by cost control system.
- Develop an efficient project communication system.
- Set up project document management system.
- Project change management through the implementation of Change Management procedure to work together with the client in managing project change which is almost inevitable occur during the normal course of engineering, procurement and construction for a real project.
- Develop and issue PEP.
- Develop an installation manual covering all the necessary engineering information, operation procedures/guidelines of the project.

7.2.2 *Project Organizations and Organization Charts*

As a project management tool, the project organization charts are applied to define the framework of the project team. As mentioned earlier, the project organization charts are different from a general network chart. In the organization chart, typically the team member relations shown by the connection lines are hierarchic implying

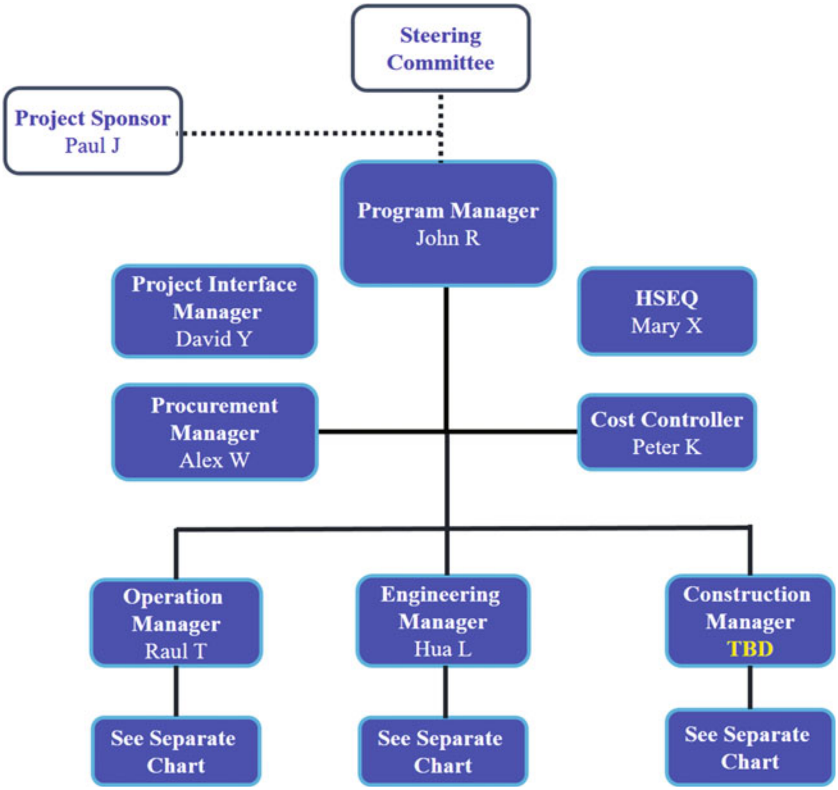


Fig. 7.6 Project organization chart showing to project management team

the relationship of supervising/reporting. In practice, there are several organization charts for a project to serve specific purpose, e.g. the chart showing the top-level management team, the chart showing the engineering supporting, the chart showing specific operation process, etc.

In Fig. 7.6, a hypothetic project organization chart shows the main members of the project management team. All the colored positions belong to the project and the PM is the top authority, although he reports to project sponsor and the project steering committee. Day to day operation is under his guidance. The following can be noticed:

- At each position in the chart, the title is explicitly shown. The job description for this position is in the project database.
- If a person is assigned to a position, his/her name is also shown and the corresponding resume/CV is ready in the project database.
- TBD (To Be Determined) indicates the vacancy of the position and a qualified person will be recruited referring the job description internally or externally.
- As mentioned before, the connection line shows the supervising/reporting relation between related positions which implicit the communication

information flow top-down/bottom-up channel. Full communication network is not shown in these kinds of charts.

- In the figure there are also boxes labelled "See Separate Chart" which link to other detailed organization charts for corresponding sub-teams/groups. These charts are populated with project members assigned with specific functions including authority and responsibility. The reporting relations are also established clearly. Of course, there may also have "See Separate Chart" blocks linking to the next level sub-organization.
- Since the offshore installation projects are typically divided into several phases and there are often changes in the project lifetime, the project team also evolves along the progress of the projects. Therefore, the updates of the organization chart promptly and accurately are necessary for a good management team.

Project organization charts are very useful for judging the strength of the project team especially the competency of the key persons in the project management team.

7.3 PM (Project Manager)

To achieve the goal of accomplishing the project safely and cost-effectively wining the satisfaction from the client, each member in the project management team plays vital role and is indispensable to the project. For example, the HSEQ manager who leads the team to ensure the implementation of the project's HSE policy, and QA/QC activities with developed quality control system and related procedures; the PEM (Project Engineering Manager) leads the effort of engineering supporting for various operation process and tasks from estimating calculation, analysis/simulation to structural and rigging design to ensure all the technical issues for the installation operation are addressed promptly, accurately and cost-effectively; the POM (Project Operation Manager) focuses the efforts to ensure all the needed equipment being prepared and all the crew with hands-on experiences being assigned to the task team and fully understanding the operation procedures, so that the task can be carried out as planned, etc.

All the project management members work under the leadership of the PM who is full time involved with the project activities from the kick-off to the closeout and he/she is responsible for all the important decision-makings.

For offshore installation projects, each time not only the facilities to be installed are different, the location of the offshore site is different, also the installation season may be different. Therefore, the challenges faced by the project may be completely new to the project team. The success of the project is always based upon the project management team's ability to manage and co-ordinate activities in a timely, concise and uniform manner. It cannot only depend on the experiences of crews, leadership and management skills of the project team especially the PM are critical.

An effective function of the project management team is to ensure that the client's requirements in terms of quality, schedule and performance are met in accordance with the contract. In order to meet these objectives, the important roles and responsibilities of the PM include:

- Serve as the prime representative to the client and responsible for all project matters. He/she is responsible for the outcome (success or failure) of the project.
- Be responsible to the project stakeholders for delivering a project's objectives within scope, schedule, cost, and quality.
- Ensure project teams are aware of the scope of work, procedure, standards and interface with the client through the issue of the PEP.
- Define the project strategy through design, procurement, construction and commissioning to ensure successful performance.
- Involve with the planning, controlling and monitoring, and also managing and directing the assigned project resources to best meet project objectives.
- Collect metrics data (such as actual values for costs, schedule, work in progress, and work completed) and report on project progress and other project specific information to stakeholders.
- Promote team building and developing quality, schedule and safety consciousness in order to generate good communications, commitment and enthusiasm.
- Be responsible for identifying, monitoring, and responding to risk.

The above list is not the complete list of the role and responsibility, a competent PM should not throw himself/herself into the simultaneously going project activities, but identify and select the most critical tasks to directly involve and delegates qualified management personnel to represent him/her for the day to day operations under his/her supervision.

For example, the project communication is very important as we discussed earlier. Usually 80% of the PM's time is spent in communication. A PM will not miss the project management meetings, the important meeting with the client representatives. However, other meetings can be handled by, say, the project interface manager or project coordinators. It should be kept in mind that for all the assigned participations, the project interface manager/project coordinator is still under the supervision of the PM who retains the responsibility and accountability [8].

Easily to see that to be a successful PM capable of dealing with a host of problems every day, it's not enough to only depend on intelligence and technical knowledge. Good vision and management skills including communication skill are the key fundamentals. By carefully developed PEP, the strictly carrying out the PEP and keeping continuous improvement, the established project goals can be fulfilled through the joint efforts of the whole project team. During the project life cycle, among various phases, some tasks being completed and new ones being started, working load varies. A good PM should always keep a full picture of the project progress in his vision and know exactly what are the most critical issues for the time being and where is the weakest link of the team and put his/her efforts on the right spot. Since the performance of the PM is closely related to the project's success or failure, the selection and assign a qualified candidate is a very serious and careful process. Both the contractor cooperation and the client are heavily involved. In vast majority of cases, an ideal PM candidate is a well-trained certified PM with extensive experiences of project management in the corresponding industry.

7.4 PEP (Project Execution Plan)

The PEP is one of the primary documents for the offshore installation project and is probably so universally in the industry. The strategy for implementing the execution phase is laid out inside the PEP to define how the project will be undertaken. Therefore, it sets the project management framework and an overall direction for the project that has been approved by the parent cooperation of the project team and the client's senior management, as well as understood by project stakeholders. The PEP, at a high level, also provides the reasoning of the strategy adoption, explaining how alternatives have been challenged and how the available resources are to be optimized to meet project objectives. A well developed PEP reflecting the best project management practice is generally accepted by the industry.

A PEP generally includes a number of formal, stand-alone plans for particular areas of project process, e.g. HSE management plan, QA/QC plan, value management plan etc. The related specific activities, resources and organization to be applied are detailed in the PEP, so as to demonstrate how the project's quality and HSE requirements will be achieved, and how the project objectives will be met. The PEP document does not repeat the details of these plans but provides the necessary signposts towards other associated documents such as individual project plans, procedures, work instructions etc. Therefore, the PEP of a project is the ultimate source of guidance to the project team and should be the starting point when developing detailed project documentation.

The PEP document is a key deliverable item for the project's sanction and also the highest level project execution document, together with its referenced standalone plans, should be made available to all project stakeholders.

For illustration purpose, the following is a typical PEP contents for a floatover project:

- Project Plan Objectives and Scope
- Brief Project Description
- Organisation and Manning Levels
- Project Management
    - Project Goals
    - Project Specific Information
    - Execution Strategy
- HSE Management
- Quality Management

- Engineering Management
- Procurement and Expediting Management
- Fabrication Management
- Loadout of the Topsides
- Transportation of the Topsides
- Floatover Operation
  - Mobilisation Activities
  - Preparations for the Topsides Installation
  - The Topsides Installation
  - Demobilisation Activities
  - Close Out Report
- Subcontractors
- Project Communications
- Communications Planning
- Field Operations
- Document Control
- Project Schedule
  - Project Schedule
  - Progress Monitoring
  - Reports
- Project Controls
  - Reference Documents
  - Project Cost Control
  - Invoicing and Billing
  - Material Requisition
- Contract Administration

  Considering that the floatover project is often a part of the T&I project which has its own PEP, care must be taken to ensure no conflict between the PEPs. Always keep in mind that the high level, over-arching PEP for the complete project, say, the EPCI project is indeed the governing document and always take precedence.

7.5 IM (Installation Manual)

The project IM is another most import document of an offshore installation project. Different from the PEP file, it describes the overall project activities involved with focus on safety for personnel and equipment. For a project of floatover platform integration, the IM contains all the necessary information about the platform, the offshore site, the installation equipment and summaries of the operation activities. It also provides references for the sources of the detailed information such as analysis/design reports and drawings/sketches. It serves as some kind of the project encyclopedia.

To help getting some feeling on this kind document, the following is the structured contents of an IM based on the past practices. A single vessel floatover project for a fixed platform integration can have the IM structured as the following:

- Introduction
  Present brief description of the field layout, the site installation restriction, basic information of the platform topsides and the jacket, transportation/floatover vessel information, etc. Provide the sources of relative information.
- References
  List important reference documents:
  - Operation manuals and procedures developed for the projects
  - Supporting documentation including:

      Analysis reports such as transportation stability report, mooring analysis reports, floatover motion simulation report, etc.,
      Design reports such as DSS & skid beam design report, vessel fendering design report, LMU design report, etc.,
      Weight reports,
      MTOs

    All these reports record the engineering work of supporting the development of operation procedures/manuals/working instructions.
  - Technical specifications of floatover operation related equipment, e.g. mooring system specification, vessel motion monitoring system specification, LMU specification.
  - Other Documents
- Rules and regulations
  - All planning and execution of transportation and installation of the platform topsides will be carried out in accordance with rules issued by the client approved regulatory organization, e.g. DNV Rules for Planning and Execution of Marine Operations, 2015.
  - The client's project specifications included in the contract document.
  - All operations as approved by the client. Major independent operations shall have a signed "Certificate of Approval" issued by the projects warranty surveyor on behalf of the client prior to commencement.
  - The proposed marine equipment spreads, procedures, safety requirements and manning requirements shall fully compliant with corresponding Statutory Authority's legislation and regulations.

  - All marine vessels employed by the project will comply with the relevant Marine Orders, as required by the IMO (International Maritime Organization).

- Organization/Administration/Communication
  In this section the same kind of project organization information presented in the PEP is repeated here with all the organization charts related to the floatover operations at various phases. The job descriptions of involved key personnel, e.g. PM, client representative, operations manager/leads, engineering manager, vessel captain, etc., are also included.
  Prior to the commencement of the operation and during the operation, a series of meetings such as punch list/co-ordination meetings, ready for operation meeting, go ahead decision meeting are put into plan and the corresponding attendees are decided. Guidelines for handling deviations are also laid down.
  Communication network charts and the guidelines of on-site communication between vessels, between onshore and offshore are also included in this section.
- Safety
  Safety of project personnel including crew and representatives from various parties such as the client, the contractor cooperation, the subcontractors and the vendors is emphasized for all phases of the work. Details are referred to the developed "Safety Management Plan", "HSE Management Plan", "Emergency and Contingency Procedures".
- Certification
  By this manual, all vessels involved with this installation project are requested to go through a suitability survey performed by qualified personnel from the projects operation staff. The MWS and client representatives may also attend this survey, which includes general checking of the vessels certification, maintenance standard. The onboard personnel qualifications and certification, including health and safety training are also included.
  All equipment used for the mentioned operations are requested to be certified and commissioned/tested prior to being activated.
- Criteria
  All the criteria for installation operations are clearly defined based on the DB (Design Basis) of the project and derived through engineering analysis/design and the operation procedure/working instruction. The criteria belong to the following categories:

  - Environmental design criteria involving mooring system design and deployment, docking/mating operation, etc.
  - Operational criteria including the restraint of operation around the stand-off mooring; the criteria for docking covering cutting of sea fastening; controlling of gap and clearance between mating cone and receptor, vessel and jacket legs; mating load transfer operation control and the clearance between the topsides bottom and the floatover vessel deck during the undocking operation.

- Weather windows criteria including the window size and environment criteria corresponding to the following five (5) operation phases are defined:

  Floatover vessel together with the topsides sail to temporary mooring site and hooking up with the mooring system
  Vessel and jacket preparation
  Pre-floatover operation
  Floatover operation
  Post-floatover operation

- Tidal influence, which addresses the amplitude restriction for the docking and final position of the floatover vessel within the jacket slot.
- Visibility criteria, which defines the minimum required visibility during movement of any units during the on-site operation.
- Weather forecast criteria, which clearly puts down the requirement of receiving the weather forecast no less than the number of hours, say 48, before the vessel is towed to the site. There are also weather forecast requirements for long distance transportation and the on-site floatover operation.

• Primary equipment systems
  This section lists the primary equipment including various kinds of vessels to be used in the operation and related information.

  - Transportation/floatover vessel and built-in equipment such as navigation lights, bow towing cradle, emergency towline, ballast systems, personnel facilities.
  - AHT vessels and the onboard equipment
  - Fendering system to be installed on the floatover vessel
  - Docking mooring/berthing system
  - Topsides loadout link-beam/grillages
  - Positioning monitoring system
  - Motion monitoring system
  - Environmental data acquisition system
  - LMU.

  Documents such as "Equipment Manual" are referred for extensively detailed information of these equipment.

• Workscope activities
  All involved offshore activities are fully listed. For each identified operation activity, discussion with details on equipment involved, operation steps and requirements for performing the operation, etc. More extensively detailed information relative to the operation activities can be found in the procedures/reports in the Appendices. The following are the list of the activities:

  - Platform installation site preparations
  - Mobilization to installation site

- Jacket preparation
- Transportation/floatover vessel at site preparations
- Hook-up to temporary mooring system
- floatover operation/docking
- floatover operation/load transfer
- Float-under operation/undocking
- Disconnection from mooring system
- Post installation activities

• Contingency procedures

In this section, the preparation for contingencies is discussed with a list of events and how to handle it on-site. The list mainly cover the unexpected failure to the mooring systems, vessel built-in equipment and the installation equipment and problems caused by the external factors such as environment and third party vessel movement. Suggestions on how to handle each situation is briefly discussed, the more important is to have the on-site personnel to work together and apply their experiences in finding an effective solution.

The importance of the contingency procedure has never been emphasized enough. One of the lessons learned from the failure of floatover operation happened to the Lufeng 7-2 DPP (Drilling Production Platform) offshore integration in 2013 is: "*…There were no contingency measures to address the failure of outer leg lowering system…*" according to Wang et al. [9] (Fig. 7.7). In brief, the Lufeng DPP is a fixed platform working in the water depth of 106 m in Lufeng offshore field in South China Sea. The 8-leg jacket was designed for the floatover installation using the technology of so called low deck floatover which means that the elevation of the topsides during the transportation and the mating is low and the topsides will be elevated to the design the height after the completion of mating by strand jack systems. This technology

Fig. 7.7 The jacket and the integrated topsides of Lufeng 7-2 platform (courtesy of CNOOC, Ltd.)

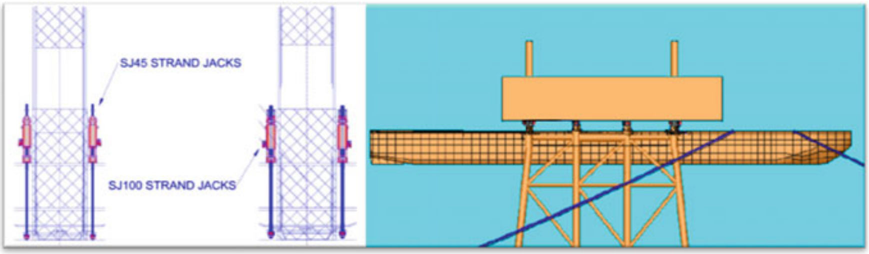


Fig. 7.8 Illustration of the platform integration and the topsides mating leg lowering strand jacks for four (4) outer legs and four (4) inner legs

had been successfully applied to the installation of facilities for HelWin and BorWin Windfarms projects in the North Sea as mentioned earlier.
The developed method of topsides mating with the eight (8)-leg jacket was to first lower the four (4) outer topsides mating legs to connect with the corresponding jacket legs, then complete the four (4) inner legs. After all the connections to be completed and the whole weight of the topsides to be transferred to the jacket, the topsides will be lifted up by the strand jack system pre-installed on the topsides (Fig. 7.8).
During the operation of lowering the outer topsides mating legs, because of the malfunction of the 100Te lowering strand jacks, accident occurred with mating cones and the jacket legs being damaged and one of the mating legs free dropped into the corresponding legs and the others could not be properly lowered. Under the situation of emergency, since there was no contingency procedure in place to guide the action of releasing the 100 Te strand jacks, a consequence of events happened and led to the failure of the floatover operation. Interested readers can find detailed information in the aforementioned article.
The opportunity for this kind of accidents is quite slim, but the cost will be tremendously high to the projects when they occur and sometimes might cause casualties.

7.6 Summary Comments

In this chapter, the discussion touched several important issues for offshore installation project management, which are vital to the success of the project. However, the coverage is very limited and it should bear in mind that project management is quite comprehensive. Through the materials presented, hope the readers can gain some basic ideas on how the integrated efforts can be realized through well-established management systems. The more important is that if one have the opportunity to be assigned on this kind of projects and then he/she is able to identify his personal role and responsibility accurately and can contribute to the project through personal efforts and communication with corresponding parties. With conscious efforts in development of management skills and gaining experiences through lessons learned activities, the staff members of the project management team will grow with a fast pace.

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Chapter 8
Engineering Analysis and Model Test

Abstract Although floatover operations are performed by the crew at the installation site, engineers play important supporting roles in PEP development, operation procedure development through intensive engineering efforts. Besides engineering analysis/simulation of motion and loading calculation, the work scope also cover the structural/mechanical design, technical specification for equipment fabrication, QA/QC and on site supporting, etc. Discussion in this chapter covers a wide range of the engineering work with multiple engineering disciplines. Successfully accomplished projects are referred for some technical details. Through the discussion it is very clear that the engineering work is not the isolated efforts. Communication under the project QMS system is vital for the success. The importance of the early engineering involvement for the project success is also addressed.

8.1 Engineering Plays a Vital Role in Floatover Projects

Talking about topsides floatover installation projects, it seems quite simple and clear that the focus is on the offshore operation activities for delivering installation services without much engineering involvement. It might be true to only look from the surface. In fact, for a real floatover project, engineering activities are always intensive and the project engineering plays a vital role throughout the project life cycle. Although engineering plays a supporting role in the project, almost all important decision making, planning as well as operation procedures are carried out based on the corresponding data coming from analysis, calculation and model tests. The equipment designed by the engineers often become the key elements for operations to achieve the goal of safe, on-time and cost-effective performance [1].

Occasionally, there are perceptions that without the analysis and calculations, the project can still be successful based on the experiences. Unfortunately, it is not true for most of the situations, since even for the same design of the platform, many

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factors vary including the environment at offshore site, the infrastructure around, the orientation of the platform, the transportation route, etc., which demand variations in installation equipment and installation methodology.

The risk will be too high to plan and execute the operation purely based on the experiences gained from past similar projects. For example, to perform an open sea fixed platform floatover installation the installation criteria need to be set up properly and the weather window need to be identified for the docking and mating operation. Improper criteria hurts the project definitely: if the environmental criteria is set too low, then there will be higher risk of structural damage, installation failure, even casualty; on the opposite, if the criteria is set too high, then it can cause a very long waiting time for the vessels offshore, at least adds costs to the project.

The engineering support efforts on a floatover project covers a wide spectrum: from quick, simple estimate by hand calculation to intensive time-domain simulation which may last hours followed by post-processing of large amounts of generated data. There are also the needs of structural analysis and design for floatover equipment fabrication and structural enhancement, such as grillage, fender system, skid beam, etc. Engineering involvement starts as early as from the project bidding stage and continues until the close out of the project.

