Submarine Cable Laying and Installation Services

For the Offshore Alternative Energy Industry

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Abstract: In the submarine cable laying industry there are currently two primary users of installation services, the Telecoms industry and the Power industry. There is a growing third market in the submarine cable and installation services industry, and it is the Alternative Energy industry. Additional challenges in the alternative energy market deal with the number of offshore/underwater generating stations that must be interconnected and the fact that in some situations, such as underwater generating plants, the generator units must periodically be surfaced for maintenance and/or repair.

This paper will identify the commonly utilized submarine cable laying methodologies and marine assets employed to install submarine fiber optic cable (SFOC) and power cables. It will further elaborate the utilization of currently available installation services and the application of these existing services to the unique world of alternative energy.

Introduction

In the world of offshore subsea installation work there exists established companies with marine assets to perform the required work. Likewise, there are existing companies that perform ancillary services such as project management, system engineering and associated planning, coordination and operations activities.

These existing companies and marine assets can be utilized to perform required installation work for the alternative energy industry. There are unique differences in the use and application of marine assets for the offshore oil & gas industry and the alternative energy industry. This paper will demonstrate those differences but more to the point this paper will demonstrate similarities that both industries offer in marine asset utilization.

The Operating Environment

Alternative Energy systems in the marine environment attempt to make use of large open areas of the near coastal ocean to provide a base for installation of multiple generating plants. These generating plants take the form of offshore structures to support windmills, subsea structures to support tidal current generators and subsea moorings to support wave generators. All of these generating systems are designed to sustain an existence in an environment identical to the offshore oil & gas industry.

The oil & gas industry has been operating in the marine environment for the past 60 years. This duration of continuous operations has resulted in advances in vessel design, systems design and operating standards developed to meet the ever increasing water depths of operation. Currently the oil & gas industry operates in water depths to 3,000 meters and is expected to surpass this standard operating depth within the next 3 – 5 years.

Water Depth Challenges

In the offshore industry, water depth is crucial to the design, cost and schedule of installed systems. In the alternative energy industry, critical components that are keyed to water depth include structures and cabling. Deeper water equates to more critical design of the:

- Structure tower or gravity base
- Power Cable design and;
- Subsea electrical components

The permitting process generally becomes less involved with increased distance from shore. This is the current state of affairs for the industry. However, in general, the further offshore you venture the deeper the water depth and the higher the cost.

The deep water challenges can be summed up as follows:

1. Larger offshore structures to reach the seabed and larger surface machinery required to install the larger structures.
2. Increased weight of large diameter power cables in deeper waters requiring the use of larger cable handling machines for installation.
3. Larger crane handling capability for lifting and lowering objects to the seabed.

4. Larger vessels to hold the increased weight and length of structures and cable.

The good news is that the offshore oil & gas industry has been operating in deep waters and the required marine assets exist to provide installation services to the alternative energy industry.

The downside is increased scope & scale in deep waters directly translates into increased cost and schedule for installation services.

Existing Marine Assets

The oil & gas industry have several marine assets available which could provide required services to the alternative energy industry. Nomenclature for vessels in the offshore industry is varied. Offshore construction vessels, OCVs, are the primary choice for deepwater installation work. Basic vessel requirements for offshore construction work are as follows:

- DP capable
- Accommodations for 45 persons+
- Minimum 800m² deck space
- Multiple crane capability (25 - 100mt)
- Subsea reference or positioning system

These vessels are in high demand and short supply. In the current oil market environment, with oil prices over $130/bbl, the oil & gas industry is on an increasing expansion of new fields and infrastructure to produce and transport oil. This has resulted in high day rates for OCVs ranging over $100k per day.

A2SEA Vessel Overhead View

Project planners must be cautious in their system design and approach to offshore installation requirements. Downsizing the system is not always an option. However placement of generating systems in areas suitable to reduce the size of the required structures can go a long way towards reducing requirements for large offshore construction vessels resulting in reduced installation costs.

The shallow water environment, in most cases, can result in utilization of smaller and less costly marine assets. These vessels generally cost in the range of $35k to $65k per day plus fuel. Fuel costs for these type vessels will average $15k - $25k per day.

