

Mudline Tree with electric spring return actuators as delivered to Total for the K5-F project (photo: Schlumberger)



Progress in Subsea Actuation Technology –

Fail-Safe Functionality Sans Mechanical Spring

The quest to discover new forms of subsea actuation efficiency has led to an all-electric solution.

BY ANDREA RUBIO AND CARSTEN MAHLER

As the industry continues to face a market deemed as the most severe downturn in decades and prices having fallen more than 50% since 2014, cost-efficient subsea technologies vital to survival, such as electric actuation, are being actively explored. Some of the methods proposed for cost reduction are simplification; standardisation; increased efficiency of marine operations; reduced cost of inspection, maintenance, and repair; and lean subsea concepts. One specific subsea technology that addresses each of these areas is all-electric subsea actuation technology.

Electro-Hydraulic Versus All-Electric Actuation

Christmas trees are placed on the wellhead and intended to control the hydrocarbon extraction from the reservoir. Each tree consists of several isolation valves as well as a choke for flow control. As the Christmas tree valves, together with the downhole safety valves, build the barrier to the reservoir,

these valves must close in case of an emergency.

The fail-safe function is realised by adding strong mechanical springs to the valve. In an emergency, these springs push the according valves to the closed position. However, this means that each spring must be operated every time the valve is operated. This causes a high instantaneous power demand when the valve is operated. Additionally, each valve and actuator assembly must be held in position once the valve is opened.

The instantaneous power for tree valve actuation dictates the layout of the distribution system. For electro-hydraulic systems, the power is generated by the hydraulic power unit (HPU) that provides the system with pressurised hydraulic fluid. The whole distribution system works as a hydraulic accumulator, so each time a valve is operated, the distribution system must be reloaded. In case the

distribution system capacity needs to be extended, special hydraulic accumulator units are added to the system.

The same principle applies to all-electric systems (AES). However, as the resistance for electricity in copper wires is much lower than it is for fluid in hydraulic lines, the electric power unit must provide the system with enough power to operate the valves directly.

The continuous power for holding the valves in the opened position is accomplished in a different manner. In typical electro-hydraulic systems, the hydraulic power is routed through an activated directional control valve (DCV) as well as a dump valve. Both are fail-safe devices that are activated by a solenoid valve (SOV). In case the control system switches off, the SOV (either actively or passively by power cut), the hydraulic control function line to the tree valve opens and the valve is closed by its

mechanical fail-safe spring. The fluid that was stored in the hydraulic actuator is vented to the sea.

Currently, available electric tree actuation systems work by utilising a similar principle. A mechanical spring is compressed when operating the Christmas tree valve. To avoid high continuous power consumption, a dedicated electric clutch mechanism holds the valve in the open position. Once the power to the clutch is switched off or cut, the spring pushes the valve to the dedicated fail-safe position.

From a functional point of view, the main difference between electro-hydraulic and all-electric subsea production systems is as follows. The electro-hydraulic system requires two different types of power distribution: a high-power hydraulic distribution for valve operation and a low-power electric distribution for piloting the hydraulic power. As the all-electric

system operates with just one power source, both power levels must be provided electrically.

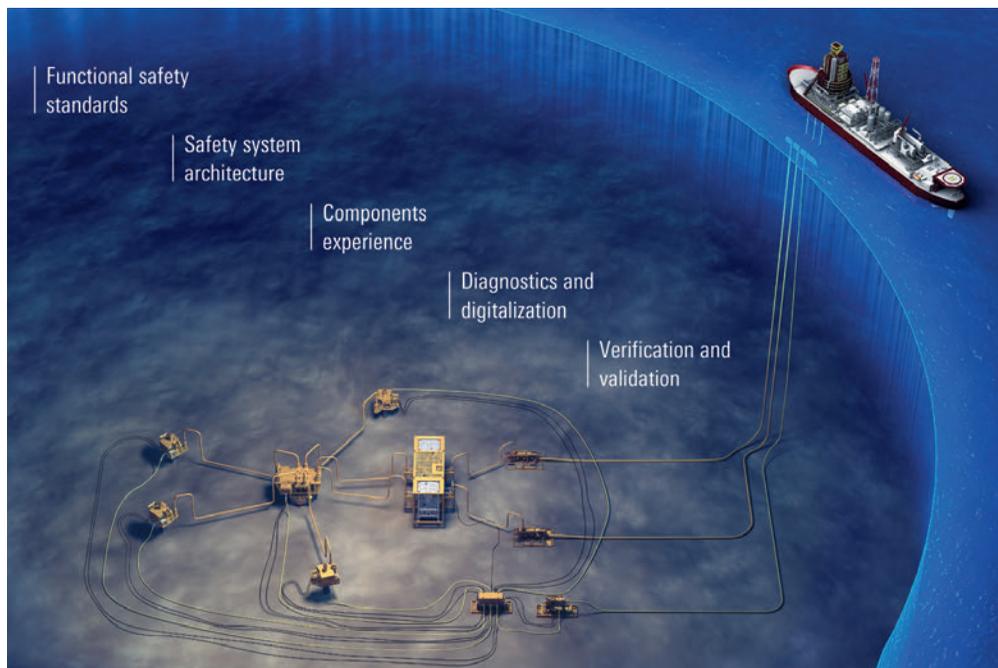
Hydraulic-operated Christmas tree types have in common that the hydraulic actuators can be mechanically overridden by a remotely operated vehicle (ROV). Therefore, each of the valves provides a dedicated standardised interface. These can be either linear or rotary type.