8.1.1 Engineering Team on the Project

Engineering team consists of engineers and drafters covering various disciplines typically including naval architecture, structural engineering, mechanical engineering and marine engineering. The team's size and team-members generally change along the progress of the project since the whole installation process is broken down into numbers of tasks and each engineer may only be involved in a couple of them. The whole team is led by the PEM who reports to the PM and is responsible to ensure:

- the DB to be verified/developed and in accordance with the contract requirements
- the list of project engineering tasks needs to be initiated and maintained throughout the project
- the clear definition of engineering SOW related tasks and appropriate assignment of engineering resources
- the engineering progress to be kept in line with the schedule requirement
- the implementation of the procedures/guidelines relative to engineering analysis and design
- the update and consistency of the data to be used in engineering analysis and design
- the participation in the development of conceptual and detailed designs including review and approval.

The gravity center of the PEM's responsibility is on how to make sure the engineering analysis/design results to be dependable, meeting all requirements by project-adopted criteria and to be delivered on time. Different from EPC projects, the engineering team on the offshore installation project is not a group of employees physically around the PEM in daily activities, but formed by various task units, therefore the communication among the team is quite important. Sometimes, engineers need to work alone and away from the office, e.g. to provide on-site technical supports and it might be necessary to make decisions on technical issues by himself/herself. Obviously, the competency of the assigned engineers is quite essential.

8.1.2 Engineers—Their Quality and Challenges

Recall the discussion above on engineering disciplines. From the first glance, the engineering assigned to the installation projects seem no difference from engineers in other areas of the industry. However, because the special working environment of the offshore installation project like the topsides floatover project under discussion, more challenges exist and in turn, the competency requirement is relatively higher. In the following, the discussion focuses on the challenges to be faced by the engineers when carrying out assigned tasks and the corresponding capability they should possess in order to meet the challenges.

- Working independently
  For a floatover topsides installation project alike, generally only a few engineers are assigned to the project and almost everyone has different working task. Quite often, not so many person-hours budgeted. The assigned engineer should immediately get into the role by understanding the requirements, the available information can be used and then quickly decide how to approach by a plan.
  Getting advices from engineering leads/manager may be possible, but it is beneficial to the engineer to have him/her mindset of finding solutions by himself/herself. Especially, when under the situation such as aboard a vessel or working at a remote location, etc. it is difficult to make convenient contact for assistance.
  The ability to work independently comes from conscious efforts in the enhancement of engineering background and continuously learning from the project practices. This kind of learning is not purely following a "go-by", since every installation-campaign may come across new factors comparing to the already completed projects.
- Clear engineering vision to catch essential issues
  To carry out the engineering analysis and calculation for a floatover topsides installation project is different from common research projects and academic work. Often the schedule is tight and the budget is limited. Therefore, efforts and time should not be evenly distributed. It is very important for an engineer to be

able to clearly identify the critical issues and focus on them and at the same time try not to miss important details. This is also applicable to other offshore installation projects.
For example, the tidal information for some offshore installation project may not be very critical. However, for the floatover project, the information is extremely important for the planning and procedure development related to the loadout and mating processes.

- Multidisciplinary
As the common cases, most engineers received deep and solid training focusing on one engineering discipline, say, structure, mechanics, etc. and build their strengths in the same discipline through working in the industry. However, when assigned as the supporting engineer at the installation site, he/she is expected to answer all the technical questions. Of course, sometimes the questions can be forwarded to onshore team for answer; even in this case to pass the question more accurately, the knowledge and comprehension of the problem play a very important role. The best approach is to build strength in relative disciplines and fully knowledgeable of the technical issues.
For example, a naval architect assigned aboard the floatover vessel, it is better for him/her to be familiar to the sea-fastening, grillage and fender system design. In the same way, if a structural engineer is knowledgeable on the ballasting planning, then he/she can provide assistance when needed. The two engineers can thus to provide more complete engineering supports.
- Principles
An engineer on the project shall follow all the procedures/working instruction in performing the design/analysis and on-site supporting. He/she should understand that all the developed and approved procedures have gone through thorough QA/QC by qualified project personnel. Small changes may lead to unexpected consequence and cause cost increase, time lost and even huge damages.
A good example is the ballasting plan developed for installation operations. All the ballasting/deballasting steps and the related data come from analyses repeated many times and optimized to meet the requirements by the operation criteria. The plan is quite comprehensive with many steps for operation, which sometimes looks not necessary intuitively in the eyes of persons lack of knowledge in naval architecture. However, one-step skipping may lead to a large list angle and even put the vessel in danger. Unfortunately, this happened in the real projects.
If there is the necessity of changes to be made, the engineer should follow the exact instructions put in the procedure of making changes.
- Communication skill
It should not be an issue for communication inside the engineering team for most of the cases, since their backgrounds are close; the thinking habits on technical topics and the technical language are the same. However, the terminologies onboard may sound very novel for an engineer first working with the

superintendents and crewmembers. Engineers should make conscious efforts to catch up and make the idea exchange hurdle disappear.

Also believe it or not, a lot of the engineers have the same habit or weakness, i.e. eager to bring in all the detailed information when starting the discussion on technical issues. This kind of communication often makes the audience lost in the overwhelming amount of information. The efforts need to be made to make their speech more concise and easily to be understood and followed by their audience.

- Continuously improvement

  In offshore operation, every project is "new" and cannot be carried out by copying accomplished projects. Application of the accumulated experiences is important but needs good judgements. After the accomplishment of each assigned task, serious "lessons learned" session should be gone through and documented for future reference.

  Some findings can lead to new technology development, e.g. the loading cases worked with and the structure/equipment design for the floatover installation helped in the development of the new concept vessel for topsides installation and decommissioning.

8.2 Categories of Engineering Work

8.2.1 Installation Criteria Set Up

In the early stage of the offshore platform EPCI projects, developing/selecting installation method is an important task. One related topic is the operability checking for the proposed method, which needs intensively engineering efforts in the installation equipment identification including vessels, the schedule/cost

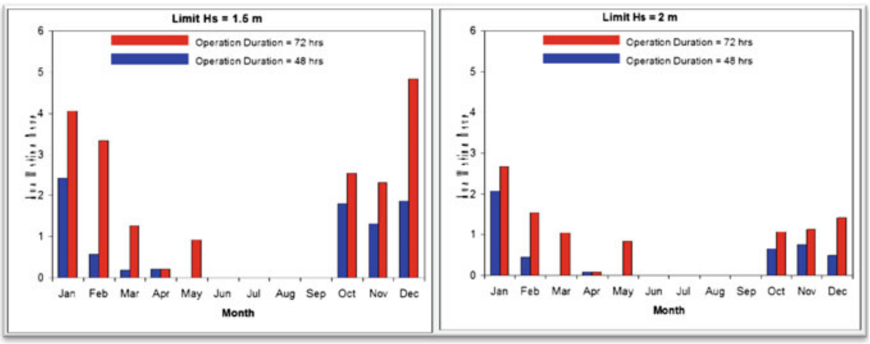

Fig. 8.1 Example of WOW

estimate as well as comparison with other options based on the available field and production system information.

When the method is selected, criteria for the operation and the equipment design should be set up based on engineering analysis and calculation. As for the criteria of operation, the WOW or operation weather window for each offshore operation campaign need to be defined.

From the illustration in Fig. 8.1, it can be seen that when the environment limitation is low (more conservative), the WOW will be long (plot on the left) for the same weather window width.

8.2.2 Analysis and Simulation Supporting Operation Procedure Development

To ensure the safety of operation, heavy engineering analysis and simulation need to be performed and the operation procedure is developed based on the analysis/simulation results. A typical example is the development of the topsides transportation procedure. The simulation of the marine operation along the transportation route leads to the details of the transportation procedure including the vessel outfitting, stability checking, towing tugs selection and shelter selection along the route, etc.

8.2.3 Floatover Equipment Design and Qualification

Floatover equipment design includes the design of skid-beam, grillage/sea-fastening, LMU, DSU, DSS, etc. They are designed or technically specified by the engineers. The dynamic design loads come from the motion simulation.

An engineer assigned on the design of a piece of specified equipment should always keep in mind that improper design of any part of a floatover equipment may cause disastrous consequences. In the case of Lufeng 7-2 DPP floatover accident, as the investigation results shown that the applied methodology concept should have no problem, but the design of the strand jack system for both the mating leg lowering and the topsides lifting had issues, which led to the failure of the floatover operation. The poor quality of the fender system caused the damage of the already installed jacket, which drew the concern of the structural integrity. These kinds of vivid lessons should always be remembered.

8.2.4 Emergency Handling

Engineers, especially senior leveled engineers should be well prepared for emergency handling. The most important for him/her is to be acquainted with the procedures relative to emergency handling. The capability of assisting damage control and resolve the problem is on the identification of the key technical issues and the resource including himself/herself. The bottom line is to provide solution as soon as practical. A lot times, there is no enough time to carry out comprehensive study by computers. Ability of hand calculation as well as referring to existing solutions from accomplished projects is vital for success.

8.2.5 On-Site Supporting

On-site engineering supporting is essential either for the operation or for the fabrication. After the operation working instructions are developed and issued, or the IFC (Issued for Construction) drawings and MTO (Material Take Off) issued, there are still quality and safety issues. Engineers who carried out the analysis and design should be on-site for critical activities to help make sure all the requirements to be satisfied. Sometimes new technical issues may appear and needs to be resolved at the site.

8.2.6 Model Test

Engineers on the project, in general, will not carry out the model tests, especially the transportation/floatover simulation test by themselves. Their responsibility is to develop the model test specifications for the institute with specialty. In the specification, the details of the goals of the model test should be addressed clearly and relative information should be included.

Related engineer should be at site for important model test activities. The data generated from model test will be analyzed and compared with the results derived from numerical analysis. Based on the comparison results, the analysis models will be calibrated and updated.

8.3 Engineering Work Quality Management

8.3.1 Analysis/Design Philosophy

In the industry, different from research work, engineering analysis/design is based on the probabilistic design to reduce the risk of failure to the lowest allowable level. It is not pursuing the "perfect" solutions. Since the time and budget are often limited, engineers should learn how to make balance between the quality/effectiveness and the cost. All the requirements from the regulatory rules and standards must be satisfied and improvement based on that is encouraged, but project schedule and cost effectiveness also are important goals to achieve.

8.3.2 DB (Design Basis)

At the beginning of the project, no matter what task is assigned, an engineer must first concentrate himself/herself on the efforts to fully understand the DB. All the requirements and necessary inputs must be included with correctness/accuracy assured. If the needed information is missing or inaccurate, immediately work out with the client to get the DB developed or updated. Only after the DB is approved, the analysis/design activities commence.

Any changes on the contents in the DB must be documented following through the change procedure. The corresponding information must be distributed to every relative personnel and the analysis/design work must be updated accordingly.

8.3.3 Analysis and Design Procedures

For each kind of engineering tasks, there should be an available corresponding cooperation leveled procedure available. If not, a procedure should be development under the guidance of the PEM.

The procedure main contents should include:

- The guideline of performing engineering analysis/design relative to the specified topic, including software, modeling, inputs, data processing, reports, etc.
- Related regulatory rules and guidelines
- QA/QC instructions
- Checking list including self-checking, disciplinary checking, inter-disciplinary checking.

Newly developed procedures should be reviewed and approved following relative document control procedure. Obsolete procedure should be put away.

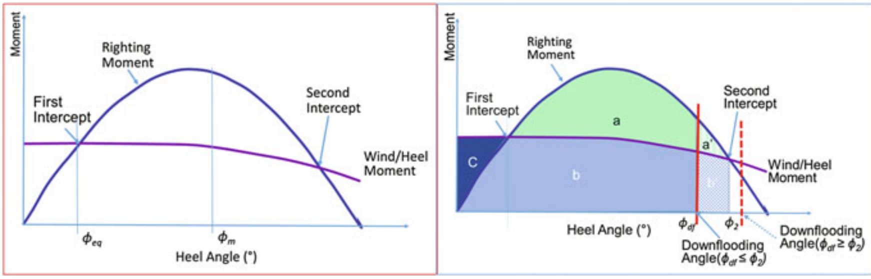

Fig. 8.2 Heeling moment/righting moment curves

8.3.4 Involvement in the Early Stage of the Project

Engineering work often plays important role in installation methodology development, which is closely related to the other parts of the EPCI. Therefore, early involvement of engineering will be beneficial to the whole project and beyond. Many times, the engineering analysis on the offshore installation related tasks could identify issues in the platform design. Earlier corrective action based on the analysis results leads to the reduction of time lost and cost.

Prompt communication between the engineering team and other groups in the project is beneficial to all parties.

8.4 Analysis and Simulation Work

8.4.1 Stability Analysis

Stability of vessels during loadout, transportation and floatover operations is an important marine safety issue. Stability analysis is not only the calculation and check of the GM (Metacentric Height) value, but also include the dynamic stability checking against certain stability criteria. Stability capacity of the transportation/floatover vessels together with the platform topsides onboard must meet the criteria set by the project selected regulatory organization. The concrete provisions may vary, but they represent similar standards. The following is an example of the criteria by DNV on intact transportation stability of the loaded transportation barge. It consists of three (3) indices (refer to Fig. 8.2):

- GM $\geq$ 1.0 m
- Positive righting arm range $\Delta\phi = (\phi_m - \phi_{eq}) \geq 36^\circ$ (see the left graph in Fig. 8.2)

With $\Delta\phi = 20 + 0.8\phi_{\max}$ calculated based on the design environmental condition. In it, $\phi_{\max}$ is the sum of the maximum dynamic heal angle induced by the wave and the static inclination angle from the design wave. Obviously motion simulation of the loaded vessel need to be performed.

- Area ratio

$$R_A \geq 1.4$$

Where the definition of R_A being as the following:

$$R_A = \frac{A + C}{B + C}$$

The three (3) related areas are defined in the following referring to the right graph in Fig. 8.2.

$$A = \begin{Bmatrix} a & for & \phi_{df} < \phi_2 \\ a + a' & for & \phi_{df} \geq \phi_2 \end{Bmatrix} \quad \text{in green;}$$

$$B = \begin{Bmatrix} b & for \phi_{df} < \phi_2 \\ b + b' & for \phi_{df} \geq \phi_2 \end{Bmatrix} \quad \text{in light blue;}$$

$$C: \quad \text{area in dark blue;}$$

with ϕ_{df} being the downflooding angle which can be either less than the second interception angle ϕ_2 as indicated by the solid red line or no less than ϕ_2 as shown by the dashed red line;

Damaged criteria also needed to be established correspondingly. Details of stability criteria can be found in the relative regulatory documents.

The stability analysis report has to be issued and approved by the MWS before the vessel sails away or the commencement of the operation. Both intact and damaged stability capacities are verified to meet the requirements by the established criteria.

8.4.2 Transportation Motion Simulation and Hydrodynamic Load Calculation

The simulation and calculation are based on the hydrodynamic analysis of the loaded transportation/floatover vessel using wave radiation-diffraction program such as WAMIT, WADAM, HYDROSTAR, etc. To perform the hydrodynamic analysis, a mesh model of the submerged hull of the vessel is created and the viscous damping effects are also considered in the modeling. In the analysis, the forward speed of the vessel is generally not included (Fig. 8.3).

The analysis should cover all the wave incident directions in the horizontal plane. Generally, five (5) directions (0°, 45°, 90°, 135°, 180°) or nine (9) directions (0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5°, 180°) are considered, because of the symmetric characters of the vessel. The frequency dependent motion transfer functions can be shown as the RAO (Respond Amplitude Operator) curves depicting the six (6) DOF (Degree of Freedom) motion response of the vessel as a rigid body corresponding to the regular wave. The RAO curves of a typical transportation vessel are shown in Fig. 8.4.

The accuracy of the transfer function elements is critical, which is directly dependent on not only the mesh model of the submerged hull but also the mass distribution of the system formed by the vessel, the topsides as well as the grillages and sea-fastenings.

The hydrodynamic analysis results will be used as the inputs for motion simulation, air-gap analysis, dynamic stability study, weather window identification, mooring system design, vessel/topsides integrity checking as well as loading estimate for floatover equipment design.

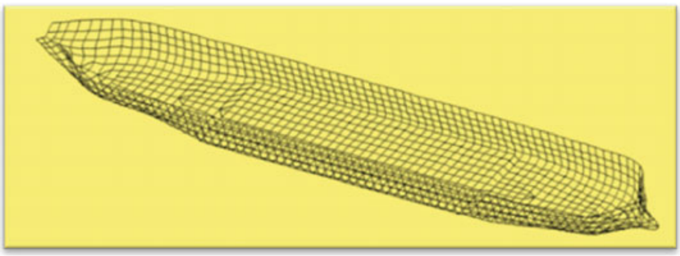

Fig. 8.3 An example of vessel hull mesh model for hydrodynamic analysis

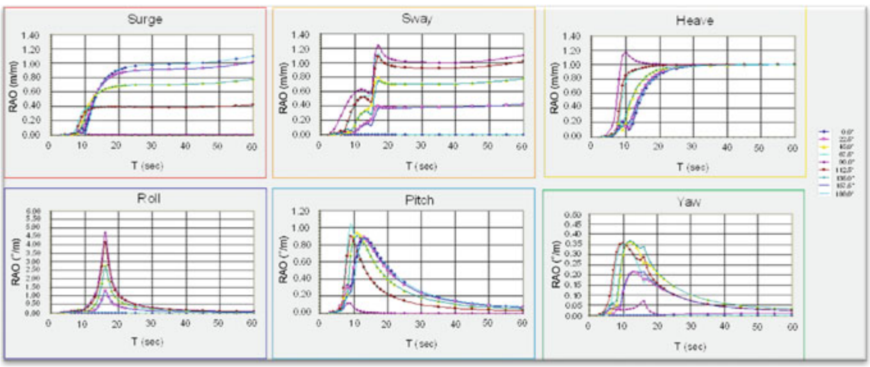

Fig. 8.4 RAO samples

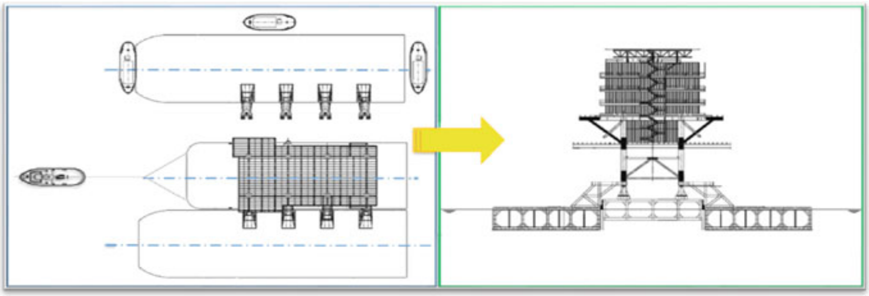

Fig. 8.5 Topsides transfer operation

The motion simulation can be performed in both time domain and frequency domain by applying the design environment conditions including wave, wind and current in each identified direction to find the extreme values of motion speeds and acceleration values at COG or specified spots at the system. For example, when carry out the mating process information, the motion speeds and accelerations at the tips of the mating cones are of great interest.

8.4.3 Topsides Transfer Simulation and Catamaran System Transportation

8.4.3.1 Topsides Transfer

As discussed in the earlier chapters, the operation activities of the catamaran floatover are more complicated and more challenging comparing to the single vessel floatover, because more vessels are involved and there is one extra step of topsides transfer for most of the cases. During the topsides transfer operation, three floating structures are side-by-side exposing to the offshore environments. Relative motions and induced response loads on various structures and transmitted to the topsides have direct impact to the structural design and the operation criteria setting-up. Especially for the situation when topsides was originally designed for lifting installation but later changed to the floatover, rigging design and topsides structural integrity verification all need the relative load estimation.

As shown in Fig. 8.5, the operation of the topsides transfer is carried out at the selected site with limited seastate environments. When the transportation vessel with the topsides arrives, the two (2)-floatover vessels will be moved close to the transportation vessel one by one on each side of it and parallel positioned. The hook up of the supporting structures on the floatover vessels are properly connected to the topsides mating legs in the illustrated example. Environment induced motions of all three (3) vessels will create loads on the supporting structures and the topsides. To catch the extreme values of motion and loading as well as the history, time domain multi-body motion simulation need to be performed.

The simulation is divided into two (2) steps:

- The hydrodynamic analysis using potential theory to identify the hydrodynamic characteristics such as nature period, added mass, damping coefficients, etc. for the system consists of the vessels and the topsides.
- Conducting the time domain motion simulation of the system with the analysis model established based on the physical and hydrodynamic properties.

For hydrodynamic analysis, the challenges include the possible inaccuracy caused by the small gaps between the barges and the irregular frequency phenomenon. Engineers should be clear about these issues and select software capable of handling these issues and carefully set up the proper analysis model accordingly.

When there is small gap between the side-by-side vessels, then resonant interactions between the two hulls can occur, similar to pumping modes in moonpools. With the linear potential theory, the amplitude of the resonances is generally over-predicted and inaccurate RAO values are generated. Simulation based on these values leads to unrealistic motion and load estimates. Software such as WAMIT, ANSIS, etc. can handle this issue by applying various kinds of gap surface lid approaches and generate reasonably accurate RAO values. These software can also help to remove irregular frequencies. Readers interested in theoretical discussions can find related literatures easily.

To perform the time domain motion simulation, enough environmental cases need to be defined including the (H_s, T_p) and wave direction. In the earlier stage of the installation method development, the design of the supporting structures, their arrangement on the floatover vessel and the corresponding grillages and sea-fastening structures are not finalized, sometimes, the vessels are not decided. Under these situation, options of the supporting structures should also be considered by adding corresponding cases.

