DHXT – a structured modular approach to subsea design

BY PAUL WHITE, MICHAEL WENHAM / GE OIL & GAS
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Abstract
Standard subsea products offer many advantages; they offer improved quality coupled with improved safety, reliability and reduced risk. This is easily understood if it is considered that from design, through manufacture, build, test and installation, standard interfaces are defined and on multi-build projects, offer a high level of repeatability. There are also a number of key commercial drivers to consider - using standard parts allows improved planning, improved stocking of spares and of course leverages economies of scale. It is also a more efficient mode of operation since standard designs include the re-use of engineering which allows for improved cycle time. In the oil and gas industry this shortens the time to first oil or first gas with its attendant improvement in field economics and net present value for the development. Consequently, throughout the oil and gas industry there is a growing sense that standardization can offer a significant advantage.

Introduction
The oil and gas industry has in the past been and remains one of the world’s most conservative industries – hardly surprising since the consequences of failure are significant and can be damaging to organizations as well as the environment. We are then, presented with a paradox - a degree of standardization offers lower risk, improved safety and reliability but each customer or oil company supports their own standard, believing it to be the best for them.

Clearly, if we can realize the benefits of standardization but also allow for the incorporation of our customers’ key needs we create an improved solution that delivers value to all stakeholders.

GE has, for some time, delivered what are called “Structured Products”. Our product structuring philosophy aims to deliver standardization but is also able to incorporate a degree of modularity to accommodate variances in configuration that meet the demands of our customers’ individual specifications. This product management philosophy has been field proven in other GE businesses such as Aviation and Healthcare.

![Structured product philosophy](image)

FIGURE 1  Structured product philosophy.

Subsea tree product landscape
The subsea tree product portfolio is primarily segmented by two different parameters, the first being depth and the second being tree type.

With regard to depth; different technologies are required depending on the water depth; as an example, running small lightweight trees from a jack up rig is very different from running high capacity guidelineless systems from a dynamically positioned drill ship in 10,000 feet of water. The systems are very different as they are required to work in different environments and accommodate a range of different load cases.
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There are two main types of subsea trees:

- Vertical
- Horizontal

They are so called due to the general arrangement and orientation of the valves in the tree. A vertical tree has the valves arranged vertically with the production tubing suspended in the wellhead. A horizontal tree has the valves arranged in a horizontal orientation and the production tubing suspended in the tree.

GE Oil & Gas offers subsea tree products for all applications. Our subsea tree product landscape is shown below in Figure 2, incorporating “S-Series” systems for shallow water, “M-Series” systems for medium depth applications (these typically use guide wires) and “D-Series” systems for deepwater. Our deepwater horizontal tree, the DHXT, is designed for operation at 15,000 psi and in water depths up to 10,000 ft. This subsea tree system addresses a significant proportion of subsea tree opportunities in water depths in excess of 750 m in areas such as the Gulf of Mexico or West Africa.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Vertical</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100 m</td>
<td>SVXT</td>
<td>SHXT</td>
</tr>
<tr>
<td>“S Series”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 - 750 m</td>
<td>MVXT</td>
<td>MHXT</td>
</tr>
<tr>
<td>“M Series”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>750 - 3,000 m</td>
<td>DVXT</td>
<td>DHXT</td>
</tr>
<tr>
<td>“D Series”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 2** Subsea tree structured products

**DHXT deepwater horizontal subsea tree: design to installation**

The design of any subsea system impacts operational activity. This section highlights some of the key innovative features of the DHXT and describes how these features deliver efficiencies and a high degree of flexibility in installation and operation.

**Tree size and weight**

DHXT is a system that is designed to maximize operational efficiency. Key factors in the installation of such a system are the overall weight and the physical footprint of the subsea tree. It is possible to install the DHXT with drill pipe from a rig or, in a more cost effective manner, by installing the tree using a heave compensated winch and an ROV spread. This “tree on wire” method delivers huge operational savings compared to the more traditional rig deployment methods.

Size and weight optimized systems improve handling of the subsea equipment on the installation vessel but more importantly open up the operating envelope of such vessels.

As significant wave height increases, the operating envelope of the vessel cranes is degraded - minimizing system weight maintains the vessel operating envelope.