Vessel Types

The types of vessels required for installation services consist of the following:

- Tugs & barges for shore landing services and transport services of offshore pieces.
- Heavy lift capable vessels for handling and installing offshore structures, deployment of generator assemblies and associated piece parts.
- Cable lay capable vessels for laying and burial of power cables required for inter-field connection and power transport to shore.
- Sub-sea capable vessels with ROV or diving assets to perform inspection services of the subsea plant.

All of the above vessels are available in today's market place with no need for special builds or purpose conversions. These vessels can be categorized by what is commonly referred to as a "vessel of opportunity".

Diving & Light Construction Vessel

The above requirements can be covered by one vessel which we will call the “Swiss Army Knife” model, which we will cover in the proceeding pages. These Swiss Army Knife vessels are rare and costly. Utilization, scheduling and operational restrictions all need to be taken into account when considering this type of vessel. They are generally deep draft vessels that cannot operate in shallow water areas. However they bring a lot of capability to the project in one package.

A realistic method of installation is to break up the work load and spread it across different specialty assets to be mobilized and utilized at strategic phases of the installation process.

For instance, a tug & barge can be the most valuable asset for installation services since it can be utilized as a flat bed truck for movement of material to/from shore and worksite. It can likewise be utilized for near shore installation of cables. Securing a barge unit in the field can pose problems since they need to be either tied up to another vessel or anchored in a 3 – 4 point moor arrangement for stability.

For heavy lift, jack-up lift boats can provide the required lifting capability. Jack-up legs provide good stability offshore for installation services. These units are widely available along the Gulf coast of the US and can perform the required structure installations and setup of the generator packages.

Cable laying and burial is the most specialized part of the installation. Handling machinery for cable installations is not easily or readily available to the industry as stand alone equipment. Most cable handling machinery is contained within cable laying vessels. There are resources available that can provide the necessary cable machinery, but in today’s submarine cable market availability may require a long lead time.

Cable laying vessels are generally large marine assets of 110 meters or larger. They are limited in their scope for generator and machinery handling or heavy lifting due to their specific application design. They do contain large amounts of cable storage and redundant machinery handling systems for installation services. Cable lay vessels are expensive and availability is very tight in today’s market.

One option to hiring a cable vessel is to consider the procurement of the necessary cable machinery or use a contractor that has a portable set of cable machinery for mobilization onto one of your marine assets. However, availability is limited in today’s tight market.

Subsea Assets

Cable burial or protection can take place either in-situ during installation or post-lay. The in-situ method utilizes a cable burial plow and post lay involves an ROV with a cable jetting tool. Burial plows are large pieces of equipment (9 mtrs long and 18mt) requiring large handling equipment for launch & recovery. Plows are not easily mobilized to a vessel of opportunity.

The ROV, however, is a smaller unit with a smaller overall footprint which mobilizes very quickly to vessels of opportunity and can provide required burial protection of the cables. The downside is that the cable will not be buried simultaneously with cable installation.

Deep Sea Trenching ROV

Divers can be utilized in shallow water areas for inspection & installation services. Divers can work in all water depths to 500 meters. However, deeper water entails higher cost and riskier operations. Generally speaking, diver working depth for this type of work is limited to 20-50 meters. Divers are normally utilized in the near shore cable installation activities such as cable landing services, post lay inspection, and installation of cable protection in environmentally sensitive areas where burial may be prohibited.

Any reduction in size of marine assets must be weighed against system requirements such as deck loading capacity, size and weight of sub-sea and surface components to be installed, and the amount of endurance required for stay-at-sea capability.

Defining system requirements is key to determining overall project schedule, development and installation costs.

Installation Requirements

Requirements for installation activities will vary depending on the type of generator to be installed. We will identify submarine cable requirements for 3 types of generator installations as follows:

1. Wind Farm
2. Tidal Generator
3. Wave Generator

Wind Farm Generator

Wind farm generator installation requires use of marine assets that can handle & install the following:

1. Shore side facility to mobilize and stage all parts/pieces to be installed.
2. Vessel to store on deck and deploy steel structures (towers or platforms) for installation from the sea-bed to above the surface to support wind generator assembly.
3. Vessel to store on deck and lift the nacelle to the top of the steel tower.
4. Vessel to store on deck and lift blades for installation to the nacelle.
5. Vessel to store on deck and deploy power and communications cables required for connection back to shore. This includes cable handling machinery.
6. Vessel with necessary sub-sea equipment to monitor, record and bury the subsea plant.
7. Shore landing & burial services to receive cable(s) ashore and terminate to the utility outside plant.

