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SUBSEA TECHNOLOGY

Enabling low-cost subsea tie-ins with electrical high-integrity pressure protection systems (eHIPPS)

As subsea field developments move into deeper, higher-pressure environments, cost-efficient tie-back solutions are increasingly critical. This article explores qualification of the world's first electrically powered High-Integrity Pressure Protection System (eHIPPS), a breakthrough that could lower subsea project costs and simplify tie-ins to existing infrastructure.

ENDRE BREKKE, Siemens Energy, and **MARKUS GLASER,** Advanced Mechatronics

As offshore oil and gas operators venture into deeper waters and harsher, more remote locations, the economics of field development projects have become increasingly challenging—particularly for long tie-backs from high-pressure wells (10,000 to 15,000 psi). The cost of subsea flowlines and risers, which must be rated to the full shut-in tubing pressure of the well, represents a substantial portion of CAPEX on these projects.

Subsea High-Integrity Pressure Protection Systems (HIPPS) are automated safety mechanisms designed to prevent over-pressurization of downstream equipment by rapidly isolating high-pressure sources when predetermined thresholds are exceeded. High pressure can result from loss of well control, a process trip, inadvertent valve closure downstream of the HIPPS valve, hydrate/wax blockage, transient production scenarios, and other similar events. Unlike traditional pressure protection methods that rely on relief valves, modern HIPPS technology uses fast-acting isolation valves controlled by independent logic solvers to provide deterministic pressure protection.

Installing a HIPPS near a high-pressure well or subsea manifold allows the downstream system to be designed for lower pressure ratings, thereby reducing the onerous requirements for pipeline wall thickness and associated costs. It also enables tie-ins to existing brownfield flowlines rated for lower pressures, potentially delivering substantial CAPEX savings and increasing the viability of marginal or remote field developments.

CURRENT HIPPS TECHNOLOGY AND CHALLENGES

Fast-closing subsea gate valves actuate on a shutdown command initiated by a logic solver or programmable logic controller (PLC) to autonomously detect and isolate abnormal high-pressure conditions in a flowline, preventing damage to lower-rated downstream equipment. The typical closure time of a valve is less than 10 sec.

The first subsea HIPPS was installed in 1996. Today, all operational subsea installations rely on electrohydraulic technology with mechanical springs. In these systems, thrust generated by the bore pressure and gate stem diameter drives the safety shutdown, while the spring provides the driving force to close the valve at low bore pressures during normal operation. Hydraulic pressure is used to supply the force needed to open the valve.

While these systems have performed reliably in operation, they do have inherent drawbacks, including reliance on long-distance subsea umbilicals to transmit pressurized hydraulic fluid for system operation. Connecting the umbilical to a hydraulic power unit (HPU) on an existing topsides facility can be challenging or impossible, depending on where the HIPPS must be installed. As umbilical length and HPU capacity increase, costs can become prohibitive, limiting the application of the HIPPS.

Additionally, temperature changes affecting viscosity and pressure losses in hydraulic lines can degrade the hydraulic response time of HIPPS systems, potentially limiting their ability to meet stringent closure-time requirements over the life of the field.

The presence of fluid-facing components, such as pumps, filters, reservoirs, accumulators, valves and seals, also increases potential failure modes and maintenance requirements. In subsea applications, maintenance access is both costly and logistically challenging, often requiring the use of remotely operated vehicles (ROVs), vessel mobilization and production shutdowns. Maintaining high reliability over multi-decade subsea service life is a constant engineering challenge.

Electrohydraulic HIPPS have limited capabilities for diagnostics and condition monitoring. While system operability can be verified through testing, it often necessitates curtailing or temporarily shutting down production.

TRANSITIONING FROM MECHANICAL TO ELECTRIC

The challenges and logistical complexity associated with electrohydraulic HIPPS have led to increased interest in electrically powered HIPPS, also known as eHIPPS. eHIPPS technology offers several advantages over mechanical systems, including:

- Eliminates the need for a topsides HPU and long-distance hydraulic umbilicals.
- Reduces failure points and increases reliability, as no fluid can leak.
- Lowers lifetime maintenance costs, due to the elimination of pumps, filters, reservoirs, etc.
- Permits lighter and more compact HIPPS modules, simplifying transport and installation
- Faster manufacturing schedule and lower cost through elimination of piping and associated inspections and flushing requirements.
- Software and functionality are reconfigurable after deployment (i.e., setpoint for valve closure can be raised or lowered, depending on field conditions).
- Easy integration with other control and safety systems, due to standardized, straightforward interfaces (i.e., incorporation into a digital twin).