The system occupies a footprint of approximately 4.2 x 4.2 m and including a control system, weighs approximately 40 tons. This is a very competitive system weight when viewed against existing deepwater systems. This system weight has been achieved by careful management of the system center of gravity during the design process. As each component was added to the tree assembly, the center of gravity was recalculated and design changes made to keep it within the center of the re-entry mandrel. Subsea equipment is required to be run level, so this efficient management of the center of gravity in three dimensions allowed the system to be designed without the need for any counterbalance weights. This, in turn, minimizes the overall weight and maximizes operational efficiency.
Drill-thru options

Typical horizontal tree completions require two trips of the blow-out preventor (BOP) stack. The process of running and recovery of the riser and BOP requires a significant amount of rig time. The first BOP run occurs after installation of the surface casing and high pressure wellhead housing. Once the BOP is landed and tested, the remaining drilling operations can take place. Once drilling for the production casing is completed, the well is made safe and the BOP is removed to facilitate tree installation. Finally, after the tee is installed, the BOP is re-run and final drilling and completion operations take place.

Each BOP trip can add perhaps 36 hours of rig time to the overall well construction costs. Accounting for rig moves, logistics and trip times, a saving in excess of $1MM per well can easily be achieved by eliminating one of the BOP trips.

The DHXT system also incorporates an innovative approach to the design of a number of tree system components that allows the 12¾” hole for the production casing to be drilled and the 10¾” or 9½” production casing hanger to be run through the tree. This approach means that, providing the 13¾” intermediate casing hole section can be drilled open hole or without BOP control, one full BOP trip can be eliminated. In a typical 3-well development, using batch setting operations can save four rig moves and three BOP trips which could amount to an operational saving over three wells in excess of $6MM.

Deepwater operations and high bending loads

Deepwater operations require the use of long strings of marine riser to facilitate drilling and completion operations. Very high riser tensions are required to maintain these riser strings in a stable state, free from buckling and damaging vibrations induced by environmental influences. These high riser

Traditional Csg Program
(Conductor + 3 off Csg)
1. Open water drilling
(36/30”, 20” x 18 ¾” Hsg)
2. Install 18 ¼” BOP on well head
3. Drill 17 ½” for 13 ¾” Csg
4. Drill 12 ¼” for 9 ¾”
5. Pull BOP
6. Install tree
7. Reinstall BOP & complete

Slim Csg Program
(Conductor + 2 off Csg)
1. Open water drilling
(36/30”, 20” x 18 ¾” Hsg)
2. Install 18 ¼” BOP on HXT
(Tree off crit. path activity)
3. Drill 12 ¼” for 9 ¾”
(Thru tree)
4. Complete well

FIGURE 4 Example of well casing programs
tensions coupled with subsea equipment weights and vessel offsets impart significant bending loads into any subsea system. The DHXT has been designed to operate in water depths of up to 3000m (10,000ft), and as such employs the DwHT-H4 tree connector. This tree connector has been specifically designed for operation in these challenging environments. This connector has a bending capacity of 7.11 MN.m (5.25MM ft. lbs). The DwHT-H4 connector offers high capacity at an efficient and effective weight. On the DHXT, the DwHT-H4 tree connector is plumbed to the ROV panel, with all connector functions located on a dedicated panel. This allows the connector to be operated by ROV hotstab. This means that while running the tree on wire, the tree can be landed, locked and tested autonomously by the ROV without any further external communication. This arrangement limits intervention operations, improves operational flexibility and contributes to the overall philosophy of lowest installed cost.

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Lowest Installed cost
GE structured subsea products employ the philosophy of lowest installed cost. Our customers, of course, are interested in competitive systems from a capital point of view. However in Subsea operations, this is not the only capital cost that needs to be considered, as the “as installed cost” or “overall installation cost” is a critical factor in the assessment of system performance. The DHXT has been designed from the ground up to optimize the installation window and operating envelope as well as to facilitate efficient intervention on the subsea equipment by ROVs.