8.4.3.2 Towing of Catamaran System

After the transfer of the topsides from the transportation vessel to the floatover vessels and the completion of the outfitting, the catamaran system is ready to be towed to the platform integration site. To make the towing operation safe, transportation analysis is to be carried out before the commencement of the operation. The catamaran system transportation simulation is more complicated and more challenging comparing to the single vessel topsides transportation, since the two (2)-floatover vessels cannot be taken as a single rigid body.

As illustrated in Fig. 8.6, under the environments, here mainly the waves, there are several kinds of the relative motions possible occurring on the two (2) vessels and in turn the motions will create loads on the topsides supporting structure and the topsides supporting legs and then transmitted to and distributed in the topsides structures. The values of the loads have direct impacts on both the topsides structure design as well as the design of the supporting structure and grillage/sea-fastening design. It is also related to the relative operation criteria development.

As illustrated in Fig. 8.6, the relative motions between the two (2) vessels can be divided into squeezing, splitting, bending and racking. The motions induced by the environments, mainly the waves here, will create forces/moments at the topsides supporting structures on the floatover vessels and the topsides supporting legs which will be transmitted to and distributed in the topsides structures.

The analysis results should be compared to the model test results and through the calibration of the analysis model, dependable analysis results can be generated so that adequate structural and equipment design will be assured.

8.4.4 Floatover Simulation [2–4]

In this section, the discussion is focused on how to conduct floatover simulation including how to divide the operation into stages, the analysis model setting up for each operation stage, the basics of time domain analysis, etc. Since the numerical analysis approach is the same as the common practice in offshore industry, the analysis details are not covered here. Interested readers can find relative information in published literatures.

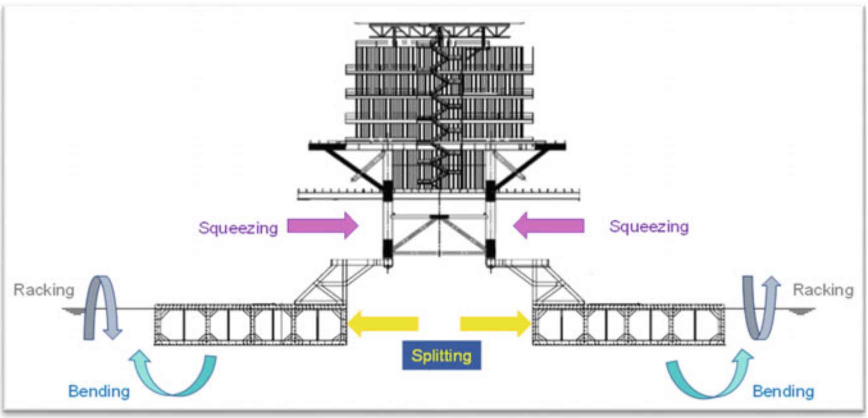

Fig. 8.6 Illustration of relative motions of the two floatover vessels

8.4.4.1 General Consideration

The floatover simulation or the docking/mating simulation is essential for developing a safe and effective floatover operation plan and procedure. The workload is also the heaviest and most challenging among all the engineering tasks. The docking/mating operation duration ideally is quite short, but the relative position between the floatover vessel(s) with the topsides and the pre-installed jacket keeps changing. Motion caused contacts and the induced loads between the vessel(s) and the jacket legs and between the LMU elements are the most concern. To catch the details of the operation, time domain nonlinear analysis is preferred in order to monitor the motion and corresponding loads created on the involved structures to identify the extreme values. However, in reality the relative position of the vessel to the jackets varies starting from the docking process until the premating stage and the vessel draught, ballast and topsides weight transfer change continuously after the commencement of the mating process. Therefore, to carry out a continuing time domain analysis, the analysis model itself needs to update continuously, which is unpractical. In practice, the floatover operation process or the docking/mating operation process is divided in the following operational stages and the simulation/analysis is carried out for each stage with an unchanged system model and corresponding boundary conditions:

- Docking stage with the floatover vessel moving into the entrance between the jacket legs until the platform topsides and the jacket being aligned. In this stage, the focus is on the horizontal loads created by the contacts between the vessel and the jacket legs.

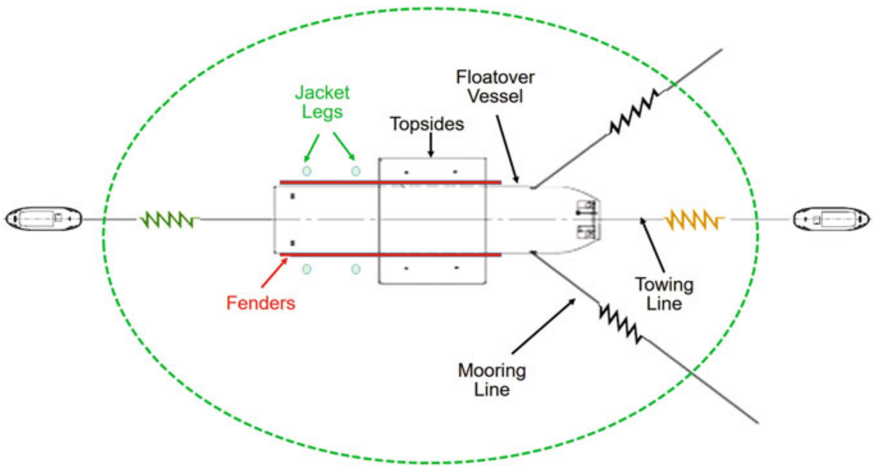

Fig. 8.7 Analysis model for docking stage simulation

- Pre-mating stage with topsides is aligned with the jacket legs but prior to the engagement between the mating cone tips and the jacket leg tops. At this stage, the vertical motion induced by the environments is the focus.
- Mating and load transfer which is divided into three (3) sub-stages:
  - 0% load transfer stage: initial contact between the mating cone tip and the LMU without vertical load transfer, the main focus is the simulation of the relative motion and the contacting load.
  - 50% load transfer stage with 50% of the topsides weight transferred from the floatover vessel to the jacket legs.
  - 100% load transfer stage with the topsides weight completely being transferred from the floatover vessel to the jacket.
- Post-mating stage with the floatover vessel being separated and off touch with the bottom of the topside. The simulation of the vessel motion between the jacket legs is the focus at this stage.
- Vessel withdrawal stage, which is the opposite inversed, the inversed process of the docking stage.

8.4.4.2 Analysis Modeling

- Docking stage
  During the docking stage, when the floatover vessel moves in the slot between the two rows of the jacket legs, there will be various possible scenarios for the contact between the floatover vessel hull and the jacket legs. For example, one scenario is that the port side fenders of the vessel touch the two (2) jacket legs; another may be that only one (1) jacket leg is touched by the starboard side

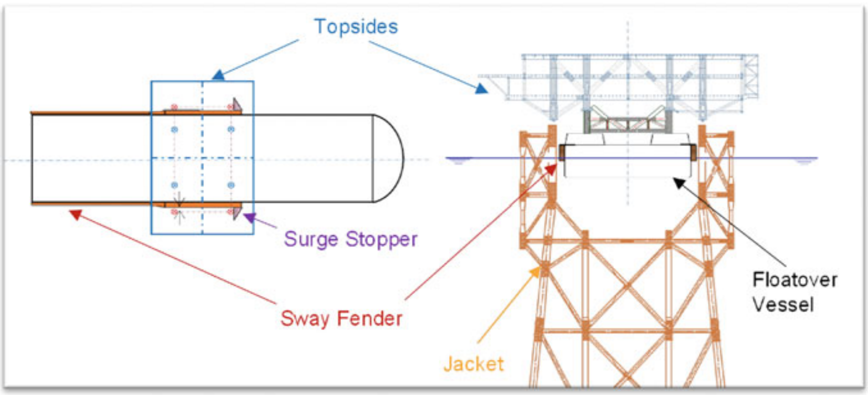

Fig. 8.8 Pre-mating/mating process illustration

fenders; or it may be that one (1) leg of each side of the jacket is touched by the port/starboard side fenders respectively, etc. Cases need to be studied should be identified before the analysis starts.
In Fig. 8.7, the analysis model for docking stage simulation is illustrated. The structures and bodies inside the green dash line circle are the elements included in the analysis model including their geometries and properties:

- The vessel hull position with its dimension
- The mass properties and hydrodynamic properties of the floatover vessel loaded with the topsides
- The stiffness of the jacket legs
- The stiffness of the mooring lines and towing lines
- Fender friction coefficient and hysteresis damping of sway fenders (Fig. 8.8).

- Pre-mating stage
  At this stage, the analysis model includes the same components as the model used in the docking stage, but parameters need to be adjusted:
  - The static gap between the jacket legs and the sway fenders of the floatover vessel should be defined clearly
  - Gap between the mating cone tips and the top of corresponding legs should be specified
  - Surge fender should be included in the model
  - Mooring lines may be changed to the mating lines and the corresponding information including the stiffness value should be updated
  - The towing line properties most likely need to be updated.
- Mating stage
  - The draft of the floatover vessel together with the topsides at 50% load transfer need to be calculated based on the available stiffness information of the LMU
  - For the three sub-cases, the vessel mass properties and hydrodynamic properties need to be updated for each case
  - LMU stiffness and damping need to be included
  - The equilibrium loading conditions of the vessel and the jacket legs for each sub-case need to be updated
  - The modeling of the DSU stiffness for three (3) sub-cases should be different and the analysis models need to be adjusted accordingly.
- Vessel withdrawal stage
  - Base on the requested minimum gap between the top of DSU and the bottom of the topsides, the draft of the floatover vessel is determined
  - The vessel is completed separated from the topsides and the mass property as well as the hydrodynamic properties need to be modified
  - Surge and sway fenders and the towing line are included in the model and the corresponding data need to be updated.

8.4.4.3 Analysis Method

The motion simulation of the vessel together with the carried topsides is performed in the time domain, and the analyses cover all the defined directions of the environment. The most important environmental factor is the wave/swell. To perform the analysis, the following should be kept in mind:

- Analysis duration
  To ensure the analysis to be able to catch the extreme response properly, the recommended simulation period is suggested to be at least two (2) times the predicted exposure time. For floatover operations, 1.5 h should be conservative in general.
- Time series
  Random wave time series is generated from the selected wave spectrum. Not only the series length, but also the statistical quality of the wave data is very important. For the floatover operation, the wave spectrum with Rayleigh distribution is assumed. For each generated wave time series, the data should be checked by the Weibull distribution fitting. Unqualified time series leads to the "garbage-in-garbage-out" analysis.
  Generally, three (3) to five (5) time series are generated for each simulation case to use.
- Time step
  The motion simulation in discussion is non-linear time domain analysis, of which the stability and accuracy of the analysis are quite sensitive to the size of the time steps. The size of the time step may be selected based on the calibration with available model test data. One example is to choose 2^{16} time steps for a 1.5-hour simulation and leads to the time step of 0.0824 s.
- Tidal information
  Tidal information is important for the simulation of docking/mating stage and vessel withdrawal stage. The information should be accurately chosen for the analysis.
- Extreme values
  The time series of motion and load as the output of the analysis will go through the Weibull curve fitting to identify the extreme values of the motion and loads.

8.4.4.4 Analysis Software

Software such as SIMO and MOSES can be used for the simulation analysis. These software have been benchmarked by the model tests and were used in the past projects. If use SIMO, for each selected case, the hydrodynamic coefficients and wave forces calculated by WADAM can be directly input to the simulation model. When SIMO is used for the mating process simulation, it's capable of handling dependency of the LMU horizontal spring stiffness on the vertical gap between the mating cone and the receptor. This is quite important for the initial touch simulation in the 0% load transfer stage.

The simulation is quite comprehensive. To handle the data processing, model generating, special developed software routines can improve the analysis effectiveness.

8.4.4.5 Limiting Sea-State

The results of the motion simulation are used as the inputs to structural analysis to check the structural integrity of the topsides and the floatover vessel. The results are also used for the grillage, sea-fastening and other floatover related equipment design, such as the LMU design or technical specification.

The other purpose with importance of the floatover simulation is to find the limiting sea-states for each stage of the floatover operation. This is an iterative process with the metocean data provided in the DB. The basic idea is that for a specific floatover operation under the assumed sea-state, the analysis will provide the maximum loads on the concerned structures, which are compared to the allowable value specified in the DB and the equipment design.

The sea-states or the random wave is represented by the statistical values of the significant wave height H_s and the corresponding peak wave period T_P in pairs. For floatover operation, generally a few values of T_P are selected to cover both wave and swell as the inputs and through the analysis to identify the maximum corresponding H_s value. After the analyses have been carried out covering all the possible cases, the limiting H_s values are identified corresponding to the specified T_P values.

The final results will be used in the weather window identification and the floatover operation procedure development. In Fig. 8.9, the plots present an

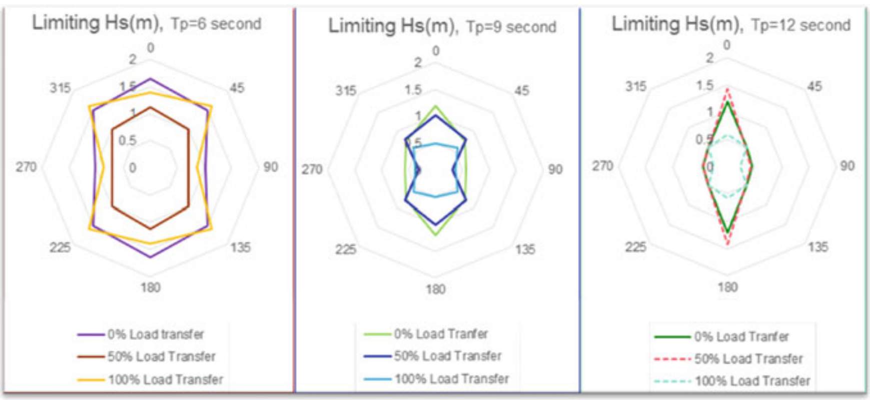

Fig. 8.9 Limiting H_s value results

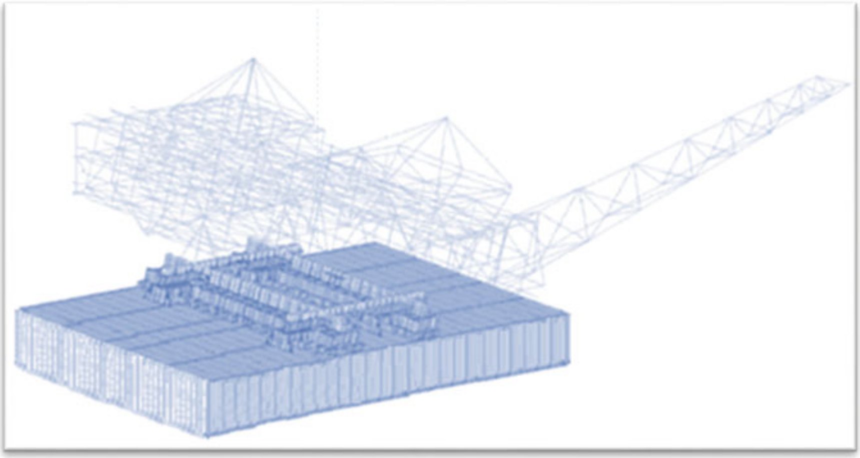

Fig. 8.10 Topsides structural integrity checking analysis model

example of the limiting H_s value analysis results. Three values of T_P are selected: 6, 9 and 12 s. The simulation covers the stages of 0, 50 and 100% load transfer during the topsides/jacket mating process.

From the contours in the plots, is shows clearly that the operation is controlled by the beam sea and the wave with $T_P = 12$ seconds possessing the lowest H_s limiting value, which is consistent to the practical situations. The plots can be used for mating operation weather window identification when the orientation of the jacket is already decided, otherwise it can also be used as one of the factors in deciding the platform orientation.

8.5 Structural Analyses

There are several important structural analyses to be performed in the floatover operation such as the vessel hull global strength analysis, local strengths checking, topsides integrity checking, and the global structural analysis for the DSS, grillage and sea-fastening analysis under different kinds of loading conditions. In the following, the global structural analysis and the topsides integrity checking are briefly discussed.

8.5.1 Global Structural Analysis

The so called global structural analysis is actually serve the purpose of the structural integrity checking of the DSS. The design of DSS will be discussed later. Three

(3) loading conditions are considered in the DSS design: the loadout condition, the transportation condition and the floatover operation condition.

For the loadout loading condition, the analysis model comprises the DSS and the topsides on it. For transportation condition and floatover operation condition, the global structural analysis model includes the FE (Finite Element) model of the DSS, grillage and the sea-fastening with the topsides structural model as a super element as well as a section of the vessel hull as shown in Fig. 8.10. At both ends of the transportation/floatover vessel, linear constraints are introduced to incorporate beam element behavior representing the vessel hull global characteristics. Springs to ground (water plane area) are added to the hull at the bottom surface and to the beam elements to account for the change in buoyancy and to compensate the inaccuracies of the chosen method.

For different loading conditions, the model, the boundary conditions and the applied loads are different. The relevant loads including gravity loads, inertia forces due to accelerations, pressure loads, prescribed displacements as well as concentrated forces and moments are to be applied to the model for the analysis. The governing loads of the DSS design are discussed later in the DSS design section.

The analysis approach can be considered as "quasi static" in the sense that the extreme reaction values are derived from the combination of the results from "stillwater" analysis and the wave analysis.

- The "still-water" analysis to calculate the "still-water reactions" of the topsides by applying the topsides weights
- The wave analysis with applying six (6) equilibrium sets of unit inertia loads and assumed hydrodynamic pressures.

The wave analysis go through all the critical directions, typically the beam sea induces the highest reaction.

Among the three loading conditions, the transportation loading condition takes a large part of workload. The dynamic loads in the floatover operation within the selected weather window are considerably less than those in the transport condition, therefore the floatover installation condition is not considered the governing condition for DSS design. Often, the installation condition is evaluated based on the results of the transportation condition.

8.5.2 Topsides Integrity Checking

One of the important engineering analysis tasks is to check the structural integrity of the platform topsides to see whether its elements are strong enough to withstand all the extreme loads going through each stage of the floatover operation.

If the topsides installation method is altered to the floatover after the topsides design is completed, this analysis is extremely critical. The analysis results will be the basis of the topsides modification. This is also applied to the jacket modification in many cases.

When floatover is chosen as the platform integration method at the beginning of the platform development, this issue should be addressed thoroughly during the topsides design. However, before the offshore installation starts, analyses are still carried out to verify the integrity of the main structural members of the topsides.

The topsides structural model comprises beam members and nodes with properly modeled mass distribution. Beside the static loads from the weights of the structural member themselves and the equipment on the topsides, dynamic loads from environments are also transmitted to the topsides. The analyses will go through the cases covering each wave heading for the 0, 50 and 100% load transferring conditions to calculate the reaction forces at the LMU supporting spots and the temporary supporting spots of the topsides from the input loads.

The calculated reaction forces will be added to the structural integrity checking model to verify the members under the mating load transfer conditions. Generally, the maximum stresses will be governing.

8.6 Design Work [5]

In this section, the discussion is on the structural designs related to floatover operation. As the examples, the DSS design, the sea-fastening design and the LMU design are discussed.

8.6.1 DSS (DSF) Design

8.6.1.1 DSS Functions and Design Consideration

The DSS is a purpose-built steel structure to support the integrated topsides during the operations from the loadout to the completion of the mating of the topsides and the jacket. As aforementioned, the DSS is an important supporting structure used in the HIDECK floatover method. It is combined with the skid beam and DSU such as sand jacks or hydraulic jacks to provide the required height and the weight supporting. The DSS can be designed portable for reuse when there are multiple floatover installations being involved (Fig. 8.11).

The loads which the DSS expects to experience during the operation phases of loadout, transportation and floatover under the corresponding design considerations are described briefly in the following:

Fig. 8.11 The DSF designed for Angel platform topsides transportation is much higher comparing to other projects (courtesy to Woodside Angel project)

- Loadout
  The completely integrated topsides is lifted from its temporary fabrication/assembly supports at the loadout site and sit on the top of the DSS. During loadout, the DSS will distribute the topsides load over the maximal length of the skid beam in order to reduce the loads so that minimum vessel deck reinforcement is needed.
  After the topsides weight being transferred to the DSS, the upper level sea-fastening structures are in place to secure the topsides. The DSS with the topsides is skidded out onto the transportation/floatover vessel at the quay. The DSS design should consider the locations of the temporary supporting spots at the bottom of the topsides with the optimized load distribution in the topsides structures as well as the structural integrity of each DSS unit.
- Transportation
  After being skidded onto the transportation/floatover vessel deck and sitting on the skid-beam onboard supported by the grillages, the DSS together with the topsides is sea-fastened on to the vessel upper deck. The function of the DSS is not only to support the weight of the topsides but also to properly transmit the dynamic loads induced by the environments to the vessel. Therefore, environmental induced motion and loading need to be considered.
- Floatover operation

During the mating process, the contacts between the stabbing cone and the LMU is inevitable. The DSS should be designed to be able to accommodate the effect of impact loads, so that the mating operation goes smoothly.

8.6.1.2 Industry Standards Applied to DSS Design

The design of the DSS, grillage and sea-fastening is carried out to meet the safety and design requirements stipulated in the industry standards such as:

- Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms, API RP 2A, The American Petroleum Institute
- Specification for the design, Fabrication, and Erection of Structural Steel for Buildings, the Allowable Stress Design and Plastic Design, The American Institute of Steel Construction
- DNV Rules for Planning and Execution of Marine Operations.