All of the above requirements can utilize one marine asset or several marine assets to accomplish installation, with the exception of the shore landing services. The primary design driver for installation services is water depth and distance from the shore landing. These two parameters drive the size of the steel tower and the amount of cable onboard to run from the sea-bed up the tower and back to shore.

The primary piece of equipment for the installation contractor is crane hoisting capability to both lower objects to the seabed and hoist objects over 70 meters above the deck of the installation vessel.

Lifting safe working load capability of over 100mt may be required. However, SWL of lifting machinery will be dependant on size and weight of components to be installed. In either case, the high load lifting capacity required is not commonly found on vessels of opportunity.

A2SEA OCV Installing Windmill

In addition to lowering objects to the seabed, the installer should be capable of monitoring the placement of these objects on the seabed with either an ROV or divers. This can be provided by a separate vessel or performed from the installation vessel.

Site Survey

Prior to any installation activities, a marine route and site survey must be accomplished. Data collected during the site survey will dictate the exact nature of any required seabed preparation. With results of a sea-bed geo-technical survey, it can be determined if a suitable weight bearing geology exists for installation of required towers and associated loads to be encountered in supporting the windmill. From results of the geotechnical survey it can also be determined what additional site preparations are required for installation of wind towers such as pile driving to support the tower, cementing, rock dumping, and shore landing requirements of the trunk cable.

The marine route & site survey will encompass the entire field of installation from the windfarm offshore to the shore landing areas for landing the trunk cable(s). Specialized companies provide this service with their own marine assets to perform the necessary offshore and onshore survey work.

Desktop Study

Likewise the survey companies can provide the desktop study (DTS). This is the critical part of the installation planning process whereby the marine cable route and structure sites will be technically evaluated based on available public information of the area of interest. Critical criteria such as permitting, environmental conditions, tidal conditions, weather conditions, local government agencies for permitting, fishing activity, fishermen groups, social conditions, etc., are all part of the analysis provided in the DTS.

Swiss Army Knife Approach

The customer must consider taking the "Swiss Army Knife" approach to the installation process. This approach can provide a more costly option on a per day basis but it does have advantages. With one primary vessel performing all stages of the installation process, risk of delays due to the coordination and availability of multiple assets is eliminated, minimizing potential for schedule growth. Schedule growth due to delays of the installation assets availability and capability at the worksite directly relates to cost growth. The Swiss Army Knife vessels consist of OCV type ships.

Typical Oil & Gas OCV

The OCV is a very high spec, very capable vessel for all types of offshore construction activity, including alternative energy projects. The typical OCV has a large flat deck area for mobilization of a variety of equipment and other resources depending on job requirements.

The downside to utilizing an OCV includes cost & schedule requirements for de-mob and re-mob of different deck layouts to perform different stages of the installation process. The deck layout for installation of towers, nacelles and blades would be different from the deck layout for cable installation and burial. The customer is advised to perform necessary trade studies to determine the most cost effective marine asset solution.

Cable Installation

The cable laying portion of the installation has its unique challenges. Traditionally, cable is landed on shore and laid across the ocean or body of water with a landing on the other side. Protection in near shore areas is effected by cable burial using burial plows and/or fitting of articulated pipe in environmentally sensitive or high abrasion areas. Cable protection is primarily used to protect against fishing activity and areas of abrasive geology, such as rocks, where burial is not recommended or possible. Avoidance of vessel anchorages is highly recommended. The marine survey will determine the best route to take to preserve cable system lifecycle.

Another cable laying challenge is routing of cable from the seabed, up the side of the tower to the nacelle for termination. Attachment of the cable to the tower and nacelle must be carefully designed to support cable weight and environmental forces acting upon it for the system design life. Similar vertical routing is performed in the submarine cable industry whereby fiber optic cables are connected to oil platforms in a similar manner. There are existing designs for hang-off devices that support suspended cable so it may be secured to the side of the structure.

Cable route engineering is required by the installer or manufacturer to ensure that the proper amount of cable is made to provide for sufficient length to make all of the necessary course changes and provide for any slack requirements such that cable protection can be implemented where required. The cable engineering length is what the manufacturer will build. What you don't want is to run short of cable and have to make expensive splices, or have large amounts of cable left over from the project.

