A Step Change in Subsea Structures Installation in the Arctic Region

The Subsea Deployment System (SDS) is a cost effective alternative to a conventionally lifted installation that meets or exceeds the weight and depth capacities of existing vessels. It is particularly well suited to hostile environments and enables a medium to large anchor handling tug (AHT) equipped with a remotely operated vehicle (ROV) to transport and install virtually any subsea structure in water depths greater than 80 metres.

BY DAVID PAUL AND ARNBJORN JOENSEN

The Arctic region is a particularly harsh and challenging environment. Apart from a short period during the summer months, it is subject to very low air temperatures with large amounts of snow and at times rapidly accreted ice cover in open water. Some areas can be covered by sea ice and experience icebergs for prolonged periods. This limits the choice of suitable installation vessels and the restricted operating windows can place significant constraints on the project schedule.

Risk Reduction

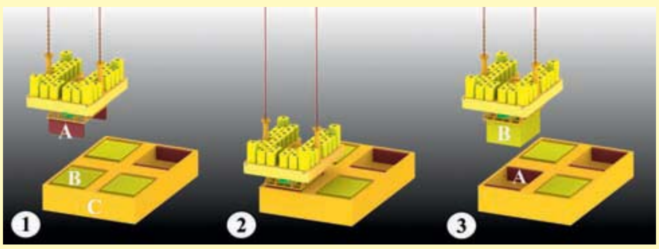
All the individual aspects of the SDS are developed from very basic principles and existing technology, both when it comes to the equipment and method.

The complete Submerged Deployment Vehicle (SDV) and structure is transported to site using a submerged tow, which largely eliminates the effects of the surface environment. Upon arrival in field it is parked above the seabed within reach of final target and consequently the weather window for lowering the structure to the seabed is short.

In addition, the lowering operation can be suspended at any time without risk to the structure or personnel. The control chains are simply withdrawn from the towers and the structure and SDV is safely anchored by the tow chain clump weight. Using a submerged tow also avoids the often critical phases of offshore over boarding and lowering through the splash zone.

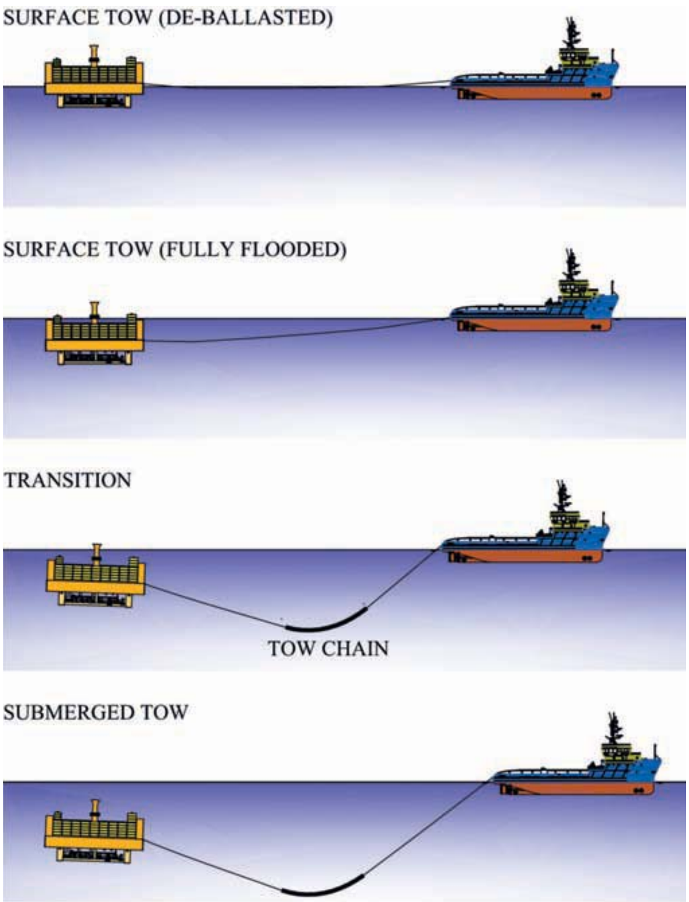
Once the over boarding has started for a conventional lifted installation, it is generally not practical to suspend the operation before the structure has been landed on the seabed. If delays do occur during the installation in deteriorating weather conditions there is a risk of overloading the hoist wires and/or structure due to increased dynamic loading. This could result in failure of the wire and catastrophic loss.