Over the past three decades, researchers and engineers have dedicated considerable time and resources to developing eHIPPS technology. Despite these efforts, technical limitations have hindered progress and restricted broader commercial deployment. Recently, a Joint Industry Partnership (JIP) spearheaded by Equinor and several partners has achieved notable advancements. Their primary aim is to qualify a comprehensive subsea eHIPPS system under API 17F, 5th edition, and API 17O, 2nd edition standards, to achieve Safety Integrity Level (SIL) 3 certification in compliance with IEC 61508 and IEC 61511.

Siemens Energy and Advanced Mechatronics are leading efforts to design and build eHIPPS. Advanced Mechatronics is providing an electrical actuation system, based on a standard, qualified actuator and rotary-to-linear (RTL) components. Siemens Energy is providing the SIL 3-certified pressure sensors and the subsea control module (SCM) with the logic solver (i.e., PLC).

eHIPPS DESIGN OVERVIEW

The eHIPPS is constructed similarly to a traditional electrohydraulic HIPPS, in that it is a fully redundant system with two (2) gate valves in series, four (4) precision pressure transducers (PPTs), and two (2) dual-channel actuators, Fig. 1. The system was designed with the following safety functionality:

- SIL 3 system
- Hardware failure tolerance (HFT) = 1 (on system level)
- Probability of failure on demand (PFD) <= 3.25 x 10-4
- Architecture 1oo2
- Type A

During regular operation, the valve is held open against thrust by a brake in the actuator. If overpressure is detected via pressure transducers, the safety logic in the SCM deenergizes the clutch winding. The clutch disengages and releases the RLM mechanism, allowing it to operate freely. Valve thrust then drives the valve into the closed position, isolating the line from the high-pressure condition.

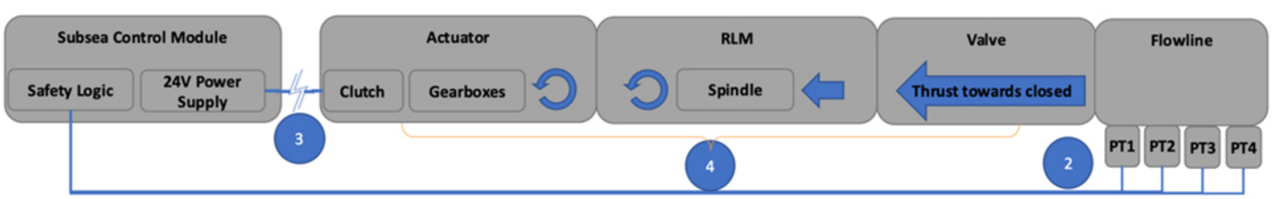

Fig. 1. eHIPPS system design overview

To open the valve under full differential pressure, the actuator utilizes integrated batteries to generate the required force to unseat and open the gate valve. Closing the valve at pressures below the trip pressure is also powered from the battery.

The actuator—which is required to operate quickly in the event of overpressure and can generate a high force to unseat the gate valve under full differential pressure—was one of several major engineering hurdles that the JIP effort overcame. The battery is "trickle-charged" via a small electrical umbilical. Without the battery to store energy, a much larger, high-voltage cable would be required, leading to much higher system costs.

The SCM utilizes a Simatic S7 PLC and 24V power supply. The S7 is a redundant SIL 3 TÜV-certified "off-the-shelf" product and has been modified and qualified to API 17F and SIL 3 (IEC 61508). The entire system was designed to ensure fail-safe operation. Figure 2 shows the main components of the eHIPPS. The areas highlighted in red are components that can fail without impacting system functionality.