Rotary interfaces are also used for so-called manual valves, which are operated only very limited times in their whole lifetime (e.g., during commissioning or decommissioning) and in cases where an ROV is available for intervention. However, all valves that use a standardised interface could also be operated with an electric subsea actuator that provides a suitable mechanical interface to the valve.

As an example, in the all-electric tree system as delivered for the Total K5-F field the redundancy concept for the electric actuation does not end inside the subsea control module (SCM), but rather applies to all electric components (including the electric connectors, flying leads, and motor windings); the likelihood of an electric actuator malfunction is minimised.

In electro-hydraulic systems, accumulation is used to provide the actuators with instantaneous hydraulic power when required. This leads to the idea of following the same approach for the proposed redundancy concept and adding an electric accumulator to the system that is trickle charged whenever one of the valves is operated. Should valve operations be needed, the accumulator provides the actuator with the required power to operate the valves to the desired position.

Because the electrical-spring-return actuators require continuous power to activate, the fail-close



Depicted in this image are the five core competencies of the participating companies in the consortium (illustration: Schlumberger)

clutch mechanism dedicated power calculations were executed. The result indicated there is still a significant power demand for each tree. Further investigation took into consideration third-party power distribution and a maximum of five trees to be operated. It was concluded that just adding a battery to the system would not be sufficient.

To minimise the power for the actuation system, the spring can be removed to reduce the high loads, and therefore, a high-power demand on the electrical actuators. Another benefit to removing the spring package is that the size of the valve assembly (and potentially the whole tree) is reduced.

As the battery must now provide the energy for fail-safe valve operation (i.e., in case of a Production Shutdown/Emergency Shutdown), a highly reliable, high-density element should be selected. The best fit to the requirements is provided by a specialised Li-Ion battery. A dedicated battery design will be required to allow for fail-safe operation over the life of the field, and therefore, comply with the OG21

requirement of reduced efforts for maintenance and repair.

The battery concept reduces power demand to the minimum. In addition, the distribution system only needs to provide the long-term average, so peak loads for valve actuation do not have to be considered in the distribution system layout.

Challenges to Technology Adoption

Even though an all-electric system with centralised energy storage provides a huge amount of benefits, there are also technical and nontechnical challenges to overcome. The biggest challenge the industry faces today is that most industry standards are written based on existing electro-hydraulic subsea technology, specifying a design with a rising stem gate valve with a mechanical fail-safe spring and a hydraulic actuator. This approach leads to technology that is qualified to a set of standards that are not relevant. To overcome resistance in operators' mind-sets, a new concept with high system availability, reliability, and safety must be defined; this

cannot be done without first understanding the operational scenarios.

To address the main challenges, a group of subject matter experts that work for different innovative companies and research organisations have combined forces to develop a robust technical solution. The joined industry consortium defined a research project with the goal of developing an all-electric fail-safe actuation system that provides higher availability and safety than any existing hydraulic system. This project is supported and co-funded by the German Federal Ministry for Economic Affairs and Energy.

The central approach to generate acceptance for the safety capability of the system is to apply well known and accepted standards for the whole product life cycle. For the safety of electric, electronic, and programmable electronic (E/E/PE) systems, the IEC 61508 [IEC 2010] as a base standard is globally accepted. Based on this standard, dedicated standards for automotive (IEC 26262) [IEC 2012] and process industry (IEC

61511) [IEC 2016] are available. However, for the development of E/E/PE safety components, only the IEC 61508 is applicable.

For this reason, participating companies contribute to the project with trained and experienced functional safety engineers. The standard defines four different safety integrity levels (SIL). The SIL is a quality requirement that specifies the reliability of a safety function. The assessment is clearly defined and it includes the probabilistic failure rate, system architecture, diagnostic coverage and systematic capability of each safety related element. For being able to claim a specific SIL, the development process of the dedicated element must cover all the aspects as stated

in the standard. In the end, this method leads to a clearly defined quality level of the safety function.

Once a reasonable SIL rating for the proposed actuation system is proven by implementing the methods in the development and validation process, confidence in this technology approach will rise with suppliers, operators, and regulators. As the all-electric topic becomes more relevant to the industry, these standard-related challenges can be seen to be solved in the future in just a matter of time. This approach shall enable the best technical solution and provide evidence that the proposed all-electric actuation system design is even safer than the current available options. ■

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