8.6.1.3 Design Load Categories and Design Criteria

For each of the three (3) mentioned operational phases: loadout, transportation and floatover (docking & mating), the corresponding load categories applied to the design and design criteria are established and briefly summarized below:

- Loadout
  - Environmental conditions include

    average reference wind speed $\overline{V_w}$
    maximum significant wave height H_s

  - Applicable design loads include

    Topsides weight W
    Wind force F_{wind}, wave load F_{wav} and current load F_c
    Skidding related loads $\sum f_i$ including pulling/push loads, frictional loads, loads from uneven (skew) skidding, etc.
    F_v: loads caused by the vessel inaccurate ballast compensation

  - Skidding arrangement and tolerances
    The detailed skidding arrangement is specified including the quay elevation, the skidding surface height above the quay, the skid shoe arrangement. For the distance between the skid beams and the skidding surface height, the tolerances are also specified clearly.
  - Operational restrictions includes the maximum skidding speed and the coordination with the vessel ballasting

- Transportation
  - Environmental conditions
    Depends on the sailing route selected and the operation time, e.g. the worst case 10 year return period monthly data along the sailing route can be used for the design.
  - Applicable design loads include

    Topsides weight W
    Wind force F_{wind}, wave load F_{wav} and current load F_c
    Sea-fastening loads
    Loads due to flooded tanks of the transportation vessel

- Floatover operation
  - Environmental conditions include

    average reference wind speed $\overline{V_w}$
    maximum significant wave height H_s and maximum current speed V_c

    The related specifications are defined clearly in the selected operation weather window.
  - Applicable design loads include

    Topsides weight W
    Wind force F_{wind}, wave load F_{wav} and current load F_c
    Impact loads at DSS
    Sea-fastening loads
    Fender loads.

  - Clearances and tolerances requirements are consistent to the values in the docking/mating simulation.
  - Operational restrictions
    The sea-fastening between the DSS and the topsides are to be released in two (2) steps:

    Upper sea-fastening is partially removed prior to the docking
    Lower sea-fastening is released after the sufficient weight of the topsides has been transferred to the jacket.

8.6.1.4 Design Checking

The designed DSS will be checked for its function and integrity through the global structural analysis discussed earlier and the local FE analysis. When elements and areas with high usage level are identified, detailed checks will be performed against the selected industrial standards issued by e.g., API, DNV, ISO.

Grillage, sea-fastening and fender designs are also very important to the success of the floatover operation. The design principles are the same to the corresponding designs in maritime operations, especially the long voyage transportation. Design details can be found in related structural design literature.

8.6.2 LMU [6]

LMU is well known as one of the most important and complicated equipment assisting the floatover operation at the docking/mating stage when using conventional floatover methods, both HIDECK and UNIDECK. The main function of the LMU is to capture the stabbing cone as the gap between topsides and the top of the substructure being reduced. The position of the floatover vessel and the watch circle of each stabbing cone are controlled during the mating operation so that the moving watch circles of the stabbing cones will not fall off the receiver cup. Therefore, geometrically, the LMU design is directly relative to the mating operation motion criteria and the operation weather window. The LMU is also designed to be able to:

- Reduce vertical and lateral impact loads between the topsides mating columns and jacket legs at the early stages of the load transfer in the mating process
- Provide horizontal and vertical flexibility in the connection between jacket legs and the topsides during the load transfer at mating stage
- Ensure the steel-to-steel contact between the topsides column flange and the jacket leg at the completion of mating operation.

A typical LMU concept is illustrated in Fig. 8.12. The opening of the stabbing cone receiver is properly dimensioned to capture the corresponding stabbing cone at the early mating stage. The steel housing and the structures are sturdy enough to accommodate the loads during the mating operation. The stroke of the piston is designed to ensure the steel-to-steel contact at the completion of topsides load transfer. The elastomeric unit in the vertical direction and the elastomeric ring in the horizontal direction realize the impact energy absorption. Obviously, the LMU design and fabrication are very demanding technologically. Therefore, in industrial practice, most installation contractors will not design LMU by their own project team. The assigned engineers will develop the specification of the LMU design, fabrication and test. A brief discussion of the LMU design specification is in the following:

- Design code and standards:
  Design code and standards are proposed for the fabricator to be used in the design, fabrication and testing, for example:
  - Euronorm/ASTM codes for specification of steel plate components
  - ISO codes for rubber components testing

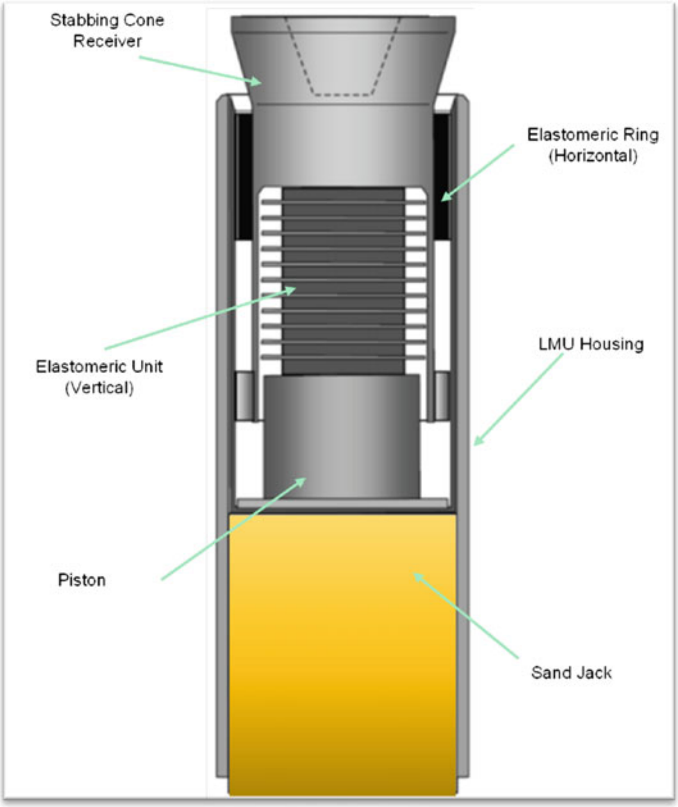

Fig. 8.12 An exemplary LMU design (based on vendor brochures)

If the fabricator suggests alternative industrial codes, the change need to be approved by the project management.

- Dimension constraints:
  - Vertical stoke mm
  - Horizontal compression distance mm
  - Overall housing height mm
  - Overall housing diameter mm
  - Overall diameter of stabbing cone receiver mm
  - Piston diameter mm
- Elastomer components related
  - Unless the EU (Elastomer Unit)/ER (Elastomer Ring) are from standard catalogue, the quality/competency of the EU/ER designing personnel need to be verified by the project management. The knowledge and experiences of elastomer component design is the key.

– Working environment

  Ambient temperature of the field during the installation period
  Dynamic loading frequency and the acting duration which is closely related to the hysteresis induced thermal effects on the elastomer physical characteristics

– The Creep of the EU under the maximum continuous loads for specified holding hours should not exceed a defined value, say 30 mm.
– LMU design concept, which mainly involves the arrangement of the EU/ER in the LMU, is proposed schematically. The fabricator can modify it with the agreement from the project management. Related information includes:

  The EU is confined vertically by the top and bottom supports and laterally by the steel housing. The top and bottom supports can slide along the axis of the elastomer to compress the EU and the housing wall provides lateral stability of the EU.
  A specified nominal annular clearance between the EU and the steel housing wall need to be assured so that there is no jamming caused by sliding motion.
  The ER limits the relative lateral translation and rotation of the EU induced by the compress.

– Load/deflection characteristics
  The load/deflection characteristics of the EU and ER are specified through load/deflection curves, based on the analysis and model test.

In Fig. 8.13, EU load/deflection curves as well as the ER load/deflection curves are put together for an LMU specification, which show the different requirements for the properties of the elastomeric components in vertical direction and horizontal direction. In the real projects, the two group of curves are presented separately with curve fitting data.
One thing needs to notice is that because the topsides weight is not evenly distributed among all the mating columns, loading conditions for individual LMUs during the mating process often vary. Therefore, it is common to find that several different LMUs are designed and fabricated for one platform, and more than one group of load-deflection curves need to be created.
The load-deflection curve is created based on the results from the model tests and the installation analyses.

- Verification test requirements
  The elastomeric properties of the designed LMU need to be verified by tests. Two kinds of tests: the scale model test and the prototype test can be considered (Fig. 8.14).
  The reduced scale model test is typically applied to the assembled unit for the verification of the global behavior, the load-deflection curves as well as the stability. The prototype tests are used to check all elastomeric elements to see whether the load/deflection curve falls in the required range in the design

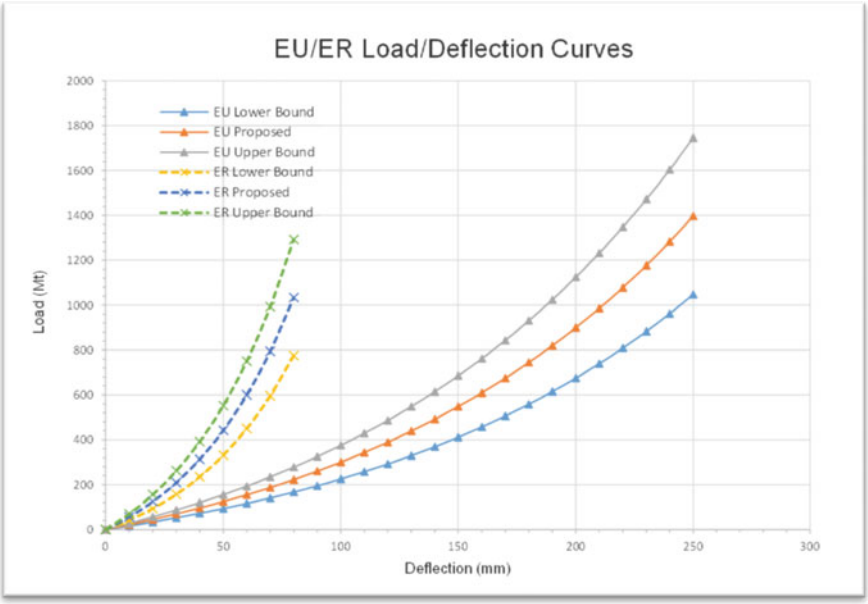

Fig. 8.13 Illustration of EU/ER load/deflection characteristics by specified curves. In real projects, the two group of curves will be presented separately with detailed curve fitting data

specification. Some details of the test such as the test compression loads for each planned test, need to be included in the specification.

The tests are conducted by using the test facilities with capacities of high compression loads. The fabricators should provide the test program for the project management to approve. For reduced scale test, the scale ratio value need to be agreed. Without the test results showing the satisfaction, the LMU cannot be installed onto the jackets.

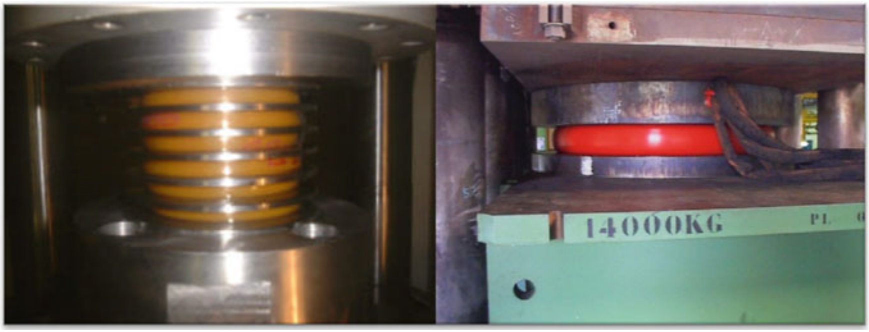

Fig. 8.14 Elastomeric load/deflection characteristics tests. On the *left* is the reduced scale test and on the *right* is the prototype test (credit to Bayu Undan project)

- The information of LMU exposedness
  As is well-known, that the LMUs are installed on the top of the jacket legs long before the commencement of the floatover operation. During this period, the LMUs are directly exposed to the offshore field environments. The related information should be specified, so that the fabricators can provide a protection system to the installed LMUs.

8.7 Model Test for Transportation and Floatover Operation

As discussed earlier, intensive motion simulation and loading calculation by computer are necessary for floatover operability and design criteria establishment. However, the numerical simulation has its own limit stemmed from modeling, inputs and calculation approaches. The most important analysis results often need to be verified by properly conducted model tests. The specialty institute with well-equipped facilities will conduct model tests and the model test specifications are developed by the project.

8.7.1 Main Contents of Model Test Specification

In a model test specification document, the following contents are considered important and should be included:

- The purpose of the model tests
  The purpose of the model tests should be explicitly depicted, although it is almost certain to be "to confirm and verify the analytical predictions on the cases most critical and/or most important to supplement the numerical analyses".
- SOW
  List the model tests need to be conducted, such as offshore transportation, pre-mating operation, mating operation, etc., and the planned cases for each kind of tests.
- Physical models
  - Model scale
    The model scale is determined by the transportation/floatover vessel. The model scales of the topsides and the jacket are consistent to the selected model scale of the vessel.
    Because of either of the transportation or the floatover operation being conducted in the specified weather window, the simulated seastates in the basin are limited. To catch the hydrodynamics and the induced motion, the

model scale cannot be too large and should not exceed 1:50. Otherwise, it would be very difficult for a basin to create the proper waves.

– Model details

△ Vessel hull

The vessel hull is to be modelled according to the design offset-table. The model is a watertight rigid body with accurate grillage & sea-fastening on the deck. The forecastle and superstructure are included for representative visualization purposes (Fig. 8.15).

Model load/ballast condition should be easily adjusted to fit the needs of a specific case.

△ Fenders

Fenders mounted on the vessel hull, both soft and hard, need to be included with proper stiffnesses matching the real arrangement. Generally, the 1.0 m nominal clearance between the jacket leg and vessel hull need to be kept during the floatover simulation at the pre-mating stage. Fenders to act in compression only.

△ Mooring/mating lines

To simulate the offshore transportation phase, the soft catenary mooring system is included, which will not affect the vessel's 1st order motion characteristics.

To conduct the floatover operation simulation, the catenary mooring lines are not necessary to model and only the mating lines, both spring and breast lines, are included because their stiffness play the dominate role in the process. The proper stiffness for each line should be realized. Also the mating lines can be easily adjusted to ensure the topsides position to be accurate during the test.

Each mating line is also instrumented for tension measurements.

△ Topsides

The model of the topsides is a rigid body with the dimensional similarity and the accurate weight, COG and inertia properties. The adequate details of the cellar deck and weight supporting structure should be included, but the main deck equipment is only included for visualization (Fig. 8.15).

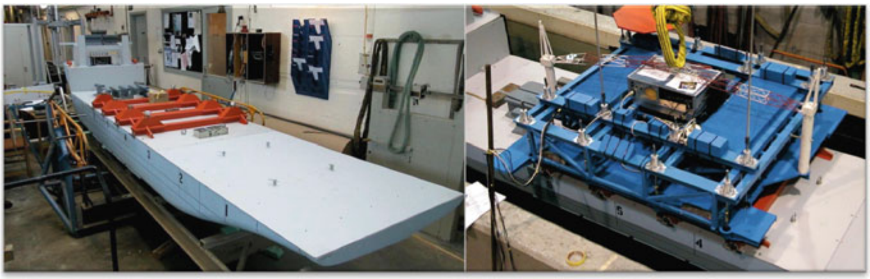

Fig. 8.15 Model of vessel and topsides for Bayu Undan project (credit to Bayu Undan Project)

△ Jacket

The details of the jacket legs from the first plan bracing beneath the free surface to the leg tops including fendering, mating line points, framing and bracing are accurately modeled. Below the first plan bracing elevation, the structure is simplified but with enough strength to support. Simplified level of detail below the first plan bracing level is acceptable (Fig. 8.16).

At the top of each leg, an LMU model with adequate stiffness is accurately modeled and the instrument of load measurements is also included.

- Coordinate system
  The coordinate system fixed on the transportation/floatover vessel is defined consistent to the coordinate system used in the simulation analysis.
- Environment specification
  Environmental cases for transportation test and floatover operation test should be specified in cases of waves and swells. The wave spectra should be defined by the spectra formula and the corresponding parameters such as the significant wave height H_s and the corresponding peak period T_p. Quite often, the JONSWOP spectrum is chosen.

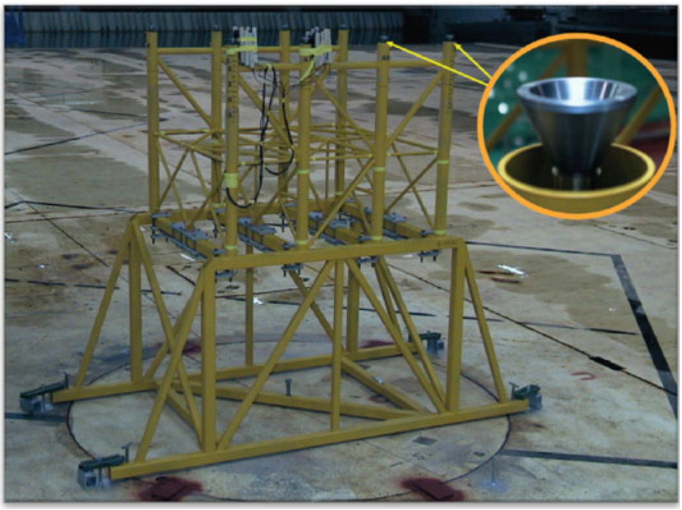

Fig. 8.16 Jacket model for Bayu Undan project. The *upper* part is modeled with accurate details including the LMU at the top of each jacket leg (credit to Bayu Undan project)

The model test wave is often a three (3) hour wave and the generated wave need to be calibrated and analyzed before the commencement of model test in the basin.

- Measurements
  - Data to be measured
    For the model test in the basin, the data to be measured during the test should be explicitly defined, e.g.:

    6 DOF motions at the COG of the topsides and specified spots at the vessel hull
    Accelerations in 6 DOF at the COG of the topsides and specified spots at the vessel hull
    Air gap values at specified locations for offshore transportation tests
    Line tension in each mating lines in the pre-mating and mating model tests
    Fender compression loads in selected fenders
    Loads at selected DSU
    Loads, including both vertical and horizontal, in every LMU.
  - All the instrumentation to be used in the model test such as transducers, wave probes, video cameras and so on should be listed.
  - The sampling frequency of the model scale, say 30 Hz (corresponding to 5 Hz in full scale), should be specified for all channels.

8.7.2 Motion Decay Test

For the model set-up for transportation tests and installation tests, motion decay tests should be planned to measure the corresponding system's natural period, damping and added masses. Among all the system hydrodynamic coefficients, the rolling damping coefficients are relatively more important since their values are small and the natural roll frequencies are in the wave frequency range.

The values of the measured coefficient values will be documented and to be compared with the values used in the simulation analysis. Generally speaking, the roll damping values obtained from the calm water motion decay test can hardly be directly used for the simulation under the offshore environment, since the damping value various with the rolling amplitude.

8.7.3 Transportation Model Test

The focus of the transportation model tests are to measure the roll damping of the transportation vessel mounted with the topsides during the long voyage along the towing route. The results will be compared to the value used in the simulation model. Different cases are defined by H_s and T_p pairs of the wave, as well as the wave incident angles. Generally, the beam sea and the quarter sea will be considered. However, since along the transportation route the vessel can be navigated to avoid the beam sea situation, the most extreme beam sea condition is often considered as an accidental condition. In Fig. 8.17, the model is under the quarter sea wave.

The derived roll damping value from the measured data will be compared to the value used in the motion simulation of the topsides transportation.

During the transportation model test, the air-gap value, i.e. the value between the bottom of the topsides and the wave crest can also be measured. The minimum air-gap value will be statistically derived from the measurement data.

The model test duration is generally 3 h. Of course, as mentioned earlier, motion and acceleration at specified spots will also be measured. The results will be compared to the results of three (3) hour time domain simulation.

8.7.4 Pre-mating Test

More cases and measurements are involved in the pre-mating tests. The environment includes both swell and sea and they may be non-collinear. Beside the quarter sea and the beam sea, the heading sea is also included. Various values of the clearance between the hull fenders and the jacket legs are considered covering the situations of free of contact, one (1) side of the hull contacts with the jacket legs and

Fig. 8.17 Model test of transportation condition for Bayu Undan project (credit to Bayu Undan project)

two (2) sides of the hull contact with the jacket legs. The pre-mating test is a three (3) hour test and during the pre-mating test, there is no contact between the mating cone and the jacket legs. The test model is also tuned up based on the motion decay test, e.g. the damping level (Fig. 8.18).

The measurements cover the following:

- Motions at the COG of the floatover vessel together with the topsides induced by the first order and seconder order environmental loads
- Motions at the specified mating cone tip
- Loads in the mating lines
- Loads on the specified fenders.

The test results will be compared with the results from the simulation analysis in the analysis model calibration. The results of the fender loads can also be used directly for the improvement of the fender design and arrangement.

8.7.5 Mating Test

The test model of the mating tests is different from the test model of pre-mating tests in the arrangement of the relative position between the stabbing cones and corresponding jacket legs. For mating tests, the contact between the stabbing cone and the corresponding LMU will occur during the three (3) hour model test with some cases of no initial contact at the band, some cases of initial contact. The LMU models are activated during the model test (Fig. 8.19).

Fig. 8.18 Model test of pre-mating condition for Chengdao Central Platform III of Sinopec (credit to the project)

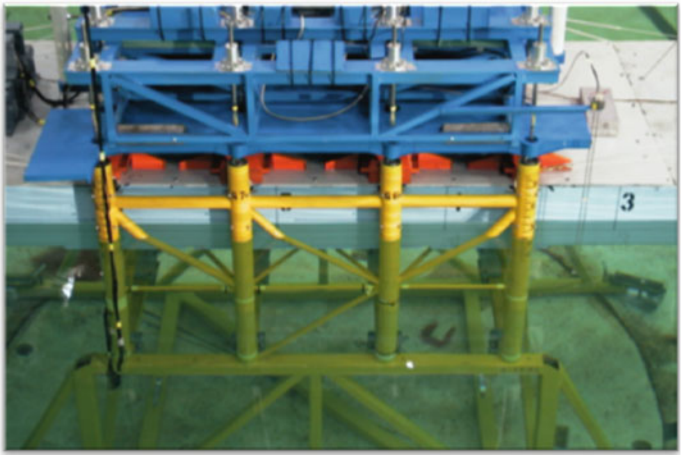

Fig. 8.19 Model test of mating condition for Bayu Undan project (credit to Bayu Undan project)

The focus is more on the LMU loads, both vertical and horizontal. Motion results are also compared to the motion simulation analysis. Environments setting is similar to the pre-mating model test.