Therefore a suitable and substantial weather window is required to cover the entire installation. When using the SDS the structure and SDV are parked close to the seabed at the end of the tow so the final lowering period is short with less risk of delays. Even if adverse weather does occur during lowering, the system largely eliminates the dynamic loading on control chains, the structure and its



1. The SDV – c/w ballast weights (A) equivalent to the weight of the module (B) – is lowered to the foundation structure (C).
2. The SDV is landed to the slot where the module is to be recovered. The control chains will be lowered into the towers to provide stability. The module is connected to the SDV interface frame and then the ballast weights are disconnected.
3. The control chains are recovered and the SDV is "lifted" clear of the foundation structure with the module (B), leaving the ballast weights (A) in the empty slot.

Horizontal, vertical and rotational control by means of chains lowered into the SDV control chain towers, which behave as soft springs and minimise dynamic loading



SDV towing transitions

connection to the SDV thereby reducing the risk of a failure.

No Tension Change

During the final set down with a conventional installation there is a rapid change of tension in the hoist wire as the structure lands on the seabed. This can result in snatch loads in adverse sea states and consequently it is desirable to fully release the load as soon as the structure lands. This largely precludes the option to reposition the structure if it has been landed off target.

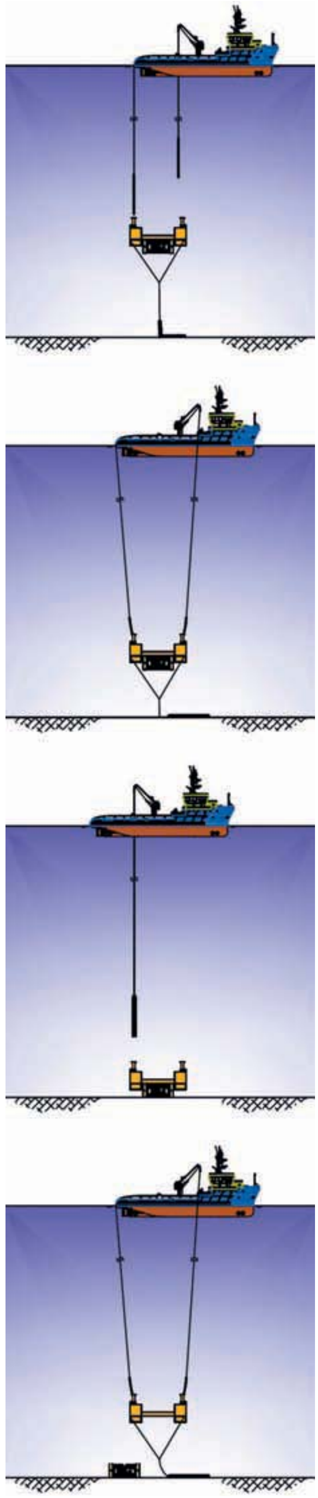
The SDS differs from a conventional installation in that there is no significant change of tension in the control chain down lines when the structure touches the seabed. There is no possibility of snatch loading and the set down is unaffected by the surface environmental conditions. It is also possible to land the structure and reposition it if required.

The only hoist wires used in the SDS are associated with the control chains. These are subject to relatively low dynamic loading which reduces the likelihood of failure and even if failure did occur it would not result in loss of the structure.