The last challenge to laying cable in the wind farm is the multitude of connections to be made to multiple windmills. All of these connections can individually run to shore (expensive) or can be terminated to a sub-sea sub-station or junction box specifically designed to combine the power from all generators and run a single cable to shore for termination. Connections to the sub-sea sub-station can take place with existing technologies utilizing wet-mateable connectors[1]. These type connectors are used in the oil & gas industry. Investigation has indicated that wet-mateable HV connector designs exist for use in the subsea industry. This could simplify the cable handling for installation and future maintenance or replacement.

For AC power export applications the new XLPE multi-core cable designs allow the use of a single cable. Depending on the HV requirements these cables can be very large in diameter, harder to handle, higher in cost, have long lead times and require specialized handling for deployment. An option to the single multi-core cable is to utilize 3 single core cables. This option will simplify handling; is more readily available, is lower in cost, and is easier to handle on the deck of a ship with standard deployment machinery. Likewise storage of the cable on deck can be in the form of cable reels, depending on individual lengths per windmill.

It is has been proposed to bind the 3 conductors on the surface vessel to make one twisted 3-strand cable for deployment over the stern for laying on the seabed. This concept can provide savings in time & money for procurement of the necessary cables and availability of the necessary deployment resources.

Cable Machinery

There are several types of cable machines that are commonly utilized in the submarine cable lay industry. The most common types are Cable Drum Engines (CDE) and Linear Cable Engines (LCE). The CDE is a capstan type machine consisting of a steel drum of 4 meter diameter with 3 wraps of cable reeved onto the drum to provide payout and pickup of the cable. The CDE also contains an ancillary machine called the Draw-Off Hold Back (DOHB) unit and is a 4 wheel pair LCE fitted forward of the drum engine and acts as a hold back device to the cable when paying out. The DOHB tails cable onto the CDE in order to generate cable gripping friction.

The LCE is a multiple wheel pair device consisting of vertically opposed rubber tires which hydraulically close down on the cable. Hydraulic squeeze force creates cable friction between the tire pairs to hold the cable. These machines are normally utilized to deploy fiber optic cable from cable tanks. However, when recovering cables from the seabed that are wet and/or covered with marine growth, LCE's are not the preferred machines. This is due to decreased friction and higher slippage. Higher outboard tensions are also encountered when recovering cable requiring a pulling force that can create slippage with an LCE.

Track / Belt Drive LCE

A third type of cable engine is a linear, tracked cable engine. These cable engines consist of 30" – 36" long belts or track drives that close down on the cable in pairs and provide the necessary holding force for payout and pickup. The belt or track pair machines provide a larger surface area for holding cable and are more suitable for large diameter cables. The belts are typically 8" – 10" wide gripping surface vs. tire pairs which are 3" – 4" gripping surface.

Any of the above machines are fully capable of deploying power cables. However they do have their limits. Standard submarine cable machinery has a maximum cable diameter of 150mm and deployment SWL of 25mt for the CDE. Deployment SWL of the LCE or tracked engines depends on the number of wheel pairs. A good rule of thumb is 1 metric ton for every wheel pair and 2 – 3 metric ton for each tracked pair.

4 Meter Cable Drum Engine

There are endless deck configurations which can be accommodated for cable deployment. The most critical is deck length for separation of the machines from the cable tanks and the vessel stern chute. There must be sufficient deck length to provide for cable minimum bend diameter between the cable tank and machine. Room is also required for fitting of cable stoppers or other rigging to the cable aft of the machine and before the stern chute for repair operations or stoppages for any reason.

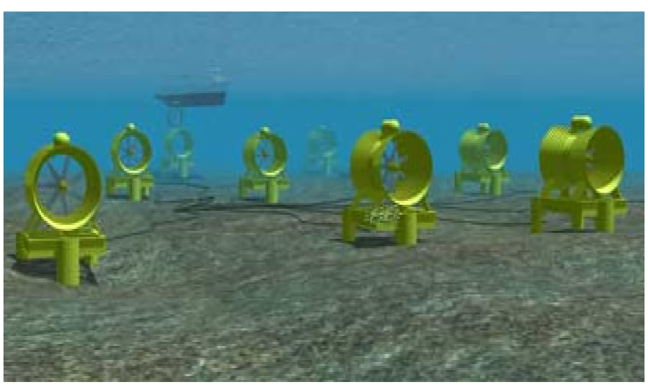
It is the author's opinion the cable drum engine would be the preferred machine to use for a majority of power cable installations due to its higher SWL capacity, no-slip payout & pickup capability and ability to handle large diameter cables. Unfortunately, this machine is the largest and heaviest of all of the cable machine types and hence the most difficult to mobilize and demobilize. Most CDE's are permanently fitted to cable vessels whereby the LCE is the portable machine of choice.