8.7.6 *Model Test Results and the Data Evaluation [7–9]*

- Model test results
  For the model tests discussed above, many cases are included and tons of various kinds of data are generated. The model test basin will make the results available for the project and a model test report will be delivered. In the model test report, the following information can be found:
  - Description of model test set-up including the details of the physical models, the environment simulation, the instrumentation and setting up, the model test cases.
  - Results of motion decay tests for various operation conditions: transportation, pre-mating and mating.
  - Measured time series for each model test case.
  - Post-processing results of the measured data including response spectra, statistical values, extreme values, etc.
  - Evaluation of the model test results.
- Analysis model calibration and design improvement

With the accumulated experiences in the floatover operation, engineers can make relatively dependable prediction of the relative motion and the involved loads during the offshore operation processes and ensure the safety and effectiveness. However, there are limits on the accuracy of the simulation resulting from the modeling, the handling of the nonlinearity, etc. Quite often, the model tests are conducted after early computer simulation being already performed. With the available model test data, the engineers on the project can calibrate the analysis model and improve the analysis accuracy.

One example is the prediction of the LMU loads. Without the details of the interaction between the topsides and the DSU, the connection between the topsides and the DSU is often treated as a single rigid body. With this assumption, the LMU loads will be very high from the computer simulation, which leads unrealistic conservativeness. In addition, the damping coefficients, especially the roll damping coefficients for different operation conditions are important but the accuracy of the values cannot be determined without the model test results.

The fenders on the vessel hull play an important role in reducing the impact loads on the LMU and the loads transmitted to the topsides. The carefully designed model tests can provide information to make the design and arrangement of the fenders optimized.

8.8 Summary

In summary, engineering involvement is the key for the success of a floatover project. Engineering involvement covers a wide range from the supporting of the project planning to the details of the equipment design and operation procedure/working instruction development. On the other hand, the engineering efforts are not the isolated activities by the engineers with their communication limited merely to following the management instruction. Active communication between engineering team with other parties internally as well as externally to keep the response promptly with accurate information is vital for the integrated efforts of the project team.

Another important topic is the early involvement of the engineering. Often the perception is that the installation activities happen in the very late stage of an EPCI project and the project installation team starts late. Offshore project experiences show that late start of installation team involvements may lead to inability of meeting important installation requirements and cause delay and cost increase. Even in the pure installation projects, similar situation can happen by late involvement of the engineering personnel. The whole project, especially the project management team should fully understand the importance of the earlier involvement of the engineering team.

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Chapter 9
Operation Execution

Abstract As the offshore installation projects in general, floatover operation is a campaign involving vessels, equipment, crew, engineers and management team at the offshore site. Every step for each task must follow the instructions specified in the operation manual strictly. The discussion in this chapter focuses on the one vessel floatover operation. Operation activities of loadout, topsides floatover installation and post-installation are presented with details form preparation to actions at each stage. Contingency procedure and its importance are also addressed through the discussion of a real project.

For an offshore construction project, the success is judged by the delivered services of each offshore operation spree. Offshore operation execution is vital for the success of the project. Every experienced PM knows how to get the team ready for the final campaign.

9.1 Installation Procedures and IFC Drawings

To perform at offshore site, all the activities are intensive and full of challenges and the time for completion is generally very short. The skill and knowledge requirements for the personnel are very high, but that is not enough. There must be all the needed hardware available and ready for them to use and a well-developed marine operational manual with detailed instructions for them to follow.

Two kinds of documents, as the results of engineering work, need close involvements of the PM. One is the operation procedures developed for each defined tasks. Operation manuals with detailed operation instructions will be based on them. The other one is the IFC drawings and MTOs for equipment to be fabricated and technical specifications for equipment vendors.

The PM is responsible in assigning project personnel to review these documents and design for operability and constructability. The PM can also delegate these responsibilities to POM and project construction manager depends on the established organization of the project. The operation procedure development.

In reviewing of the relative documents, the following are emphasized:

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- Safety
  The proposed actions in the operation procedures and the details of the drawings and MTOs need to be checked thoroughly against the relative analysis/design procedures and applicable codes to ensure the practices being safe. Checking results will be documented.
- Operability
  Working instructions and design drawings/specifications are reviewed to assure that the designed equipment and the arrangements including the control method and location of control station, the spacing, etc. satisfy the requirements from installation and operational considerations.
- Exactness and simplicity
  In the operation procedure and working instructions, items of guidelines should be as concise as possible without ambiguity and easily be understood with exactness by the operation personnel. The design should be as simple as practical. Unnecessary complicated design should be avoided. The bottom line is functioning and operation friendly.
- Cost effectiveness
  Ensure that the approach of the operation and the design of the equipment are the most economical and the best schedule saving comparing to the alike projects and similar equipment.

The relative procedures/working instructions for a floatover project can include the following documents:

- Mobilization/demobilization of equipment
- Mooring installation manual
- Topsides loadout procedure
- Topsides transportation manual
- Topsides installation manual
- Seafastening manual
- Survey manual
- Safety and emergency response procedure.

There are also working instruction documents as the attachments to some procedures/manuals listed above. The organization of the documents may vary, but the coverage of the topics is almost the same.

The equipment designs with drawings to be issued typically include:

- Loadout skid-beam and link beam design
- DSS design
- Grillage and sea-fastening design
- Vessel fender system design
- LMU, DSU design specification
- Mooring system analysis and design.

Approved procedures/working instructions should be documented and available for all relative personnel. Instructions in these documents should be literally followed during the installation operation. The IFC and construction specifications should also be strictly implemented during the construction.

9.2 Platform Integration Operation Activities

Recall the discussion in Chap. 7, it covered the tremendous efforts being made, starting from the beginning of the project to finalizing the installation methodology, on the development of the PEP, IM as well as relevant procedures/working instructions based on the engineering analysis/design results. At the same time, the discussion also covered the installation related equipment being designed and fabricated or procured to support the platform integration operations. From now on, the discussion will focus on the platform integration activities following the PEP. The whole operation process consists of the following individual activities:

- Transportation vessel outfitting
  Prepare the vessel with grillage, skid beams, rigging for loadout, sea-fastening supports, mooring equipment, etc. Perform necessary local reinforcements if needed.
- Topsides preparation
  - Insert the DSUs in the corresponding DSS
  - Prepare the topsides structure to ensure that its leg stabbing cones match with DSS assembly, which includes skid shoes, and lifting the topsides to the desired height satisfying the requirements for transportation and mating operation.
  - Lift and position the topsides onto the DSS ready for loadout.
- Jacket preparation
  - Prepare the top of the jacket legs with transition pieces matching the leg stabbing cones of the topsides.
  - Position and secure LMUs inside the corresponding transition pieces
  - Adding fendering strips at the jacket legs at the water surface area if needed
  - Prepare the legs with mating-line connecting spots.
- Loadout
  Move the topsides (together with DSS from the quayside of the construction yard) onboard the vessel by skidding.
- Transportation
  - Install sea-fastening and prepare for transportation.
  - Transport the vessel mounted with the topsides to the platform integration site.
- Standby
  The vessel is temporarily stationed at a safe distance from the substructure; but connected to the mooring system for the floatover operation preparation such as working on the ballast system, hydraulic jacks, etc.

- Docking
  Hook up the mating lines to connect the vessel with the jacket and move the vessel enter the substructure slot.
- Pre-mating
  The vessel is positioned to align the topsides stabbing cones with the corresponding LMU receptors. The vessel motions are limited to suit the chosen LMU geometry. No weight transfer occurs.
- Mating
  Remove sea-fastening and lower the topsides to initiate contacts between the stabbing cones and corresponding LMUs and start topsides load transfer from the vessel to the jacket until the topsides is completely supported by the jacket (mating operation of floating structure can be fulfilled by reducing the draft of the floater's hull through de-ballasting as shown in the topsides installation of Kikeh spar).
- Post-mating
  - Separate the vessel from the topsides by further vessel ballasting
  - Withdraw the vessel from the integrated platform
  - Release the mooring system attached to the vessel and tow the vessel to the demobilization yard.
- Completion
  Perform required welding at the connection between the topsides and the jacket legs.
- Site cleaning
  Demobilize and clean all involved marine spread at the site.

In the above discussion, the vessel is implied not self-propelling; however, there have been quite a few projects completed using self-propelled semisubmersible heavy lifting vessels and some of them are DP vessels. Nevertheless, the activities involved still similar to the general description presented in this book. It can be seen clearly, that individual activities listed above are not independent. Some activities must wait for the completion of specific operation before its commencement. Obviously, the integrated team efforts are essential for the success of actual installation work. An installation management team is needed to ensure that critical activities are executed in the correctly defined sequence and the pre-defined criteria to be achieved.

9.3 Task Force Management

There are many ways to organize the operation teams; an exemplary organization chart for the floatover operation team is shown in Fig. 9.1.

At the stage of installation, the POM plays a critical role. He/she should be very clear about the main tasks involved and the consequence of the operation and capable of clearly identify the interrelationship between activities, so that to be able to allocate resources to various task groups and provide necessary supports at the right time. Each person in the team may be involved with multiple task assignments and working in a specified task group at different time duration. The POM should be also able to delegate certain authority and responsibility to the group leads of the task group.

Fig. 9.1 An operation team organization chart

For example, in the loadout operation team, the "loadout superintendent" is the center working closely with the "vessel superintendent". Personnel under the loadout superintendent will be directly carrying out all the relative tasks to implement the plans and monitor the work progress. Organization charts of working force for other tasks are similar and all the group leads in charge of the assigned task group will directly report to the POM (Fig. 9.2).

The POM as the supervisor takes care of the coordination among all related parties including the MWS through the coordinator to ensure all the planned progress be realized. The focuses are in:

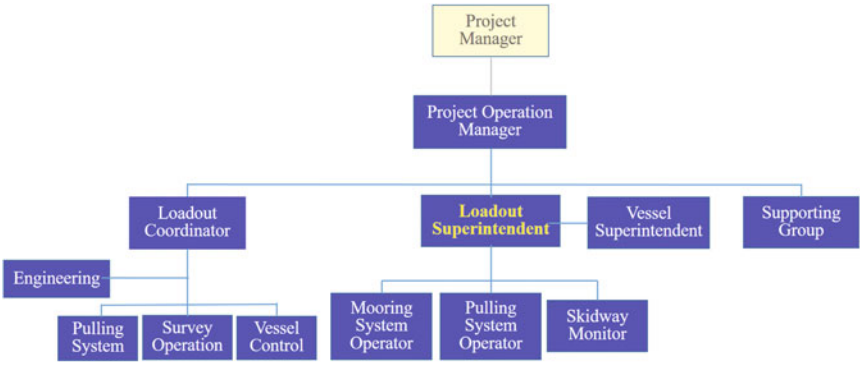

Fig. 9.2 An operation team organization chart for loadout operation

- Implementation of the safety management plan for the safety of both personnel and equipment.
- Have the full safety/risk analysis conducted for the installation activity and incorporate the results in the operation procedures.
- Ensure smooth communication between all relative persons and/or vessels with good and timely flow of information with high accuracy.
- Closely monitor the operation progresses and directly involve in important decision-making, e.g., establishing dependable reporting channels, attending important meetings such as "punch list, coordination meeting", "ready for operation meeting", "go ahead decision meeting", etc. The bottom line is that all the tasks are carried out strictly following the approved operation procedures/working instructions and satisfy the specified requirements on quality and schedule.
- Have a contingency procedure approved and in place to be used by responsible manager in handling the operational deviations encountered during the course of operation.

In the following sections, some detailed discussions will be given to a couple of tasks.

9.4 Loadout and Pre-sailaway

After the completion of the integrated topsides at the yard, it is the time to move the topsides onto the transportation/floatover vessel. Not like the case of modules or small decks, moving the large, heavy integrated topsides from the quayside of the construction yard to the transportation/floatover vessel is very challenging and involves safety issues.

Generally, the topsides will be rolled or skidded aboard the vessel with specially designed equipment and methods, which can be classified as "*skidded loadout*" and "*trailer loadout*". In this book, the discussion is on the former method.

For skidded loadout, the rigging, e.g. the DSS, not only need to be designed structurally strong enough to bear the heavy weight of the topsides, but dimensionally it should also satisfy the requirement of the height of the topsides during the transportation and the floatover operation. At the same time, the requirements on stability of the vessel loaded with the topsides and the dynamic loads induced by the environments acting on both the topsides and the vessel are specified. The operation criteria should be established based on the engineering analysis/simulation and the model tests. The procedure of loadout operation must be developed, reviewed and approved by the project management and the client before the loadout operation commences. All the loadout related activities will follow the procedures strictly. The whole process of loadout operation and related activities are described in this section. In addition, activities of post-loadout for preparation of sailing away are also covered [1, 2].

9.4.1 Preparations

- Quayside preparation
  - Sufficient space and water depth
    As illustrated in Fig. 9.3, near the quay of the harbor, quite often, the water is constrained. It may put some limits on the accessibility and maneuverability of the vessel. In addition, the water depth is critical: vessels chosen for transportation/floatover operation are generally large and deep. At the same time, the freeboard is limited in order to align the skid beam onboard with the on land skid way. On the other hand, there must be enough clearance between the vessel bottom and the seabed to avoid running aground. Based on the available tidal information and the bathymetry data, careful calculation to check the window for the safe operation is necessary. For some cases, dredging operation need to be arranged before the loadout operation starts.
  - Quayside strength checking
    Based on the skidway layout on the surface of the quay, and the topsides weight distribution during the loadout operation, the strength of the quay need to be checked, especially at the front edge area. Local strengthening of the quayside may be necessary. In the area adjacent to the quay front edge, to enhance the lateral stability of the quay wall and to gain more vertical resistance, steel piles may need to be driven into the sea bed for the skidway paving.
  - The loadout skidding system (DSS with skid shoes) will be installed under the topsides during weighing. All temporary supports used during topsides construction and any obstacles against loadout operation are to be removed. The skidway onshore foundation design is based on the load intensity from the quay wall stability analysis. The steel skidway together with the reinforced concrete mats will be laid on the ground from the weighing site to the edge of the quay wall.

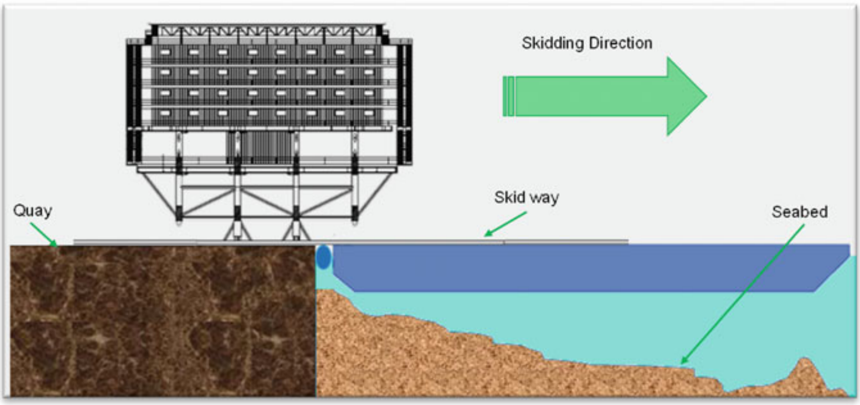

Fig. 9.3 Loadout at the quayside

- Mooring facilities
  At the quay, the necessary facilities for the mooring/berthing of the transportation/floatover vessel(s) may need to be available depending on the project. For example, when large heavy lifting vessel is chosen and the transverse loadout method is considered, the bollards with enough holding capacities for berthing the vessel may need to be added. Generally, the vessels' existing mooring system onboard will be used during the loadout operation.
- Path clearing
  Before the commencement of the loadout operation, all the temporary structures used in the construction stage and any potential obstacles will be removed.

• Topsides preparation

  - Mount on the DSS
    As aforementioned, for the floatover operation, the elevation of the topsides bottom need to meet the required value and DSSs (sometimes is also called Loadout Support Frame) are specially designed. After the final weighing, the completed topsides will be loaded on the DSSs from the weight supports during the fabrication. The DSSs are positioned on the skidway. The connecting beam connects the two (2) DSSs on the same skidway. Skid shoes are underneath the DSSs and the skidway is well greased to reduce the friction force (Fig. 9.4).
  - Upper Seafastening
    In general, the DSUs are installed on the top of the DSSs and the topsides supporting columns directly sit on the DSUs. To resist dynamic loads generated by the vessel motion during the transportation, seafastening structures such as braces and plates are installed to connect the topsides supporting columns and the DSSs.

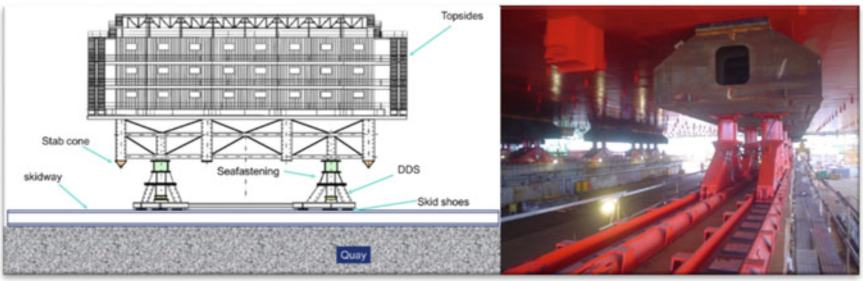

Fig. 9.4 Preparation of the topsides for loadout. *On the left*, the topsides is mounted on the DSS and sea-fastened. The DSSs with the skid shoes are on the skidway ready for moving. *On the right*, skid shoes can be clearly seen (Photo courtesy of ALE)

  - Hook up with pulling system
    Although winches can be used for loadout operation, for massive integrated topsides, strand jack systems are the better choice. The pulling system will be further discussed later.

- Vessel preparation
  The vessel preparation is carried out at the outfitting shipyard and the preparation is for the whole topsides installation operation including topsides loadout, transportation and topsides installation. Through the preparation activities such as structural modification/reinforcement, equipment installation/inspection/commissioning, etc. to make sure that the vessel is suitable for all the operations mentioned above.

  - Stability
    At the stage of selecting the vessel(s) for the topsides installation, the vessel stability should have been checked based on the available information and estimation. When the topsides is near completed and all the related onboard installation related equipment have been designed, carefully stability checking for the whole loadout process, along the sailing route and during the docking and mating operation is performed in order to conform to the regulatory rules.
  - Structural integrity
    To perform the loadout operation, the amount of topsides weight being transferred from the quay to the vessel varies during the process of performing planned ballasting/deballasting operations. Pulling activities also create loads on the vessel hull. Hull capacity of handling shear force and bending moments need to be checked. Environmental loading impacts on the vessel structural integrity during the transportation and installation should also be checked.
    Any identified weak spot of the hull structure should be taken care of by local reinforcement or hull structural modification.
  - Skid beam and grillage
    Skid beams are installed on the upper deck of the vessel. To better distribute the total weights of the topsides and associated structures as well as installation assistant equipment, grillages are designed and welded on the upper deck of the vessel at specific locations. The skid beams will sit on the grillages (Fig. 9.5).
    The top of the installed skid beams should have the same elevation of the top of the skidways on the ground of the quay. Seafastening using shim plates, gusset plates and shear plates will be installed following the design to deal with external loads in longitudinal, transverse and vertical directions during operations mentioned above. All the grillage and Seafastening installation should follow the design specifications of materials and welding.

Fig. 9.5 Skid beam layout on the vessel: the *left picture* shows the skid beams for transverse loadout of KBB platform topsides and the *right picture* shows the skid beams for the loadout operation to pull the topsides onboard the vessel from the stern (*Left photo* courtesy of COSCO and credit of the *right photo* to a barge modification project)

– Fenders

Depends on projects, fenders can be installed at the vessel outfitting yards before the topsides loadout or be installed at the stage of topsides installation preparation at the place near to the offshore site when the transportation vessels arrive. Here we suppose that the fenders are installed at the vessel-outfitting yard before the loadout operation.

The examples shown in Fig. 9.6 were used in a completed floatover project. The designs and the building materials may vary based on their position and specific function, but the basic functions are the same:

To prevent high impact loads between vessel and the substructure.

To limit the motion of the vessel loaded with the topsides during the docking and mating phases. When the gap between the vessel hull and the jacket legs or the substructure columns is small on each side, say about 1 m, inflatable fenders can be used for limiting the yaw and sway motion of the vessel.

To prevent the vessel surge motion overshooting during the docking stage.

To achieve the goal of limiting the vessel's motion and reduce the impact loading between the vessel hull and the jacket legs, there are several possible options:

Purely using mating lines without fenders

Purely using fender systems and no mating lines

Combination of fender systems and mating lines.

Among them the third option is often selected by projects. A typical fender system arrangement on the floatover vessel is shown in Fig. 9.7.