Early in the design phase, GE carried out a full operational analysis of the DHXT system which covered all operations relating to installation and intervention. A critical review of all intervention operations was carried out with a major ROV contractor. The results of this review were inputs to the system design which resulted in a very efficient layout on the ROV panel. Common functions are located on dedicated panels that limit free flying of the ROV and allow optimization of all docking and attachment points. At the rear of the DHXT there is an interface that allows two point docking of the ROV. This interface is designed for installation on wire operations where once docked, the ROV and ROV gyros can be used to orient the tree onto the correct heading to allow easy and efficient make-up of the well jumper connector. The efficiency measures are not limited to ROV operations - on the top of the DHXT, the design employs an extended re-entry mandrel which is used to ensure easier land out of the BOP on the tree, improving efficiency, particularly when using dynamically positioned vessels.

Early engagement on installation allows GE to carry out a number of project-specific run and installation analyses, which include important project and particular vessel and Metocean characteristics. This analysis allows optimization of running and handling procedures to ensure that the lowest installed cost is achieved as early as possible as illustrated in Figure 6.
Overall, DHXT offers a compact weight efficient system, designed and optimized for lowest installed cost.

**Standardization & Modularity**

Standardization + Modularity = Structured product.

The DHXT employs a number of standard interfaces. This philosophy is applied from design, through manufacture, test, assembly and installation. The application of repeatable processes, procedures and methods improves quality and reliability as well as reducing risk. It is however recognized that some degree of system flexibility is required to meet a wide range of field applications; for this reason and consistent with the structured product philosophy, DHXT can be configured in a number of standard configurations:

- Base case production tree
- Enhanced production tree
- Gas lift production tree

The enhanced production tree includes additional valves on the annulus side of the tree, and the gas lift producer includes a gas lift choke. All these options can be accommodated within the base case system design without major design changes. This flexibility is designed in from the start with real estate protected to allow configuration of any one of the base case designs.

The DHXT modular design approach is flexible enough to manage a range of service conditions. These will include the management of various fluids, gases and chemicals that are required to be injected into the well at various points on the subsea tree assembly to aid production conditions, and likewise to allow the mounting of sensing devices designed to relay critical well information back to the flow assurance management team onboard the host vessel for analyses.

The tree modularity is required to be tempered with simplicity - simple flexibility often means cost savings, and avoiding unnecessary complexity in the base case ensures cost control.

In addition to the standard but modular system configurations that can be accommodated, the system is supplied with standard quality and service packages that are configured to meet individual customer’s budgets and needs.

**Incorporation of structured sub-assemblies**

As previously described, the DHXT is a structured product. Within the overall DHXT assembly are major sub-assemblies which in themselves are structured products. The result of using these well-defined proven building blocks means that approximately 80% of the DHXT system is made up of structured parts.

The controls are provided by our field proven EH-Mux ModPod incorporating the latest communication technology provided by the SemStar5 subsea electronics module. Pressure and temperature sensors from GE Sensing are optimized and use a standard range of sizes and ratings. Tree valves and actuators use designs with a proven track record and qualification history. Flowline export connections utilize the same hubs and connectors as used on the GE range of subsea manifolds.

This structured approach applied to sub-assemblies delivers a range of flexibility and interchangeability with improved quality, reliability and reduced risk.

FIGURE 7  ModPod subsea control module
Flexibility and future proofing is further provided with the provision of SemStar5-R. This is a secondary independent subsea electronics module that is easily changed out by ROV. SemStar5 provides two major advantages. It allows standard pre-configured ModPods to be manufactured, maintaining reliability and reducing lead time. Secondly, it provides significant flexibility in the selection of downhole gauges and the associated communication computer card. The SemStar5-R is reconfigured and manufactured in a shorter period; this allows the gauge interface to be incorporated further into the project. Additionally, should the customer wish to change or upgrade his downhole gauge in the future, the SemStar5-R is readily changed out. SemStar5-R can also provide a degree of backup to the primary control system if required. This flexibility with regard to interchangeability of downhole gauges and system backup represents a significant advantage over existing systems.

**Conclusion**

Structured products that incorporate standardization and modularity, coupled with a lowest installed cost design philosophy can offer huge benefits in subsea developments which are demanding in nature and involve high levels of inherent risk. The DHXT is a state-of-the-art subsea system, designed from a blank sheet of paper that challenges many of the accepted industry norms and practices. Innovative design, advanced engineering tools and a robust and benchmarked design process combined with cost containment and risk management have made this system a reality. This is a reality that delivers a cutting edge advantage, solving subsea problems for GE customers worldwide.

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