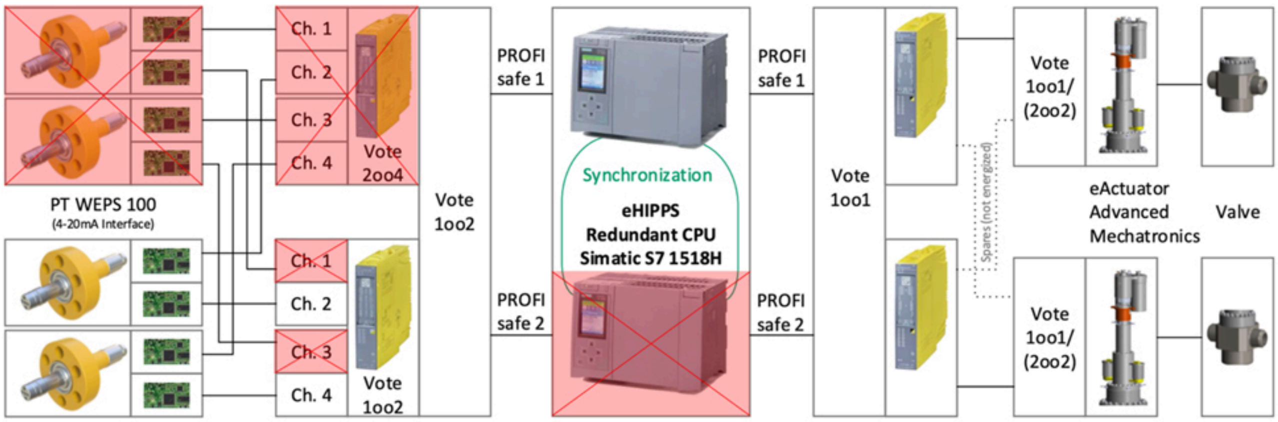

Fig. 2. Overview of components, showing eHIPPS redundancy (components colored in red can fail without impacting functionality).

The SCM can also power and communicate with non-SIL sensors and actuators and simultaneously perform non-SIL functions alongside its SIL-rated capabilities. This may simplify and save costs by eliminating the need for additional SCMs.

Exemplary performance characteristics of the eHIPPS system are as follows:

- Design
  - 10-inch gate valve
  - 136-mm stem diameter
  - 39 bar ambient pressure
- Close to open (highest force)
  - 828 kN max. required to push the valve into the open position (active operation)
  - 90 seconds travel time for the 300 mm stroke
- Open to close (safety case, highest speed)
  - 275 kN thrust (closing force) generated by the valve (passive operation)
  - 7 sec travel time

DIAGNOSTICS AND FLEXIBILITY OF OPERATION

A notable advantage of the eHIPPS versus a traditional electrohydraulic HIPPS is its ability to perform real-time condition monitoring and diagnostics. This capability enables operators to assess the health and functionality of critical system components, such as the brake, clutch, drive train and battery. At any given time, the battery's performance—including capacity, voltage and temperature—can be tested by applying a load, all without physically moving the valve. Additionally, partial stroke testing can be seamlessly performed to unseat the valve without disrupting production.

The eHIPPS system can be integrated easily into fields by simply connecting it to the power and communication network. The eHIPPS eliminates the need for any hydraulics.

The system's ability to initially configure the closing speed of operation in a trip situation and pressure levels allows for flexible performance. With eHIPPS, the "trigger value" and voting requirements can be modified directly from the surface, eliminating the need to adapt or replace hardware and components—an issue commonly encountered with traditional electrohydraulic systems.

Siemens Energy's Subsea DigiGRID serves as the foundation for the control architecture of the eHIPPS, utilizing open and standard interfaces that are vendor-agnostic. DigiGRID, a qualified generic control, safety and monitoring system, is designed to manage any component within a subsea process setup. Its primary purpose is to extend the interfaces of topside Safety and Automation Systems (SAS) and Digital Twin systems, all the way to the seabed.

CONCLUSION: PLANNING FOR INITIAL FIELD INSTALLATIONS

The eHIPPS is expected to reach Technology Readiness Level (TRL)-4 later this year and is currently undergoing final testing in Norway and Germany. The system will be ready for initial field deployment in 2026. Its qualification marks a significant achievement in subsea engineering by reducing the cost of tie-ins and improving project economics for smaller, remote, deepwater fields. **WO**

ENDRE BREKKE, Solution manager for Subsea Electrification and Control at Siemens Energy, specializes in subsea power and control systems, system architecture, and digitalization of offshore production. He holds a Master of Science degree in Engineering Cybernetics from the Norwegian University of Science and has over 28 years of experience in the energy sector. Mr. Brekke has led innovative projects, including Siemens Energy's Subsea DigiGRID™ and Subsea Power Solutions control system. He is fluent in multiple languages and frequently shares his expertise at industry conferences.

MARKUS GLASER holds a Ph.D. in systems engineering and brings over 25 years of expertise in developing highly reliable mechatronic drive systems. His extensive experience spans a wide range of applications, from bone elongation implants to mission-critical defense systems. Currently, Mr. Glaser serves as the head of the Research Institute for High Integrity Mechatronic Systems at Aalen University, where he leads pioneering research in the field. He also collaborates with Advanced Mechatronics, contributing his expertise to the development of innovative solutions that enhance the reliability and performance of mechatronic systems.