Arctic Advantages

The reduced weather sensitivity of the SDS increases the operating window for hostile regions, reduces weather downtime, and increases the available installation season. Extending the typical summer installation periods by a month on either end could significantly decrease the field development time. The installation capacity of the SDS also permits the use of larger structures with fewer subsea tie-ins resulting in further schedule savings.

Ice accretions will significantly affect a vessel with a lot of deck equipment such as an HLV reducing the summer working period.



Positioning of the SDV will be by means of two control chains suspended from the installation vessel and lowered into the chain towers

An AHT by comparison has relatively little and simple deck equipment and consequently is less effected by ice accretions. This, combined with the ability to safely suspend the tow and installation at any stage and the short installation time reduces risk and increases the 'summer' construction period.

In many cases it may be possible to load out straight from the fabrication hall into the sea thereby avoiding the potentially extremely low surface temperatures giving greater choice of structural materials.

Year-Round Installation and Retrieval

Future developments of large fields may involve subsea processing units for separation, gas compression or pumping. These may require individual modules to be recovered and replaced during the field life for maintenance. This would only be possible during the summer season with conventional lifted installations necessitating additional redundancy in the process system. An alternative based on the SDS could allow almost year round installation or retrieval by virtually any AHT suited to the Arctic conditions.

The concept is for a large foundation structure housing several modules with parking bays for ballast weights. Standardising on the interface geometry of the modules and the ballast weights would permit a single-sized SDV to be used for all modules. Using parking bays for ballast weights eliminates the requirement to deploy ballast weight to replace the structure weight significantly reducing the required installation window.

This variant of the SDV differs slightly from the function of the square mode described in "How it Works" below as it does not require integral ballast chain lockers. However, it could still be used to install structures other than the designated modules if required by incorporating ballast lockers into the interface frame.

How It Works

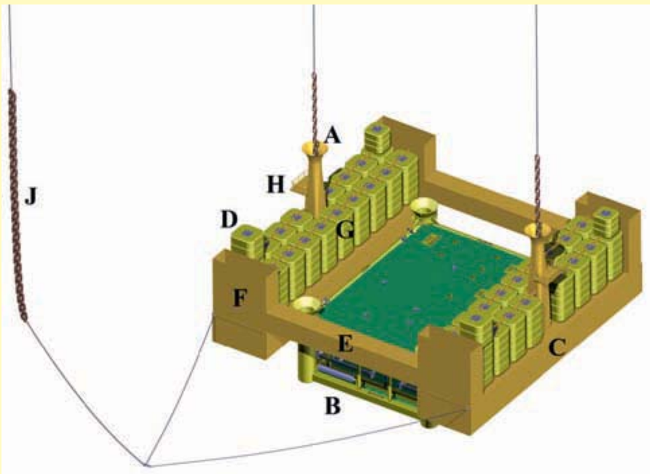
The system uses a buoyant SDV to support the subsea structure during transportation, positioning and installation. The vessel consists of solid buoyancy modules supported on steel frame/hull. The amount of buoyancy is sufficient to render the combined SDV and payload slightly positively buoyant.

The complete assembly is transported to site using a submerged tow thereby avoiding the effects of the surface environment and also avoiding the need for an offshore lift.

During final installation the position of the assembly can be controlled horizontally, vertically and rotationally by means of chains lowered into the SDV control chain towers which behave as soft springs and minimise dynamic loading.

Once the structure is landed on the seabed, ballast is added to the SDV to compensate for the weight of the structure prior to disconnection. The ballast is deployed in batches to suit the capacity of the surface vessel.

The structure may be loaded-out into the Subsea Deployment Vehicle (SDV) by a variety of methods depending on the available equipment and draught including a direct lift, a submersible barge or a dry dock.



A. **Control Chains and Towers**
The control chains are lowered into chain towers to control the SDV during installation. The weight of the chain supported by the SDV at the base of the chain towers is used to control the height of the SDV. The length (weight) of chain suspended within the chain towers provides lateral and rotational control of the SDV.