Fig. 9.6 Examples of various kinds of fenders: ① is the stern fender; ② is the side/sway fender and ③ is the surge fender/stopper (Credit to Lan Tay project)

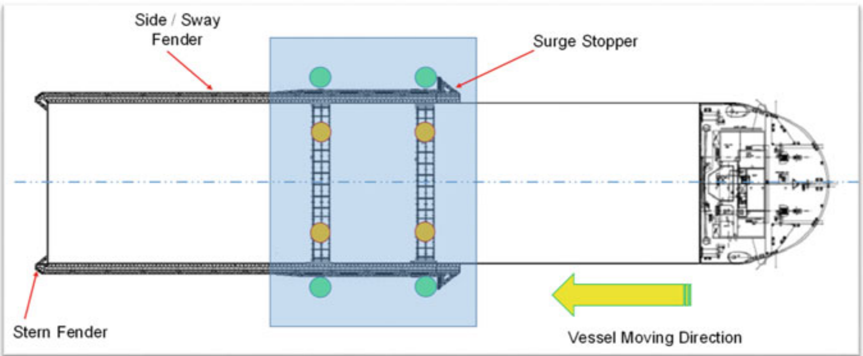

Fig. 9.7 A diagrammatic sketch of fendering arrangement

The following are brief discussions on the functions of different fender systems:

① Stern fender systemThe stern fender is also called the stern guide fender, which is designed to assist the initial docking of the floatover vessel into the jacket slot and to resist impact loading with the jacket legs during docking/undocking operations. They are mounted at the hull stern with braced backing structure connected to the vessel edge.

At the pre-docking stage, the vessel hull centerline is carefully aligned with the centerline of the jacket. When the vessel is moved to enter the jacket opening, the combined vessel hull lateral motion at the stern causes contacts between the fender tips and the jacket legs. The motion is largely induced by the yaw, which would be compensated by the tugs. At the same time, considering that any clashes generally occur at peaks of the sway amplitude, where the resulting forces are lowest. In addition, it can be noticed that the tips of the stern fenders are cuneate and enlarge the gap between the fender and the jacket legs. Therefore, the stern fenders are not subject to severe loading comparing to the side fenders.

② Side/sway fender system

Side/sway fenders are mounted on both sides of the vessel hull. As shown in Fig. 9.7, side fender on each side of the hull consist of a continuous fender member intermittently supported by beams located over the vessel transverse frames.

After the initial docking stage is completed, the hull stern passed all the jacket legs and the tugs are released, then the control of the vessel lateral motion becomes weak. The side fender system will play an important role in handling lateral loads by contacts between the vessel and the jacket legs. Consequently, the design of the side fenders are often performed with the conservative approaches.

③ Surge stopper/fender

Revisit Fig. 9.6, as shown by the example, the surge stopper is designed to stop the surge motion of the vessel and at the same time, it can dampen out the forces induced by the contact of the jacket legs and the fender. This motion suppression system incorporates a multiple spring arrangement with a specified stroke in the surge direction.

The surge stoppers/fenders are used in the topsides installation phase. It is often designed with connecting mechanism to make the installation and removing easy. For example, it can be temporarily removed during the loadout and then after the operation to be reconnected to the hull by bolts.

- Ballast system

  The loadout operation is a continuous process of moving the topsides and transferring its weight from the quay to the transportation/floatover vessel. The vertical loads on the vessel will keep changing from the moment of the DSS skid shoes onboard the vessel until it reaches its final position. The vessel ballast system will keep working simultaneously according to the developed ballasting plan to compensate the load changing. The ballasting plan generally consists of dozens of steps and each step had to be strictly followed during the operation.

  All vessel ballasting procedures/sequences will be prepared and updated by the loadout team, but the vessel ballasting/de-ballasting operation is by the vessel crew led by the vessel superintendent. Before the commencement of the loadout operation, onboard ballast system should be checked and commissioned for the readiness of operation. (For some installation projects, external ballast pumps may be used and the tests on this equipment are included.) The following activities are carried out:

  Check pump system function
  Check ballast tank valves
  Ensure all ballast system valves in correct position
  Ensure ballast control system ready for operation
  Test remote sounding system
  Test power system function
  Test monitoring equipment/weather equipment of tide, wind and atmospheric pressure
  Ensure the actual tide curve is implemented and available.

  With all these tests and checking going through successfully, the vessel is ready for the loadout operation.

- Pulling system and link-beam

  Since the preparations of the pulling system and the link-beams involve both the topsides and the vessel, therefore they are discussed separately.

  - Pulling system

    Pulling system consisting of strand jacks are generally used in the loadout operation for both maritime projects and offshore operation projects, especially for massive integrated topsides. The pulling system is designed to be capable of moving the topsides from onshore to aboard the transportation/floatover vessel without re-rigging. The pulling forces needed to overcome the friction forces between the skid shoes and the skid beams are calculated based on the values of the friction coefficients for both break-out and moving conditions.

    The strand jacks are attached at the pulling side of the DSS and anchored at the selected spot aboard the vessel. Depending on the loadout direction, if from the stern, then the anchoring spot will be on the vessel deck near the

Fig. 9.8 Strand jack pulling system: *on the left* is shown the strand cables connected to the fixed anchorage installed on the upper deck of the transportation/floatover vessel; *on the right* is the strand jack hooked up with the DSS supporting the topsides (Photo credit to Bayu Undan project)

bridge close to the bow; if the loadout is transverse, say, from the starboard side, then the anchoring spots will be at the port side of the vessel (Fig. 9.8). The whole pulling system, including extra hydraulic jacks for break-out at the initial pulling stage, shall be fully commissioned according to the operation manual.

– Link-beam with compression strut

Link-beam connects the skid beam on the transportation vessel upper deck and the onshore bridge of the skidway on the quay. The link-beam does not only function to bear the vertical loads during the time when the weight of the topsides being transferred from onshore to the vessel deck, but also to distribute compression force generated by the pulling of the topsides. Link-beams are supported on footing foundation on quay and side shell reinforcement on the vessel, each link-beam has free boundary in any direction within a limited allowance. Therefore, limited vessel motion in the vertical plane is allowed. The motion is caused by the ballasting/de-ballasting during the loadout operation.

The vertical load on the link-beam is transferred to the concrete mat on the quay and to the supporting structure mounted on the hull of the vessel at the stern or the side shell, depends on the loadout being longitudinal or transverse. In the horizontal direction, link-beams resist only compression forces to maintain the gap between the quay wall and the vessel hull. The compression forces generated during the pulling of the topsides are distributed from the compression strut part of the link-beam to the onshore bridge then reaching the concrete mat blocks. On the vessel side, the link-beams sit on the specifically installed bearing supports and the loads are distributed to vessel hull structures through the bearing plate attached to the vessel upper deck (Fig. 9.9).

The link-beams are one of the key elements to success the smooth loadout operation. They should be designed with adequate reserve for the corresponding weight of the topsides. To get the reaction loads distributed better, the beams should be installed accurately using shimming to provide close contacts to the supporting structures.

Fig. 9.9 Installing the link-beam (Photo credit to Bayu Undan project)

All the preparatory work completed for loadout shall conform to the procedures and the specification including appropriate codes and guidelines such as ABS/API/AISC/DNV, etc. Any deviation from the codes shall be reported to and approved by the clients and the MWS.

9.4.2 Weather Broadcasting and Tide Survey

- Weather broadcasting
  Weather forecast from professional meteorological institute is vital for the success of the loadout operation. The forecasts should provide weather synopsis with H_s, corresponding T_p, H_{max} of the wave and swell, 10 min wind at surface, and at 10 m above the sea surface, visibility, weather in general, precipitation, etc. Regular weather information update, say per six (6) hours, should be provided starting several days prior to the loadout operation and continuing to the end of the loadout operation.
  Daily weather meeting is held for early discovering of weather deterioration. With weather forecast for 12, 24, 48, 72 h, the favorable weather window for loadout operation can be identified for initialing the load transfer operation.

- Tide survey

  Some loadout operation is tide dependent. In that case, the ballast calculations and capacity of handling the maximum expected tide variation need to be ensured. Even the operation is not tide dependent, water level at the loadout quay is monitored several weeks prior to the planned loadout date. All the measured tidal information will be compared to the historical/predicted values to make sure there is no large discrepancy. Otherwise, modification of the loadout plan or the operation postpone may be necessary.

9.4.3 Loadout Operation

The commencement of loadout operation can only be performed after all the planned loadout activities have been checked according to JSA (Job Safety Analysis) and the results show the safety as well as the capacity of the loadout system has been proved. The loadout operation manager takes the whole responsibility of the loadout operation with close incorporation with vessel superintendent who will be in charge of the vessel control during the entire loadout operation. Client representatives, MWS, and management members of the installation project will be on site to witness the activities.

- Initial the operation

  The key figure of the loadout operation management is the loadout manager who is responsible to:

  – Scheduling and planning of all loadout activities
  – Maintaining developed schedule
  – Loadout site management
  – Communication with the client, MWS and installation project team.

  The most involved leading personnel are the loadout superintendent and the vessel superintendent. The responsibilities of the loadout superintendent include:

  – All pulling/skidding related activities
  – Checking and survey of the loadout equipment
  – Communication with the fabrication yard personnel
  – Communication with meteorological authorities
  – Coordination with vessel superintendent.

  The responsibilities of the vessel superintendent include:

  – In charge of the marine activities of the vessel in preparation of the loadout operation
  – Checking of all marine equipment installed onboard the vessel for loadout operation and ensuring all the requirements are satisfied

- Communication with the fabrication yard personnel to ensure deliverables conform to industry practices and codes
- Maintaining direct communications with loadout superintendent before and during the loadout operation
- Ensure all skid beams aboard are lubricated
- Communication with meteorological authorities
- Review loadout ballast plan and related hydrostatics calculations
- Vessel control through operating vessel marine system under the supervision of the loadout superintendent
- Ensure that the vessel is correctly ballasted to the transportation draught after the completion of loadout and a MWS certificate for sailaway to be issued prior to the commencement of the transportation voyage.

During the entire loadout process, including the pre-loadout stage, all the parties including the loadout team, the client representatives and the MWS are actively involved. The preparation of the loadout commencement not only includes the equipment checking/commissioning but also the readiness checking of all personnel involved in the loadout operation. The following activities are carried out:

- Coordination meeting to ensure all relevant parties understand their responsibility and the official communication flowchart.
- All operational personnel undergo an induction training outlining the loadout operations and their responsibilities.
- All on site personnel have completed a safety induction prior to the commencing work on site.
- All related project personnel participate in a JSA and are knowledgeable of all the hazards identified during offshore HAZID (Hazard Identification) sessions, which are recorded in the corresponding documents.

After receiving loadout approval certificate from MWS and confirmation of all loadout system commissioning, the vessel ready-to-charge and favorable weather forecast, the loadout operation will be commenced by the order of the loadout manager.

- Activities during the topsides skidding

  Three main categories cover the total topsides skidding activities and they are briefly discussed here:

  - Pulling control

    The topsides skids with the planned moving speed on the skidway under strict control of the pulling force provided by the strand jack systems. During the break out stage at the beginning, since the static frictional coefficient value is high, large pulling forces are needed. Extra hydraulic jacking equipment are often needed onboard to provide the needed push/pulling forces. After the topsides starts to move, these assistants are no longer needed except the non-intentional stop by unexpected reason before the operation is completed (Fig. 9.10).

Fig. 9.10 Topsides skidding operation: *on the left*, the topsides is at the edge of the quay and ready to be moved onto the link-beam; *on the right*, the topsides weight transfer is continuing (Photo credit to Bayu Undan project)

During the skidding, the weight of the topsides is transferred to the transportation/floatover vessel gradually and continuously. The rate of the weight transfer is closely related to the skidding speed. At the same time, the time needed to maintain the skid beam level through vessel ballasting/deballasting during the operation depends on the capacity of the vessel ballasting system. Therefore, a skidding speed is strictly controlled during the entire skidding process.

When the topsides starts to skid forward, the horizontal pulling forces are provided by the pulling cables in a synchronized manner and the pulling forces are controlled by the operation personnel in the control cabin under the supervision of the loadout superintendent to control the skidding speed.

– Vessel ballasting and control

The purpose of the vessel ballasting/deballasting operation is to keep the skid beams in line with the corresponding link-beams/onshore skidways and the horizontality of the vessel during the entire loadout process. The main tasks can be divided into three (3) categories: topsides load transfer compensation, tide compensation and correction action. The entire topside skidding process after the initialing of the operation covers three (3) stages as the following:

The topsides moves towards the transportation/floatover vessel but no load transferred to the vessel yet. Only tide compensation ballasting activities are involved by pumping in/out water into the dedicated tanks.

The topsides weight is being transferred to the vessel but not completely. Ballasting/deballasting activities cover load transfer compensation, tide compensation as well as ballast correction.

The topsides weight has been completely transferred to the vessel and the forward motion continues until it reaches the final position. The ballasting/deballasting activities cover the tide compensation and ballast correction at this stage.

In the last stage, it can be seen clearly, the operation is the internal movement of ballast water compensating for the distance the topsides move through. Ballasting/deballasting plans are developed corresponding to above mentioned tasks for each stage which have been approved by the projects, the client and the MWSs and are strictly followed during the operation. The ballasting plans with tank table of longitudinal loadout method are quite different to those of the transverse loadout method. However, the ballasting plans all cover dozens steps and for each step the detailed information cover:

Load to be transferred
Ballast tanks to be used and tanks contents
Pump capacities to be used
HLV draught
Load COG and vessel displacement.

During the development of topsides load transfer, the transferred loads onto the vessel are applied as point-loads with correct magnitude and position. The amount of the transferred load varies among the ballasting steps in a defined range. The topsides weight transfer and the corresponding ballasting/deballasting operation will lead to the change of the COG of the total vessel system and create bending moments on the structures. With the topsides forward speed is available, the ballasting steps are selected to avoid or minimize the bending moments passing into the topsides structure.

For a specific task at each stage, there are dedicated tanks assigned and based on the ballasting/deballasting activities of the corresponding step, working pumps and back-up pumps are also arranged in the plan and temporary pumps can be included when necessary.

During the topsides loadout, ballast control room is generally onboard the transportation/floatover vessel. As mentioned earlier, the ballast superintendent leads and coordinates the ballast operations under the supervision of loadout superintendent. He/She will perform the following:

Records the progress of the operation
Reports relevant data to the loadout superintendent
Maintains a logbook of the ballast operations and the records of all relevant data. The HLV Superintendent will maintain records of all orders and confirmations, tide levels, completed steps, incidents and deviations from plans.

The records and data include all orders and confirmations, start/stop of pumps, opening/closing of manholes, completed steps, tank soundings, tank ullages, incidents, deviations from plans and equipment status, etc.

The ballast engineer or other dedicated personnel perform the vessel ballast system in the control room, including the tidal compensations. Measurements and information on the tide variation, the freeboard of the vessel, heel & trim angle, level of tanks, etc. are promptly updated and available at the control room.

The regular inspections of the pumps, generators, fuel, temperatures, etc. will be taken care of by the vessel operators/engineers. The responsible vessel personnel will maintain records of all orders and confirmations, start/stop of pumps, opening/closing of valves, completed steps, tank soundings, tank ullages, incidents, deviations from plans and equipment status.

– Operation monitoring

During the entire process of the topsides skidding movement, the project team carry out intensive monitoring activities to ensure that operations are progressing properly and comply with approved plan and procedures. The measured data are also vital inputs for the pulling and ballasting operation.

Topsides skidding: foundation settlement; skidway beams deflection; quay strength behavior; topsides advancement; topsides supporting point level, load on quay at link-beams etc.

Vessel: position; deflection; draught; trim and heel; winches and mooring line tension; ballast tanks;

Pulling systems: pulling force; speed; jack pressures; jack stroke; hydraulic; shock pads squeezing, etc.

Tide

Environmental data: wind, wave and current.

- Contingency procedure

A contingency procedure should be developed and approved by the project and the client. The procedure handles unexpected problems with impacts on the safety of the operation before or during operation. This plan will be accessible to all loadout relevant personnel and fully understood by the key team members. It is the guideline for handling unexpected equipment failures including making decision to halt the loadout activities prior to or during the loadout operation.

– The hazard plan based on the HAZOP (Hazard and Operability Study) is made to address the identified issues including pulling system failure, ballast pump failure, power loss, mooring system failure, etc.
– It also includes the guidelines for aborting loadout operation in case of major failure of a part of the loadout system:

△ Prior to the loadout operation, if

Significant loadout equipment such as ballasting system becomes defective

Significant inconsistency to the loadout drawings and/or procedures are identified

Weather conditions are significant worse than the specified

Unexpected deviation of tide is found and beyond the handling capacity of the ballasting system.

△ During loadout operation, if

Serious problem appears with the vessel stability and buoyancy
Serious problems have been developed with the vessel mooring/berthing system
Very poor visibility issues occurs.

The above is a very general and brief discussion. Project by project, the contingency procedure is unique in applying to the real working circumstances. A carefully developed contingency procedure is vital for the project safety although most of the hazard issues rarely appear during the operation.

9.4.4 Post Loadout and Pre-sailaway Preparation

After the topsides together with the DSS reaches its final position on the vessel, the loadout process is completed and the following post loadout activities will be carried out.

- Clean-up
  - Removal of loadout equipment
    All pulling system components including strand jacks, fixed anchor supports will be removed. Link-beams and bearing support plates, etc. are also removed from the vessel.
  - Removal of mooring/berthing equipment not needed for future topsides installation including temporary mooring bollards on the vessel.
- Restoration of the fender systems on the vessel hull if some parts of them were removed during the loadout operation. This is for the topsides installation operation.
- Seafastening installation
  Seafastenings for transportation are installed after loadout and must be completed prior to sailaway. For large topsides, as mentioned in the past, the seafastening connecting DSS and topsides seafastening was already installed before the commencement of the loadout operation.
  After the topsides reaches its final position onboard the transportation/floatover vessel, the following sea-fastening will be completed.
  - The seafastening between the DSS and the upper grillage will be installed immediately after the topsides reaches its final position to resist the transportation induced forces from all directions including uplifting force and horizontal forces in both longitudinal and transverse directions. The seafastening consists of brackets, shear plated and uplifting structural member and the connections will be achieved by using welding and bolting.

  - The seafastening connecting DSS to the lower grillage beams which are connected to the upper deck of the vessel. The installation is also through the welding of the shim pads and gusset plates. To avoid the induced forces from ballasting system operation during vessel draft adjustment, the lower grillage seafastening installation will be performed after the vessel's draft reaches the value for voyage.

- Adjust the draft of the vessel to pre-sailaway draft, go through the inspections following the pre-sailaway inspection procedure, and receive the "Sailaway Certificate" from MWS.

9.5 Topsides Installation

Considering that the topsides transportation can be categorized as one of the maritime operation, details of the transportation operation is not depicted in this book. Interested readers can find related information and materials from published literatures. The discussion is jumped to the topsides installation at the offshore site, which covers the course of events from the arrival of the transportation/floatover vessel at the installation site to the completion of the platform integration operation. The operation process in this time period can be divided into the following stages (phases):

- Standby stage
  After the arrival of the floatover vessel with the topsides, the vessel will be temporarily moored at a location close to the platform stationing site with the substructure (here a jacket is in discussion) already in place. Preparations on the vessel and the jacket will be carried out for the floatover operation.
- Pre-docking stage
  The vessel is moved closer to the jacket but not enter the jacket opening. The topsides centerline will be aligned with the jacket centerline. The vessel will be ready for the docking stage.
- Docking stage
  This stage is vital. In the docking stage, the vessel with the topsides is moved into the opening of the jacket legs and the topsides mating columns are in line with the LMUs of the jacket. The vessel is berthed with the mating lines and ready for the next stage.
- Pre-mating stage
  The motion of the stabbing cones on the topsides mating legs are within the defined capture radius and ready for mating stage. (Some projects take this stage as part of the mating stage.)
- Mating stage
  Perform the operation to reduce the gap between the topsides and the substructure. For the fixed platform in discussion, the topsides is lowered down by vessel

ballasting. The stabbing cone will be engaged with the LMUs to transfer the topsides weight to the jacket by steps until the 100% load transfer is completed.

- Undocking/Withdrawal
  There is an enough clearance between the bottom of the installed topsides and the top of the DSS on the vessel. The vessel will be moved off the jacket opening and ready for demobilization.

In the remaining of this section, details of activities related to the field preparation and the stages after the floatover vessel arrival listed above are presented.

9.5.1 Field Preparation

When the topsides on the floatover vessel is still on the voyage to the installation site, AHTs are mobilized to the installation site. Onboard the main assistant vessel, there are floatover operation personnel including floatover operation manager (supervisor), lead installation engineer, the client representative, MWS together with assigned crew to carry out relevant preparation work. ROV (Remotely Operated Vehicle) personnel with a supervisor are also mobilized onto the AHT mounted with ROVs. The field preparation activities include:

- Jacket preparation
  - Jacket pre-installation survey
    The survey will be conducted using ROV. The survey work covers the visual confirmation of the depth of the jacket braces; visual confirmation of jacket structure being free from obstacles in the targeted elevation range beneath the surface and the video survey of the jacket to determine the existing condition.
  - Inspection of the seabed around the jacket
    The ROV survey of the seabed is also performed to ensure there is no any debris in the targeted area.
  - General inspection of the jacket for safe access and safe operation condition on the jacket including the jacket lighting equipment deploy.
  - Survey positioning reference equipment are installed.
  - LMU inspection
    When the jacket was installed, the LMUs are positioned on the top of the corresponding jacket legs. To prevent the damage from the environments, protection cover was put on each of the LMUs during the time waiting for the installation operation (Fig. 9.11).
    To prepare the floatover operation, riggers are mobilized and get access to the top of each jacket leg and assist the removal of the weather protection cover of the LMU. After the removal, the riggers will inspect the inside of the LMU visually about the water ingress and other damages. Any identified issues should be reported and corresponding measures will be taken to make every LMU meet all the requirements for the mating operation.

Fig. 9.11 *On the left*, it shows the LMU is under the weather protection cover before the field preparation; *on the right*, the LMU is ready for the floatover operation (Photo credit to Bayu Undan project)

- Environmental data acquisition equipment deploy
  - Deployment of metocean equipment such as weather sensors for wind speed and direction, air temperature, air pressure and relative humidity; current meter; tide gauge; meteorological sensors, etc.
  - The position of the wave rider buoy is verified and the system function is tested
  - The online tide measurement device is inspected and function tested
  - Data acquisition system for data acquisition, processing, storage and telemetry.
- Mooring system
  Except for the floatover operations using DP vessels as will be discussed in the next chapter, mooring system is needed. Before the floatover vessel with the topsides arrives at the installation site, a mooring system is set up by the AHTs, which is inspected by the ROVs.

