All-Electric Subsea Well Brings Benefits vs. Traditional Hydraulic Technology

Currently, the state of the art for subsea well control is based on hydraulic technology. Hydraulic fluid is supplied from a host facility to the subsea wells through dedicated tubes within an umbilical and is distributed to the wells. Shifting that trend, K5F3, the world’s first all-electric well in the subsea industry, opened to production on 4 August 2016. This paper presents the benefits of electric subsea control compared with current state-of-the-art hydraulic methods.

Rationale for Electric Production System

Expenditure Savings. When looking at the introduction of a new technology such as an electric system, successful introduction is a direct consequence of a perceived reduction in capital expenditure (CAPEX) and factors such as operating expenditure (OPEX); health, safety, and environment (HSE); and future readiness also need to be addressed.

To perform preliminary system engineering for the implementation of the electric system and provide a comparison with a conventional electrohydraulic multiplex system, a case with five oil-production wells, one gas-injection well, and three water-injection wells was used as a base case for cost. The study concludes that the electric system is likely to show a range of benefits over the equivalent electrohydraulic multiplex system.

Improved System Efficiency. Electric subsea production brings advantages in most scenarios, particularly in an ultra-deepwater field or with long-distance stepouts. Electric motors maintain their high level of efficiency and full torque capability regardless of water depth, unlike hydraulic pressure, which must overcome seawater hydrostatic pressure.

Use of high-voltage direct current for long-distance power transmission is far more efficient than use of either alternating current or hydraulic pressure.

Removing hydraulic tubing from the umbilical and reducing the number of conductors bring several advantages. The electric umbilical has a smaller cross section, allowing longer continuous lengths to be manufactured and spooled. Overall weight is reduced, facilitating the use of a smaller installation vessel. And, on very long stepouts, splices in the umbilical can be either reduced or eliminated altogether.

HSE Improvement. An all-electric system eliminates the discharge of hydraulic fluid to the environment and hydraulic-pressure safety issues.

Future Potential and Readiness. Having much higher levels of electric power available at the subsea end of the system (compared with the electrohydraulic system) offers a greater scope for powering additional tools and sensors such as multiphase flowmeters. It also facilitates the addition of intelligent wells, new sensors, and digital flow-control valves.

Technology Development

Electric Tree System. Since the late 1990s, a subsea-oilfield-services provid-

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er has been involved in the development of an all-electric subsea production system. Using a rigid product-development and -qualification program, various prototypes were developed and tested. In 2004, a successful field trial marked the next step toward actual field application. In 2006, project execution began for the first all-electric subsea production system, consisting of two-off subsea trees (Fig. 1) with an associated production-control system and installation- and workover-control system. Delivery and startup were in 2008.

**Electric-Control-System Overview.**

The all-electric system is a subsea production system that completely uses direct-current power and electric valve actuation as a replacement for conventional hydraulic subsea production-control systems. The electric system was specifically engineered with the objective of integrating the surface equipment and power- and communication-transfer media with all subsea control equipment into an overall system with increased individual-system-component reliability and availability.

At the topside, the electric system consists of a dual-redundancy master control station (MCS), two independent high-voltage electric-power units (EPUs), and a topside umbilical-termination unit (TUTU). Within the MCS is a standard human/machine interface for the control and monitoring of all installed topside and subsea production equipment. The EPU uses the host-facility electric supply, transforming it into high-voltage power for transmission to the hooked-up subsea equipment. It also includes a diplexer with a classic copper modem to superimpose the communication signal onto the power line. As a fully redundant package, the electric system routes two independent power-on communications lines by means of the TUTU down through the main umbilical to the hooked-up subsea equipment. Connected to the TUTU are tow-off anode packages, which are placed subsea and close to the platform. The anodes form part of the seawater return-current path. The power and communication lines (coaxial cable), as part of the umbilical, terminate subsea at the umbilical-termination assembly; from there, the electric power and communication signals are distributed to other hooked-up subsea equipment through electrical flying leads. Each subsea tree is equipped with two-off independent electric subsea control modules (ESCMs).

**Future Developments.**

Operational feedback confirmed that the option of having two individual ESCMs and corresponding mounting bases on a tree assembly is not the preferred option. The initial thought for this setup was that if the ESCM on one channel failed, then the other ESCM would continue to operate the tree while the failed ESCM was retrieved. In an operational environment, a tree is typically shut down while remotely-operated-vehicle or diver intervention takes place; hence, the advantage of having two trees is not fully realized and a single mounting base for a fully redundant ESCM will suffice. This approach will reduce hardware costs while maintaining the inherent system-availability figure for which the ESCM was initially designed.

The first-generation ESCM has full redundancy for each actuator and sensor. Discussions revealed that this is not always required and that noncritical functions could be operated through a single-channel approach from the ESCM. A new generation, therefore, should have the flexibility to combine full redundancy with single-channel functionality in any desired configuration.

The electric system, as deployed for KSF3, uses a coaxial cable for transmission of power and superimposed communication using a proprietary communication protocol. Implementation of advanced technology providing the capability to transmit at high bit rates and use an open-architecture communication technology could be an advantage. For power transmission, twisted-pair or quad-cable technology also can be used.

**Electric Surface-Controlled Subsurface Safety Valve (ESCSSV)**

The development of the current ESCSSV was enabled by the introduction of the floating magnetically coupled subsurface safety valve, which positions the valve-actuation mechanisms in a dedicated chamber that is isolated from well pressure. The actuation mechanism, which is a rod piston in the hydraulic tubing-retrieval subsurface safety valve (TRSV), is magnetically coupled to the flow tube. By placing the actuation mechanism in a dedicated chamber isolated from well pressure, the force required to open the TRSV is no longer affected by well pressure. This significantly reduces the required opening force, paving the way for the use of compact linear electric actuators.

Critical to enabling the design of the ESCSSV was the development of a robust, compact, low-power linear electric actuator. The electric actuator in the ESCSSV replaces the hydraulic piston assembly of the TRSV, providing the opening force to move the ESCSSV to the full open position for the well to be put into production. A mechanical fail-safe-closure mechanism, as provided in traditional hydraulic safety valves, is used to close the valve when commanded, during loss of power, or under emergency shutdown. The ESCSSV electric actuators use a direct-current stepper motor to provide the actuation force to open the ESCSSV.

**Summary**

Electric technology will lower CAPEX and OPEX by reducing the equipment needed to operate the system safely, and it will improve the environmental effects compared with existing conventional electro-hydraulic multiplex systems by removing the risk of hydraulic-fluid releases subsea; it will also improve personnel safety by removing high-pressure equipment and containment at the topside facilities.

The fail-safe-close principle based on using springs has proved to be a successful design feature in situations in which the well needed to be put into a safe state in an uncontrolled situation and is an advantageous feature that could be adopted for larger valves.

One disadvantage of this generation of the direct-current technology is the missing analog valve indication. Because of the design of the electric actuators, it is not possible to have analog valve-position indicators installed or a mechanical valve lock-open override. Both of these functions are important features during remotely-operated-vehicle surveys and wireline operations. This should be improved and taken into consideration for future developments. *JPT*