B. **Structure**

C. **Longitudinal Pontoons**
The SDV consists of two longitudinal pontoons which have ballasting facilities. This enables the SDV to be towed at a shallow draught.

D. **Castles**
The castles are positioned above the majority of the solid buoyancy and protrude above the waterline in the deep draught condition allowing fine tuning of the trim.

E. **Structure-SDV Interface Beam**
The structure-SDV interface beams are used to support the structure between the hulls of the SDV.

F. **Ballast Chain Lockers**
Ballast chain lockers are placed at each corner. They are used to trim the SDV to suit the weight and centre of gravity of the structure prior to the tow. They are also used to hold the ballast weight which replaces the structure after installation of the structure.

G. **Solid Buoyancy Modules**
Solid buoyancy modules (syntactic foam) rated to the installation water depth are located above the hulls.

H. **Ballasting System**
The flooding and vent valves may be manually operated from platform or remotely operated via radio link. The SDV will be ballasted by means of gravity alone and all valves will remain open during the submerged tow To avoid hydrostatic collapse.

J. **Tow Chain Clump Weight**
The tow chain clump weight is inserted into the tow rigging to provide the necessary weight to submerge the SDV from the deep draught tow condition to the submerged tow condition. It also acts as an anchor for the SDV when parked above the seabed.

Towing

When there is limited water depth at the load-out location, the SDV and structure will be towed in shallow draft surface tow mode until reaching a suitable location for flooding the hulls.

In deep draught mode, the SDV and structure will be towed with only the castles and control chain towers breaking surface.
When the water depth is suitable for submerged tow, the tow vessel will pay out the tow wire and tow chain clump weight. The tow chain clump weight will cause the SDV to submerge.

The tow vessel can adjust its speed and the length of the tow wire to maintain the SDV at a suitable depth. The SDV may be lowered as the water depth increases by paying out on the tow wire.

On approaching the field, the vessel slows down and adjusts the tow wire while keeping the chain clump weight off the seabed until in a designated parking area. The vessel then pays out the tow wire until the clump weight rests on the seabed at which point the SDV and structure is safely "anchored" and floats above the seabed.

Ideally the length of tow wire between the clump weight and SDV will be marginally greater than the distance between the parking area and the final target location. This allows final set-down without the need to lift and re-position the tow chain clump weight.

Positioning and Installation

Positioning of the SDV will be by means of two control chains suspended from the installation vessel and lowered into the chain towers. The height of the SDV will be adjusted by raising or lowering the control chains. The position and orientation of the SDV will be adjusted by moving the installation vessel and/or the crane.

Once the SDV is in the correct position and orientation, the structure is landed by lowering the control chains until the structure rests on the seabed. The control chains are then fully lowered into the chain towers and temporarily disconnected. The weight of the control chains contributes to the initial on-bottom stability, i.e. prior to ballasting.

Ballast weights are added to the SDV ballast chain lockers by the surface vessel crane to balance the weight of the structure. Once all the ballast is added the SDV is slightly negatively buoyant and just rests on the structure. The SDV is now disconnected from the structure.

The installation vessel re-connects to the control chains and raises them until the SDV is neutrally buoyant and continues lifting the chains until the SDV floats clear of the structure.

The control chains are then removed completely from the towers allowing the SDV to float above the seabed while remaining safely anchored by the clump weight before being towed back to shore. ■

The Authors:

David Paul, Structural Engineer, has more than 30 years' post-graduate experience in the offshore oil and gas industry. He initially specialised in the design of jackets and topsides structures but also has significant fabrication, installation and hook-up experience and has successfully led large design teams. For the past 10 years, David has been involved with the design of subsea structures.

Arnbjorn Joensen, Naval Architect and Master Mariner, has 14 years experience in the offshore oil and gas industry. He has particular experience in the marine operations associated with subsea construction, primarily as a pipeline bundle Tow Master, Field Engineer and Shift Supervisor. Arnbjorn has also been involved in most aspects of subsea engineering and construction management.