9.5.2 Stand-by Stage Activities

There is in general an OCC (Operational Control Centre) established aboard the vessel or an accommodation vessel moored at the operation site, equipped with equipment of collecting and demonstrating required information for floatover operation.

When the transportation/floatover vessel is near the platform field, the floatover operation team led by the floatover operation manager (supervisor) is mobilized to the OCC.

Other relevant personnel including client representative, MWS, meteorological expert, etc. will also be mobilized to the installation site. The assistant vessels are mobilized to meet the vessel with the topsides. The following activities take place:

- Vessel mooring hook-up
  The arrived vessel with the topsides will be hooked-up to the preset temporary mooring system with the assistance from the AHT vessels at a planned distance, say, a few hundred meters, away from the jacket entrance.
- Vessel and operation preparation
  - Vessel safety arrangement is set up
  - Vessel motion and survey system started, function tested and calibrated
  - Vessel motion responses to the on-site environments based on the forecast are evaluated to satisfy the requirements by the operation criteria
  - Vessel position, alignment control is acceptable
  - Ballast system used for the floatover operation started and functions checked to be ready for operation
  - Lighting system for operation and power supply are checked to be ready for operation
  - Communication system is set up and tested
  - Project induction is held being mandatory for all relevant personnel to ensure everyone is familiar to the vessel systems and the involved operation activities
  - Connect the vessel stern to the AHT.
- Topsides related preparation
  - Remove access to the topsides from the vessel
  - Establish access to the required areas in the grillage and on the DSS for seafastening removal operation and remove operation obstacles
  - Prepare tools to be used for the seafastening removal including cutting and welding equipment
  - Check and prepare the DSU to be ready for operation.

After all the survey, checking and preparation completed and all the checking lists are gone through with no issues and the weather conditions are suitable. A *ready for operation* meeting will be held at the OCC to authorize the commencement of the floatover operation. After the decision of go-ahead is made, the operation moves to the next stage.

9.5.3 Pre-docking Stage Activities

Pre-docking stage covers the time duration from the beginning of the movement of the vessel towards to the jacket opening to the halt of motion in front of the jacket

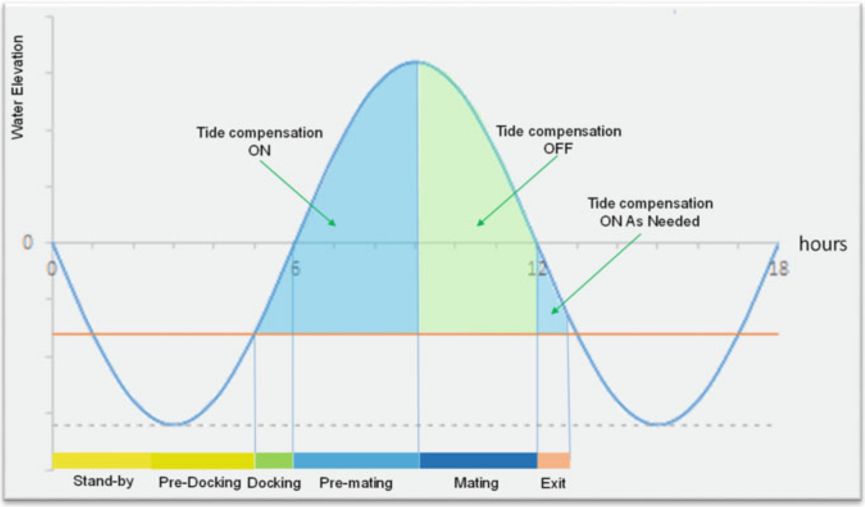

Fig. 9.12 The sketch shows the floatover operation planning with the tide including the application of tide compensation

opening. Before commencement of the vessel movement after receive go-ahead order with the acceptance from MWS, the following actions are carried out:

- Seafastening uplift stoppers are removed
- Active all DSU jacks to make the units ready for floatover operation
- Commence de-ballasting the vessel towards to the floatover operation docking stage draft
- Await the tide window—the floatover operation is always performed in the tide rising phase to be safe and effective
- Initial the tide compensation (Fig. 9.12).

The motion of the vessel in this stage is achieved by the coordinated actions of the towing AHTs and the adjustment of the mooring lines. The vessel will stop in front of the jacket opening with planned distance to the front jacket legs. The clearance between the side shell of the vessel hull and the corresponding row of the jacket legs are in the range defined in the operation procedure.

9.5.4 *Docking Stage*

When the vessel draft reaches the docking condition on even keel and the environment conditions including tide satisfy accepted criteria, the docking stage activities start.

- Active the tide compensation.
- Several elements of the seafastening between the topsides and the DSS only resist dynamic loads. Remove these elements at this stage.
- Prepare for the removal of the remaining part of the seafastening.
- Towing the vessel to enter the jacket opening with properly selected moving speed and at the same time to keep the vessel alignment using assistant AHTs.
- Prepare the connection of mating lines and make the connection at suitable conditions.
- Continue vessel motions step by step following the instructions from the OCC and closely monitor the vessel motion and the clearance between the stabbing cone and the top of the LMU.
- When the surge fender plates contacts the jacket legs, achieve sufficient compression of the fenders by the combination of mooring and stern AHT.
- After the correct position of the vessel is confirmed, engage the winch brake.

At this moment, vertically, the stabbing cones will be aligned with the corresponding LMU, but there is still enough clearance free of contact (Fig. 9.13).

Fig. 9.13 At the docking stage, the stabbing cones are aligned with the corresponding LMUs (Courtesy of Suresh et al. [3])

9.5.5 Pre-mating Stage

This stage in deed is the stage of preparation of topsides load transfer. The following activities take place:

- Confirmation of the stabbing cone horizontal motion not exceeding the capture radius
- Obtention of approval from the client for commencement of ballasting operation and removal of remaining seafastening
- Commencement of ballasting the vessel down and engaging stabbing cones
- Removal of the remaining seafastening between topsides and the DSS.

During the pre-mating stage, there can be contacts between the stabbing cone and the LUM, but there is not load transfer of the topsides weight from the vessel to the jacket yet. For the HIDECK floatover method, after the remaining seafastening are removed, the operation cannot be reversed. When the vessel draft reaches the value of the fully engagement between the stabbing cone and the LMU receptor, no horizontal relative motion then the operation is ready for mating operation (Fig. 9.14).

9.5.6 Mating Stage

Mating process is in fact the process of transferring the topsides weight to the jackets. It is achieved by ballasting down the floatover vessel for the fixed platform case. For floating platforms, the load transfer can be achieved by either ballasting

Fig. 9.14 In the premating stage, the stabbing cone is engaged with the LMU. *On the left*, from the stabbing cone movement traces it can be seen that the motion does not go exceeding the opening of the receiving cup horizontally (Photo credit to Lan Tay project)

down the floatover vessel, or de-ballasting the floating substructure or the combination. The entire process is carried out by several steps, which is defined by the percentage of the topsides weight being transferred. 100% topsides load being transferred to the jackets as well as the achievement of the steel-to-steel contacts between the topsides mating columns and the corresponding jacket legs mark the completion of this stage. Involved activities in this stage include:

- The load transfer in general begins at the maximum tide, then stop the tide compensation operation.
- Ballast down the vessel to a planned percentage, say 25 or 30%, and closely monitor the LMU deflection and the gap between the topsides underside and the top of the jacket legs during the process.
- When the status is confirmed to be acceptable, the next step commences. This kind of ballasting operations will be repeated several times following the operation manual/procedure until 100% load is transferred to the jacket (Fig. 9.15).
- Separate the topsides with the vessel through vessel ballasting and DSU retract if applicable. During the operation, resume tide compensation if needed (Fig. 9.16).
- Ballast the vessel to the withdrawal/exit draft and check the trim and heel angles to make the vessel ready for exit the jacket slot.
- Inspect the topsides seafastening area and prepare topsides installation completion report.

At this point, the platform integration is completed.

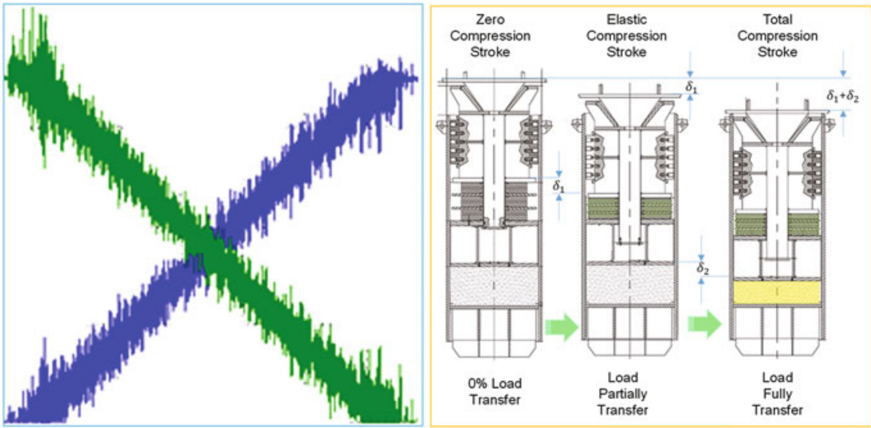

Fig. 9.15 Load transfer during the mating stage. *On the left* it shows the load changes experienced at the LMU (*blue*) and the DSS/DSU (*green*); *on the right* is shows the compression on the LMU during the load transfer

Fig. 9.16 The DSU with hydraulic jacks is ready for the retract after the topsides weight is 100% transferred to the jacket (Courtesy of Dorman Long Technology) [4, 5]

9.5.7 Undocking/Withdrawal Stage

After achieving the required clearance between the grillage on the vessel and the topsides underside and the vessel is ballasted to the withdrawal draft, then the vessel is ready for exiting the jacket slot (Fig. 9.17).

Fig. 9.17 Floatover vessel is moving off the jacket slot after the completion of the topsides installation (Courtesy of Dorman Long Technology) [4, 5]

- Depends on the vessel, the withdrawal operation varies. If the vessel is a barge without self-propelling capacity, then the operation will mainly depend on the AHTs and the mooring system. Otherwise, the vessel's propelling system can be used during this operation. The vessel will be moved out of the jacket slot.
- After the vessel exits the jacket, its draft will be adjusted to the transit elevation and it will be moved to the stand-off location.

9.6 Post-installation Operation

So far, the topsides installation is completed, but the installation project has not been completed yet. The post-installation operation activities consist of two main parts: the "in field activities" and the preparation of vessel demobilization.

9.6.1 In-field Activities

- As-installed survey of the topsides
  The as-installed survey of the topsides is conducted to check whether all the installation requirements are satisfied, e.g. the steel-to-steel contact between the topsides supporting columns and the jacket legs. In case the LMU is not fully compressed, if the full compression can be achieved naturally in future because of the creep of the elastomers, it can also be considered acceptable. The obtention of acceptance certificate from the client/MWS is necessary.
  Recall that before the vessel withdrawal, the survey of the topsides seafastening area for possible damage was already carried out.
- Survey of the jacket
  - Damage survey of the waterline part
  - ROV video survey of the jacket members under the free surface which were impacted by the floatover operation
  - ROV video survey of the jacket base and the seabed around the jacket
  - ROV video survey of subsea installations at anchor line crossing location if applicable.
- Obtention of the CPC (Certificate of Practical Completion) from the client/MWS
- Demobilize the mooring system
- Demobilize environmental monitoring equipment.

9.6.2 Vessel Demobilization Preparation

- Inspect onboard installation equipment such as DSU, removed seafastening. Prepare them for unloading at the demobilization port
- Inspect fender system for damage
- Prepare for transit to the demobilization port and plan the offloading activities at the demobilization site.

With the obtention of the CPC, the platform integration project can be considered to be successfully executed.

9.7 Mating Operation Contingency Procedure

Same to the loadout operation, there is a well-developed contingency procedure in place for the operation. It is mandatory for all relevant personnel to understand this procedure fully, before carrying out assigned tasks. This procedure addresses how to handle the identified hazard situations listed below.

- Environment related
  - Facing the tidal constraint by unexpected delay in operation
  - Tidal measurement equipment failure.
- Mooring system failure
  - Mooring anchor slippage
  - Mooring line failure
  - Mooring winch failure
  - Mating winch or mating line failure
  - Failure of releasing mooring lines, mating lines or the stern bridle.
- Failure of the towing line connecting the AHTs and the floatover vessel
- Seafastening installation problem such as the jamming of the seafastening pins
- Failure of ballast pump(s)
- Failure of tugs or vessel propulsion system if applicable
- Position/motion measurement system failure
- LMU damage such as the water ingress inside the LMU discovered during the preparation of topsides installation operation
- Failure of the surge stopper(s)
- Environment conditions at the installation site is disturbed, e.g. large wave created by the passing of large vessels, etc.
  In the procedure, measures of preventing the situation should be systematically addressed which can be as references during the preparation stage for related operation activities. The procedure also suggested the actions could be taken to solve the problems or reduce the damages. The most important are the experiences and capability of emergency handling of the operation team.

9.8 Summary

The discussion on the floatover operation execution in this chapter is quite general. The focuses are on the one (1) vessel floatover situation. All the contents covered are only as the references for the reader to gain knowledge of the operation details though the discussion is not deep and wide enough. Real learning is always through the operation practice and witnessing at operation sites.

In addition, it should bear in mind that every installation is different and the challenges may be unique. For a floatover project to be successful, it is vital that the team fully understand where the challenge comes from, build up the capability of quick identifying the issues, and have prepared solutions for them. To achieve the goal, intensive engineering and managerial efforts are needed. In addition, always keep in mind that accomplishing the assigned task safely is the most important and then follows the pursuing of cost effectiveness.

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Chapter 10
Evolution and New Source of Motivation

Abstract This chapter goes through the history of the floatover concept development and briefly summarized the process of technology evolution. The success of the execution of floatover projects since its early invention is accompanied with continuous technology improvement. The HIDECK floatover started by using selected barges towed by tugs/OCVs. To handle the floatover installation of the ever enlarged platforms in open sea with long transportation journey, self-propelled HLVs and DP technology have been introduced to make the project execution more cost-effective. Catamaran floatover technology has also been seriously considered for the platform decommissioning. New vessel concepts stemmed from floatover technology such as the Pioneering Spirit, DISV, etc. show the efforts of making the floatover operations safer, faster, less hindered by environmental conditions and cost-effective have never been spared.

10.1 Retrospect of the Application of Floatover Technology

As the HIDECK floatover method was first proposed, it was the efforts to meeting the challenge of lack of the lifting capacity by the existing HLCVs. Comparing to installing modules on the platform deck one by one using cranes, the concept of integrated topsides and the floatover method can be taken as the revolutionary progress in the platform integration. At that time, the trend of the HLCVs were already developed, but their capacity cannot handle the massive integrated topsides by a single lift. It was already observed that the development pace of increasing the capacity could not catch up the weight and size increase of the topsides in the offshore industry. Although the early success of floatover methods were inshore platform integration, the success of the operation proved that floatover method should be a new safe and cost effective option for platform integration operation and it should be applicable to open water installation for fixed platform, GBS and certain floating systems.

G. Liu and H. Li, *Offshore Platform Integration and Floatover Technology*,
Springer Tracts in Civil Engineering, DOI 10.1007/978-981-10-3617-0_10

Fig. 10.1 The heaviest single vessel floatover in open water—the integration of GBS platform Arkutun-Dagi completed in 2014. The total installation weight was 42,000 tons (courtesy of HMC) [1–3]

Especially in recent years, along with the trend of the integrated topsides becoming massive with total weight exceeding tens of thousand tonnes (Fig. 10.1). The challenge to the integrated topsides installation by HLCV is not only the lifting capacity but the safety as well. The installation practices show that with carefully prepared installation plan based on complete and qualified engineering analysis & design, the execution can be incident free for floatover method, even for the very heavy topsides. The critical installation equipment for floatover is the vessel for transportation and floatover operation. Large vessels such as H-851 of Heerema, I-650 of McDermott, and self-propelled HLVs of Dockwise and COSCO can

Fig. 10.2 COROCORO CPT Topsides was installed using floatover method in 2011. The water depth was only 5.6 m (courtesy of ConocoPhillips)

handle very heavy integrated topside for floatover installation. For topsides weighing several thousands of tons in the area HLCVs unavailable, suitable vessels for single vessel floatover or catamaran floatover can be hired with lower mob/demob costs.

In addition, the floatover technology can be applied in a wide range for water depths. It can be done in both deepwater and very shallow water depth, e.g. the 7400 Mt COROCORO CPT installed at Gulf of Paria, Venezuela with the water depth of only 5.6 m. The floatover operation used BB29 of BOA, HLCVs with the required lifting capacity cannot work in this water depth (Fig. 10.2).

Clearly, the weight and size of the topsides are not the factor to prevent the application of floatover technology. The main factor of hindering the application of floatover method is the weather conditions, especially the wave-induced motion makes extremely strong impacts. However, technology development with intensive engineering efforts and technical innovations help to overcome various kinds of hurdles and expended the floatover application opportunities. For example, in West Africa, the UNIDECK method have handled the swell induced motion issue very well and have successfully completed four (4) large integrated topsides installation using the UNIDECK floatover technology with the topsides weight up to 18,000 tonnes. The HIDECK floatover using DP vessel since 2003 is capable of reducing the WOW to half of the conventional approach, which leads to the big increase of application opportunities for floatover technology.

As to the single column floaters such as the spars, the compliant towers and the fixed platform without jacket slots for vessels to enter, integrated topsides concept is still applicable. The catamaran floatover technology can be considered mature for application, though for various kinds of reasons, the Kikeh spar installation has been the only one of real project using catamaran floatover in open water. The success of Kikeh project demonstrated the operability of catamaran floatover in the open water and a real option for platform substructures without an opening.

For all the above-mentioned reasons, floatover installation has become the favored method of choice when considering platform integration inshore or offshore.

Although the floatover operation process has been well-developed conceptually covering the operation stages/phases, main equipment, engineering analysis and design, hazard event identification, etc., the project success does not come from the repeat of successfully accomplished projects. Challenges for each project is special in the environment condition, the equipment to be used, etc., let alone the increase of the weight and dimension of the topsides following the industry trend. To rise to the challenge and solve all the problems in the operation activities, engineering efforts play the critical role. Each successful project completion contributes to the technology development and some may become a step forward progress.

As shown in Fig. 10.3, similar to all offshore installation projects, when the offshore industry frontier expands to the unexperienced area, e.g. deeper water region and new working environment such as the artic area with ice loading, new installation criteria are created. The gap between the installation requirements and the existing installation capacity is being widened. Engineering efforts under this

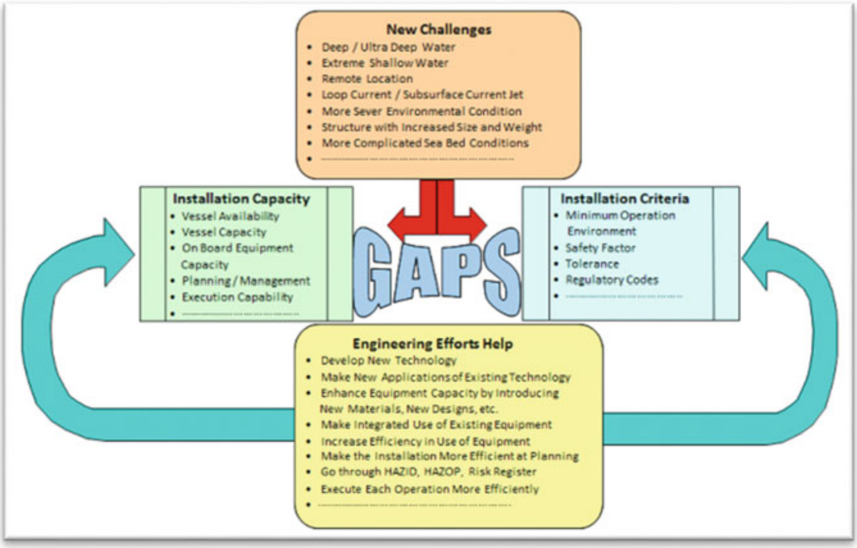

Fig. 10.3 Technical challenge and engineering efforts

kind of circumstance is focusing on the identification of issues, find the solutions, and move forward. In the real word, for the same new challenges, different approaches may be taken by different projects in pursuing the best solutions. The winners among these solutions can either make improvements to the existing technology or create innovative methods based on the methodology currently in use. All these adding together bring the floatover technology to the new level in safety and cost effectiveness.

10.2 Evolution

For the single vessel floatover, HIDECK and UNIDECK floatover methods are the most successful methods in recent years. The successfully completed projects happened in regions all over the world including Africa, Asia, Australia, Caspian Sea, GOM and North/South America. Let us look at the HIDECK technology development journey and see how the technology development has been achieved (Fig. 10.4).

- The efforts of making the floatover safer, faster, less hindered by environmental conditions and cost-effective have not been spared since the technology was introduced to the offshore industry. Measures were developed in controlling vessel motion and load transfer in the mating operation as well as the quick separation between the installed topsides and the floatover vessel after the

Fig. 10.4 On the left is the integration operation of PEMEX CA-Litoral-A platform using floatover in GOM in 2014; On the right is the floatover installation of BP CACWP (Central Azeri Compression and Water Injection Platform) topsides in Caspian Sea in 2005 (courtesy of McDermott and BP respectively)

mating completed. The designs of relevant equipment such as LMU, DSU and various kinds of fendering system have been going through continuous improvement. Rules and guidelines of design and inspection have been established. Vendors of the equipment built up capacity to deliver the equipment meeting all specified requirements. With the excellent performance of this assistant equipment, operation weather window can be widened and the floatover service region can be expanded. That is just what have been happening in the offshore field.