The final necessary piece of major equipment is a cable tank. Depending on power cable size, the tank can either be static or dynamic. For large diameter power cables (>100mm) a turntable type cable tank is to be utilized. Once again it all depends on power cable dynamic properties with regards to storage and deployment. System design must take into consideration the cost impact of requiring a turntable style cable tank. These units are not readily available in today's marketplace.

The cable may be delivered on reels. In this case a deck configuration could be utilized such that the reels could be setup on stands to feed into the cable machine thereby negating the use of a cable tank.

Tide Generator

The installation of tide generators involves the same dynamics as installation of wind farms with the added environmental dynamic of working in high tidal current areas. The necessary marine requirements are veritably the same as the previous section as follows:

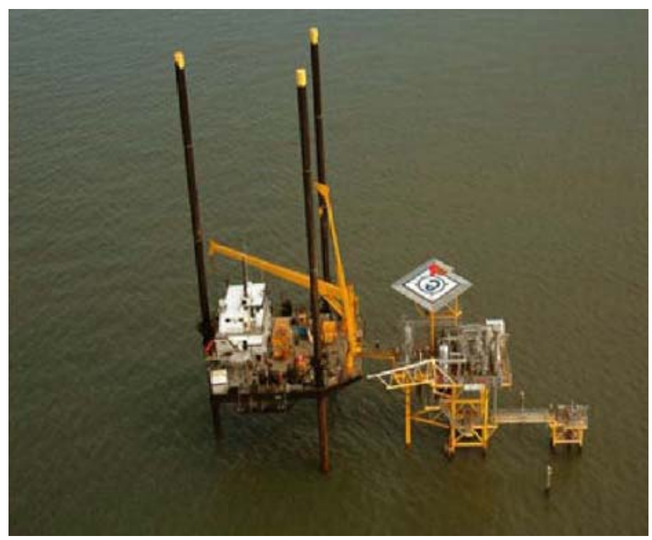


Subsea Turbine Farm

- Marine survey and site study.
- Site preparation for landing of generator and support structure to the seabed.
- Shore base for staging of equipment and materials.
- Heavy lift capability with the ability to lower heavy objects to the seabed.
- Cable laying capability for installation of power cables.
- Subsea equipment for monitoring installation and post-installation activities, direct burial or retro-burial activities and the task of hook-up of electrical cables to the various generator stations.
- Shore landing and burial services for terminating export cables with the utility OSP.

High current areas present a real challenge to using DP OCV's in that these vessels propulsion and DP systems are typically rated to operate in head on currents of < 3 knots.

The vessel types best suited for installation of tidal generators include 4 point moored vessels, or the lift boat or self-elevating jack-up style work vessels. The 4 point moored barge or vessel could remain suitably stationed in high currents. However, even these vessels are limited to currents of approximately 5 knots. Lift boats or self-elevating jack-up vessels with legs extending down to the seabed are the most logical type vessel for use in high current areas.



Typical Liftboat

Use of a lift boat vessel must be weighed against the fact that in severe currents, above 3 knots, no other ancillary subsea operations, such as ROV or diving, will be possible. Likewise other support activities from shore may not be capable of functioning in high currents. Essentially the main vessel can maintain position during the times of high currents but no other sub-sea operations can take place.

Existence of high currents creates a real risk for schedule and cost growth that must be addressed early in the planning stages. Trade study and concept of operations must be carefully thought through to determine the best combination of marine assets to use.

Burial of cable in high current areas may not be possible due to the scouring effect of the high current on the seabed. Generally speaking these high current areas in shallow water have a geomorphology consisting of hard rock bottom. The securing of the cable on the seabed must be taken into consideration to maintain the lifecycle of 25 years. Movement of the cable along the abrasive seabed will create maintenance issues in the future. In these situations, drilling may present the best solution for secure cable installation.