This kind of improvements is gradual and continuous.

- Some technical innovations stem from the efforts of overcoming the operation hurdles. One good example is the invention of handling the topsides elevations during transportation and installation using the strand jack system, which are very useful when topsides become heavier and the required platform air-gap is high. The idea is simple and straight forward, i.e. to keep the topsides elevation low during the transportation so increase the stability of transportation; when the topsides is installed, move the topsides to a required higher elevation. One of the approach is SJL (Strand Jack Lifting) technique by ALE (Abnormal Load Engineering), the other is FOHAG technique by Technip.
  - SJL technique
    As shown in Fig. 10.5, the topsides was positioned at a very low level on the upper deck of the transportation/floatover vessel during the transportation. The stability of the vessel system is surely much better than the conventional approach of jacking up the topsides before the loadout operation. The profit of the stability provement is that the vessel may be downsized significantly. It should be noticed that relative motion in vertical direction between the columns and the topsides is allowable when needed. During the platform integration, the topsides keeps its positon on the vessel deck. At the same

Fig. 10.5 Application of the "*strand jack lifting technique*" to the 6200-ton topsides in West Bohai Bay of China. The four (4) columns at each corner of the topsides are equipped with strand jacks for lifting the topsides (courtesy of ALE)

time, the columns slide down to mate with the jacket legs or preinstalled piles. The contact loads during the mating operation are understandably much lower than conventional floatover method and the LMU devices are no longer needed. Strand jacks mounted on the top of each column can then lift the topsides. Since the columns are already sitting on the solid foundation, the elevation adjustment can be made very accurate.
It sounds simple, but the operation of the strand jacks in the vertical direction should be well planned and operated very carefully.

– FOHAG technique
This approach works on UNIDECK floatover. It is different from the SJL technique in the sense that the topsides mating mechanism does not change —still use the combination of the vessel ballast system and the arrangement of the hydraulic jacks is the same as in the conventional UNIDECK method. The equipment added is called R&P (Rack and Pinion) system, of which the concept was derived from the Technip TPG500 jack-up. The layout of the R&P system is shown in the diagrammatic sketch in Fig. 10.6. The system consists of:

Transverse beams laying on the upper deck of the transportation/floatover vessel to be used for lifting the topsides to the desired elevation. Each of the beam consists of two half beams

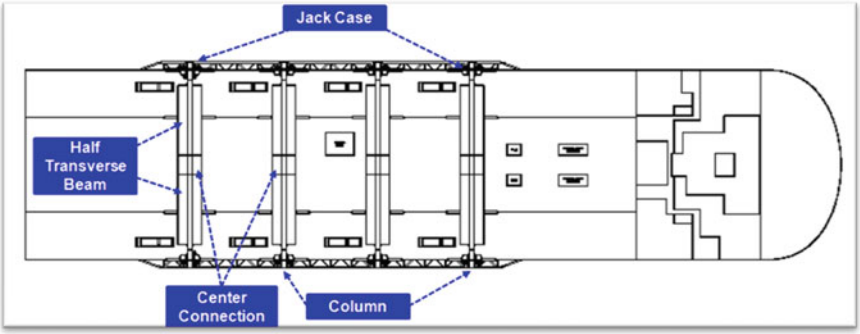

Fig. 10.6 Arrangement of R&P system

which is connected at the middle. Number of the beams depends on the topsides weight.
Corresponding to each end of the transverse beam, there is a jack case with the R&P system components which drive the vertically positioned jacking columns moving up & down inside the jack case. The ends of the transverse beams attached to column in the jack gear will lift the topsides up controlled by the R&P system as required.

This system applied mature technology from the jack-up platforms and should be dependable and safe. However, comparing to the SJL system applied to the HIDECK floatover technology, it is more complicated in the system assembling as well as the arrangement on the vessel. It can be seen that the SJL concept is well accepted in other floatover-derived technology during the discussion later.

- In the journey of the HIDECK floatover technology development, two (2) improvement actions can be considered as the step forward change maker.
  - Introduction of self-propelled vessel for floatover operation

  Originally, the offshore floatover projects used cargo barges or HLVs to carry out the operations. When the offshore projects go globalized, it becomes common to have an EPCI project be carried out by yards, sub-subcontractors, vendors located in multi-countries for the reason of quality and cost-effectiveness. Often, especially for huge platform, the topsides and substructures are fabricated at different locations where may be far away from the offshore installation site. This is true for not only fixed platforms but all other large platforms including spar, TLP and semisub-mersibles. Take the Chevron Blind Faith DDS production platform as an example, the hull was built in the Verdal construction yard in Norway, the topside was built in Louisiana and the platform were integrated at GIF in Texas.
  Several large fixed platforms installed in Southeast Asia with the integrated topsides were built in HHI, South Korea. One of the project was the Bayu Undan project of the installation of two topsides using floatover in the early

Fig. 10.7 The topsides of CQU and DPP topsides of the Bayu Undan projects were built in Ulsan South Korea and were transported the offshore site located at Timor Sea, Australia. The voyage was more than 2900 nautical miles (Based on Bayu Undan Project information)

2000s. The topsides need to be transported by a vessel to the offshore installation site one by one through a voyage of more than 2900 nautical miles (see Fig. 10.7).

Mr. Helge Røraas from AMC (Aker Marine Contractor), who was the effective project manager when the project started, proposed to use self-propelled vessel instead of the cargo barge to transport the topsides and carry out the floatover projects. By using self-propelled vessel, the time of the transportation journey was reduced to half comparing towing the barges. HLV Blue Marlin of Dockwise was chosen by the project to carry out the transportation and the floatover installation for both CQU and DPP topsides and the assigned tasks were completed successfully.

Besides significant reduction in transportation time when using the self-propelled vessel, there are more advantages such as the addition of maneuverability and smoothing the weather sensitive operations, risk reduction, etc. Since the successful completion of the Bayu Undan project, more massive integrated topsides installations have been recorded by floatover method using single self-propelled HLVs.

– Floatover using DP vessel

The floatover operation using DP vessel or "DP floatover" was also pioneered in the early 2000s. It can be seen as one-step further change in the single vessel

Fig. 10.8 DP floatover: on the *left* is the first DP floatover installation of Bunga Raya topsides in Malaysia, 2003 using COSCOL MV Tai An Kou; on the *right* is the DP floatover of Huizhou 25-8 DPP topsides in South China Sea, 2014 (courtesy of Talisman and CNOOC respectively)

floatover method. The self-propelled vessel floatover showed the advantage of significant reduction of the transportation time, but the floatover process is not changed too much comparing to the conventional floatover method. The DP vessel's involvement not only achieves the same time reduction from the topsides transportation, but changes the floatover process as well [4–7] (Fig. 10.8).

By applying DP floatover, mooring spread is not needed. The onboard DP system handles the vessel's motion and the clearance between the vessel hull and the substructure. The vessel still needs to install the fendering system including the surge stopper, but the maneuvering of the vessel during the docking stage and the mating stage does not need mooring/mating lines to assist. Obviously, the DP floatover reduces the time needed for the floatover operation and the operation is simpler comparing to the conventional approach. The advantages of the DP floatover method can be summarized in the following:

Shortens the floatover operation duration which leads to the reduction of WOW and lower the project costs

The floatover operation process does not need assistance of mooring system which makes the operation simpler and saves the time in planning and procedure development

Reduces the scope of the field preparation by eliminating the preset mooring system

All onboard mooring equipment are no longer needed.

Reduces opportunities of damaging the subsea structures near the platform because of the eliminating of the anchor installation and the use of temporary mooring system.

Vessel preparation is also minimal comparing to the conventional floatover operations

DP floatover needs intensive DP operation expertise and system redundancy. Before the commencement of the operation, DP trial should be conducted.

10.3 Concept Derived from Conventional Floatover Technology

The floatover technology has stood the test of real offshore projects and be recognized as a safe, dependable and cost effective option for offshore platform integration. The decision of applying floatover technology has been made at the very early stage in the field and project development for more and more platforms. For example, the jackets of large platforms are designed suitable for single barge floatover operation.

With ever-increasing topsides weight and the high air gap requirements, the conventional floatover technology faces huge challenges.

Conceptually the solution should not be very complicated—just make the elevation of the topsides adjustable. One of the example is the aforementioned FOHAG technology by Technip. Other options have also been developed based on the floatover concept but combines with other matured technology. Among the efforts, the self-installation concepts discussed earlier such as the SIP II and MOAB by OVERDICK Consultant Engineers are the successful examples. The installation concepts bear the evolution trace of floatover including the SMARTLEG technology, at least looking from the similarity.

For the SIP II platform installation, the operation is no longer the platform integration, but the anchoring of the entire integrated platform. The similarity to the floatover technique is at the installation without crane lifting activities. The technique can be taken as the derivative of the floatover methodology. The columns used in the platform installation resembles a bit similar to the SMARTLEG but the jacking systems might not be at the same level of complexity.

The MOAB concept actually has two versions from the installation point of view. One is represented by the Sylwin Alpha HVDC (High Voltage Direct Current) platform for which the concept can be categorized as the floatover

Fig. 10.9 Installation of HVDC platform Sylwin Alpha. On the *left*, the topsides is being installed to the substructure by floatover operation; the *right photo* shows the final topsides position after the elevation adjustment (courtesy of Siemens)

operation with the function of topsides elevation adjustment. The concept is similar to the FOHAG approach, although the mechanisms of the topsides elevation adjustment are different. The floatover vessel is needed for Sylwin Alpha HVDC [8] (Fig. 10.9).

This is a successful example of the floatover application to the platform for the industry of renewable energy.

The other version of MOAB represents the concept of the platform with capability of “self-installation” as demonstrated by the HVDC platform Borwin Beta. First, the design concept of it is quite different from the Sylwin Alpha. The topsides is designed with a watertight hull which makes the topsides can function as a vessel to be wet towed to the offshore site without the need of a transportation vessel/barge (Fig. 10.10).

On the other hand, this concept is different from the jackup, since the platform has the substructure part which by design was preinstalled before the topsides being wet towed to the offshore site and the installation is still be considered as platform integration. Therefore, it is a bit different to the SIP II concept in the sense of “self-installation”.

The topsides of Borwin Beta weighed 13,400 tonnes during the installation and the water depth was 40 meters. The operation was completed in 2013. The installation consequence had the similarity to the SMARTLEG method:

Once the topsides arrived at site, it was positioned over the substructure. Then the six platform supporting legs were first lowered to contact with the substructure pile heads. When all six platform-legs were securely connected with the corresponding piles, the topsides elevation was adjusted by using the hydraulic jacking system temporarily mounted on the topsides. The final elevation of the topsides was 20 m above free surface.

For both versions of the MOAB techniques, the capability of self-installation came from the combination of the weight supporting columns and jacking system. The columns allow the relative vertical motion of the topsides along them. With the topsides elevation being adjustable, it can be transported with lower COG and thus improve the transportation stability and/or widen the transportation vessel selection base when the vessel is needed for the transportation and floatover operation.

Fig. 10.10 Borwin Beta. On the *left* shows the topsides was wet towed to the field and the *right* one shows the platform after the completion of installation (courtesy of Siemens)

10.4 Single Vessel Catamaran Operation

Discussion on catamaran floatover was carried out in Chap. 6. The discussion covered the catamaran floatover operation by two (2) vessels. Successfully completed projects demonstrated that the catamaran floatover method is safe and a practical solution of platform integration for platforms with no opening wide enough in their substructures for single vessel to move in. However, so far there only have a few projects completed using catamaran floatover method, especially in the open water. The multi-vessel involvement might be the challenge for the decision making both technically and cost effectiveness. There have been efforts in trying to use a single pieced vessel to carry out the catamaran floatover operation, i.e., the hull of the vessel does not enter the substructure. In the opposite, the vessel will create an opening wide enough to put the substructure in it. The following are the two different approaches.

10.4.1 Skid On

The concept of skid-on is to have parallel beams or sponsons installed on to the hull of the floatover vessel. The length and the distance between the beams or the sponsons form a space to contain the platform substructure. The topsides can be carried on the beams/sponsons and moved to the position over the substructure columns and perform the mating operation.

Fig. 10.11 On the *left* is the floatover equipment by the ICON Engineering Pty Ltd for installation topsides up to 1200 tonnes. The photo on the *right* is the installation of the 1500 ton topsides of the CX-15 platform for EPZ Energy if Peru (courtesy of ICON Engineering and HortonGMC respectively)

- Cantilever beams

  First, look at the examples of skid-on using cantilever beams/frames shown in Fig. 10.11. The topsides to be installed using this kind of skid-on operation are light ones. During the transportation, the topsides are positioned sitting on the part of the skid beams/frames supported by the vessel hull. In the installation site, the vessel approaches the substructure and with the cantilever beams on each side of it and the topsides is then carried to be over the substructure for the mating operation.

  This technology is applicable to the offshore area where the lifting crane vessels are not available. The important equipment are the cantilever beams and it should not be difficult to find vessel to install the equipment for floatover operation. When topsides is heavy, it will be quite challenging for the beam/frame design and the vessel structural enhancement.

- Sponsons

  The concept of skid-on topsides installation by using vessels with sponsons installed on each side of a vessel/barge is by Gengshen Liu and Helge Røraas and the patent is pending. As shown in Fig. 10.12, the sponsons and the vessel hull form an opening wide enough for the jacket to be contained and the topsides can be aligned with the jacket and the mating operations is then carried out by ballasting the vessel.

  Different from the cantilever beam approach, the sponsons not only support the topsides weight by their structural strength, but also create buoyancy themselves. With proper design of the sponsons and the integration with the vessel, much heavier topsides can be installed by this method.

  The above two (2) options are specifically suitable to the projects of small single column floater such as the buoyant tower (CX-15), or the fixed platform already

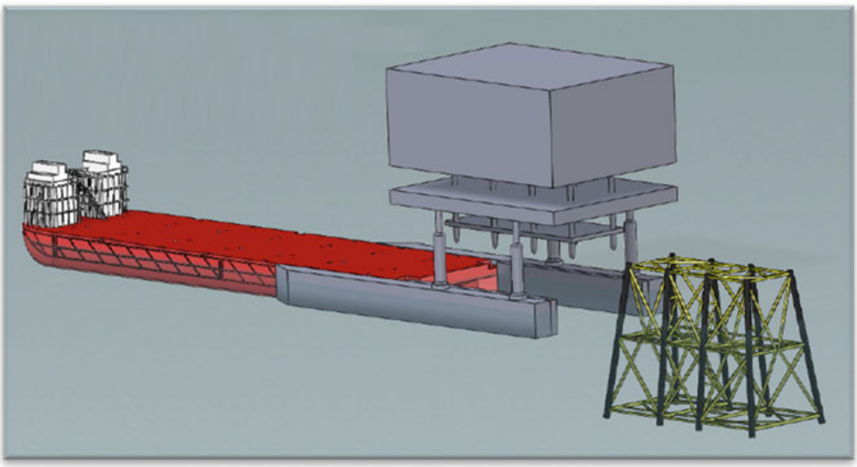

Fig. 10.12 Skid-on operation being carried out by a vessel/barge installed with sponsons

designed for crane lifting installation. There is no need for the modification of the jacket structure and the vessel preparation is relatively simple.

10.4.2 Specially Designed Vessel

To meet the market demands on the catamaran floatover, there can be two feasible approaches. One is to develop fleet with large capacity of HLVs and corresponding equipment to handle the catamaran floatover operation effectively, as the TML system developed by Twin Marine Heavylift AS. Their fleet can work on the platforms in a wide range in weight and dimension. However, the operation is still a multiple vessel campaign and the operation need to go through the process of topsides transfer involving three vessels and specifically designed equipment.

The other approach is to design a catamaran vessel with a wide opening to handle the floatover installation. There have already been several concepts in the industry. The two representative examples are the Technip DSIV and the Pioneering Spirit of Allseas. All these kind of vessels are multifunctional vessels, which can carry out installation, decommissioning and other offshore construction/service tasks (Fig. 10.13).

Pioneering Spirit is the largest existing OCV with 382 m overall length and 124 m wide. It is designed to possess lifting capacity of handling 15,000-ton jacket and 48,000-ton topsides. The slot is 122 m long and 59 m wide, which is enough for the catamaran floatover operation. However, since her depth to the main deck reaches 30 m, it needs a vessel/barge to have the topsides loaded out at the quay and then transfer the topsides to the beams on her deck. Comparing to other OCVs, she can work in much more severe weather conditions with higher working effectiveness.

The DSIV is also a multi-functional vessel by design. However, it more focuses on the floatover installation and decommissioning. The main structure of the hull

Fig. 10.13 Pioneering Spirit and DSIV (courtesy of Allseas and Technip respectively)

are two large pontoons. The hull size measures 130 m × 96 m × 12 m. When perform the floatover installation, the vessel can handle the topsides weighing up to 25,000 Mt and the air-gap up to 28 m. According to Technip, the DSIV can reduce the floatover completion time from the 21 h done by the conventional method to 12 h.

For these kind of vessels, one of the big challenges is how to keep the high utilization. The activities of decommissioning and offshore renewable devices deployment should create large working loads to various kinds of multi-functional OCVs. Especially, the large number of aged platforms need to be decommissioned in the coming years.

10.5 New Source of Motivation in New Technology Development

10.5.1 Offshore Platform Decommissioning

Fig. 10.14 There are four (4) platforms in the Brent field—Alpha, Bravo, Charlie and Delta (courtesy of Shell)

It has been always the case that all new technology developments are driven by the demands of the industry. The development and evolution of the floatover technology is no exception. Look at the special vessel designs for carrying out single vessel catamaran operation, e.g., the Pioneering Spirit owned by Allseas. The vessel is capable of handling massive topsides floatover for all kinds of substructures.

According to the industry news, Norway's Statoil has already signed a contract with Allseas for installation of three platform topsides for the drilling, processing and living quarter platforms on the Johan Sverdrup field. The drilling platform topsides will be installed in 2018, and the processing and living quarter topsides will follow in 2019. The heaviest lift will be carried out during installation of the processing platform topside that weighs around 26,000 tons.

However, the targeted market for Pioneering Spirit was the decommissioning of the aged offshore platform especially the large ones. By using this huge vessel, the dismantling operation of platform topsides will be greatly simplified and leave the most essential decontamination and disaggregation work to be carried out in a decommissioning yard onshore.

Decommissioning has been going on for years. Hundreds of installations have been taken offline since production in the North Sea started. The problem now is that so many fields have reached the end of their life and there is the assumption that there isn't the capacity in the supply chain to handle the large, heavy offshore platforms. According to an article published in 2009, Oil & Gas UK projects expenditure for decommissioning oil and gas installations on the UKCS by 2030 of £19 billion ($32.2 billion), rising to £23 billion ($38.9 billion) by 2040 for existing facilities.

The Pioneering Spirit has already been contracted by Shell to remove platforms from their Brent North Sea field, beginning with Brent Delta this year (2016) after the completion of the removal of the Yme platform on behalf of Talisman Energy. Brent Delta platform is one of four platforms in the Brent oil and gas field. The 23,500 tonne'topside' of the platform would be removed in one piece by the Pioneering Spirit. The contract from Shell also includes the removal of Bravo and Alpha with an option for Charlie (Fig. 10.14). To clean up the whole Brent field including the decommissioning of the four platforms it requires a decade and costs billions of pounds according to the estimates by Shell (Fig. 10.15).

Although the vessel's price tag reaches $1.7 billion, seems Allseas are confident in gaining large market share to be profitable. Allseas has considered building a second massive vessel even much larger vessel than the Pioneering Spirit in both dimension and capacity. The new vessel's topside lift capacity will reach 72,000 t. The vessels width is increased to 160 m, which is expected to be operational in 2020. With the two vessels, 12–18 topsides can be decommissioned per year, radically altering the decommissioning market in the North Sea.

The other new technologies developed for the platform integration could also be applied to the platform decommissioning at different regions for different size of aged platforms. Offshore decommissioning projects would be carried out in the GOM, South East Asia, Brazil and West Africa. Especially in GOM after the NTL No. 2010-G05: "Notice to Lessees and Operators of Federal Oil and Gas Leases and Pipeline Right-Of-Way Holders in the Outer Continental Shelf, Gulf Of Mexico OCS Region Dead Cost" was issued by the Department of Interior in 2010.

The new rules outlined in NTL 2010-G05 require wells that have not been used for the last five years to be permanently abandoned, temporarily abandoned, or zonally isolated within 3 years after Oct 15, 2010. According to the data from the

Fig. 10.15 Illustration of dismantling the topsides of Brent Delta (courtesy of Shell)

US Bureau of Safety and Environmental Enforcement, as of February 2015, there were 241 platforms in the GOM being “idle iron”, and a further 294 on expired, or terminated leases. It is not difficult to see that there will be large amount of projects in the region, which creates opportunities for companies with various kinds of technology and equipment. Since platforms in regions other than the North Sea are generally smaller and the environmental conditions are relatively benign, huge vessels like Pioneering Spirit may lose their competitive edge.

Any new technology developed for offshore decommissioning should not only think about “one go” operation to save time and reduce cost in a safe manner, but also to minimize the pollution to the environment.

10.5.2 Offshore Facilities of Renewable Energy and Other

The floatover technology has already been introduced to the installation of the offshore facilities of renewable energy, such as the Sylwin Alpha HVDC for the windfarm in the North Sea. With the development of the renewable energy gaining momentum, more offshore construction activities can be expected. Some technology may be directly applicable, but modification or evolution of the existing technology are surely needed because the differences in many factors. The principle of the installation methodology should still be safe, cost-effectiveness and minimizing offshore operation work scope.

In the present world, the trend of developing green energy become crystal clear, engineers with vision should seize the opportunities of innovation based on their knowledge and accumulated experiences. There are also other areas of ocean exploration and development, such as mining, aquaculture, entertainment, etc., where the technology of offshore industry can be introduced for application in the construction of infrastructure and facilities.

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