ODI Wet Mateable HP Connector

Another challenge for cabling tidal generators is generator recovery from the seabed for periodic servicing. This means the cable must either be removable via wet-mate-able connector from the generator, or have a service loop that is a minimum of twice the water depth.

Dealing with such a cable service loop creates design challenges. Excess cable must be stored on the seabed during the periods of operation. Such storage must prevent cable movement in a high current environment to maximize cable life span.

A cable reel system is one potential answer, although the author is not aware of any existing applications such as this. Such a system would require development of a prototype system from a firm that is familiar with the challenges of operating in the harsh underwater environment.

Sub-sea wet-mate-able connectors are another option. However, the extremely high voltages typically utilized in power export applications may require development of higher voltage solutions. There are companies in the industry who have developed solutions for high power applications. Whether these COTS solutions fit the needs of the alternative energy industry depends on the electrical requirements of the system design.

Wave Generator

Wave generator challenges are similar in scope to tidal generators and wind farms with the exception of high swell or sea state environment. It is the motion of the ocean that induces the power in these machines.

Additional challenges for wave generator installation is sea bed attachment. All wave generating devices; from moored buoy type devices to large scale floating devices are moored or attached to the seabed in some form. Suitable sites for placement of these types of generators provide consistent, high energy wave motion and can vary in water depths out to 50 meters. Vessel operations in near shore, high wave areas entail special risks which must be considered during site development planning.

Pelamis Wave Generator

Sea bed attachment points and cabling to shore all have similar requirements to wind farm & tidal generator systems. Similar principles apply for project planning and implementation in the marine environment. Some systems may require lifting into place while others will need to be towed into place. Subsea operations are still a major part of such installations.

Motion between the generator and the cable connection is a key risk area. Design of the mooring system is another key component to the installation lifecycle.

Conclusion

Like so many other marine projects, the critical part of implementing any installation in the marine environment begins with a sound systems engineering and project management approach. The basic principles consist of:

- Conceptual design
- Design reviews
- Trade-off analysis
- Concept of operations
- Risk analysis
    - Technical
    - Cost
    - Schedule
- Project plan
- Procurement
- Mobilization
- Trialing and testing
- Validation and verification
- Operations
- Demobilization
- System lifecycle events

Following the above principles is essential to the front end planning for determining and defining, to the greatest extent possible, future real time events that will occur during system installation and operations. In many cases, the necessary front end planning in the design cycle was not coupled to the concept of operations. When this decoupling occurs the results can be catastrophic to the overall project viability both economically and technically.

Marine assets and equipment exist in today's marketplace to provide for an effective installation of most any of the alternative energy systems being proposed. However, costs are high due to market pressures from the oil & gas and telecom industries. Operational expenses are high due to increased demand for assets; hence the required human resources are stretched. Additionally, increased cost of consumables, such as marine gas oil, has significantly increased daily operational cost.

Turnkey day rates for submarine cable installation assets are expected to remain in the $85k to $110k range for the next 2 – 3 years. Turnkey day rates for OCV's with heavy lift and subsea capability will remain above $100k per day for the foreseeable future. Day rates for tugs & barges are in the $20k - $35k range. Suitably sized DP offshore supply vessels (OSV) are around the $35k - $45k. Alternative energy project planning should plan on these day rates accordingly when considering installation costs and schedules.

With rates such as those mentioned above, it may be cost effective to charter a suitable vessel of opportunity, such as the OSV or tug & barge or both, and convert the vessels with the required deck equipment and configurations to support installation requirements. After the project and procured equipment can become part of an asset sale or placed in storage for future installations.

In either case there are companies available that can provide the necessary expertise for all project functions. Vendor sourcing and vetting is a critical part of ensuring the services advertised are what will be delivered. Project documentation will need to be written, reviewed and approved. Procurement documentation such as SOW, RFP and contracting will be required. Client representation during the project operations is a crucial part of the project execution. All of these elements need to be provided to ensure a successful, on time and in budget project implementation.

Given the number of options it is very important the installation planning be implemented very early in the project process. If there are options to be considered with regard to site selection, installation issues should be considered in the decision matrix. Good upfront planning can reduce the number of days of offshore operations and provide an opportunity to control the cost installation. In addition, it is important to fully evaluate the installation options and methodologies in view of the Life of Field Service (LOFS) strategies. Installation decisions can significantly impact the LOFS cost – both positively and negatively.

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