The value of all-electric intelligent completions

All-electric intelligent completions are increasingly popular versus hydraulic architectures in deepwater and complex multizone wells, as longer tie-backs and more challenging reservoirs become the norm. Hydraulic systems can introduce installation complexity, delay response times, and increase operational risk. All-electric completion systems address these constraints through simplified architecture, faster actuation, and continuous digital feedback. Utilizing field data and operational experience, the measurable value of electrification, how it supports real-time reservoir management, and its emergence as a standard for deepwater developments are examined.

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All-electric intelligent completions represent a significant evolution in deepwater developments. These systems help operators reduce capital and operational expenditures with streamlined installation and minimized complexity. They also help strengthen zonal control and provide broader digital insight.

As operators drill longer wells in deeper water and encounter more complex stacked reservoirs, the limitations of traditional hydraulic architectures are apparent (e.g., slower response times, complicated line management, and increased installation risk). Field studies indicate that electric completions can reduce installation time by up to 60% and lower deferred production by as much as 80%.

HISTORICAL CONTEXT AND LIMITATIONS OF HYDRAULIC SYSTEMS

Intelligent completions have been deployed for decades, starting with Halliburton's introduction of SmartWell® intelligent completions technology in 1997, Fig. 1. Reliability and functionality have always been central to system design. However, hydraulic-based systems face inherent limitations, including fluid compressibility, temperature sensitivity, complex control lines, intricate installation procedures, and maintenance requirements. These factors can influence cost, operational complexity, and overall risk.

Fig. 1. First deployment of a Halliburton intelligent completion system in 1997.

The development of reliable all-electric completion systems offers a viable option for multi-zone complex reservoir projects. These systems help reduce installation complexity, increase system reliability, support faster zonal control and reservoir monitoring, and lower both initial and life-of-field costs. Together, these capabilities support greater value extraction, even in the most complex reservoir conditions.

ADVANCEMENTS IN ELECTRONICS AND THE SHIFT TO ELECTRIC POWER

Recent improvements in high-temperature electronics have helped strengthen the reliability of all-electric completions under typical wellbore conditions and operational environments. This transition to electric systems parallels the transformation of subsea production systems through the replacement of fluid power with distributed electrical power, digital control, and embedded diagnostics.

In all-electric completions, the downhole system functions as a network of addressable devices rather than hydraulic circuits. This design can improve controllability and convert previously unobservable downhole parameters into measurable data that can be monitored, tracked, and managed throughout the well lifecycle. This can help reduce intervention requirements and support higher reserves recovery.

SINGLE-LINE ARCHITECTURE FOR ELECTRIC COMPLETIONS

A key advantage of the transition from hydraulic to electric infrastructure is the adoption of a single-core tubing-encapsulated conductor (TEC) that powers and controls the entire completion system.

The TEC line provides a single protected conduit for power, telemetry, and command signals. Electric systems depend primarily on conductor integrity, length, and pressure-tested electrical interfaces. This shifts performance sensitivity from environmental factors to measurable electrical characteristics that can be designed, tested and validated.

DETERMINISTIC CONTROL AND IMPROVED MONITORING

From a control perspective, completions consist of a series of downhole nodes. Each interval can include an electromechanical interval control valve (ICV), pressure and temperature gauges, and position and health sensors. This arrangement can provide more deterministic control that allows operators to target specific zones and verify results through position feedback rather than relying on movement from surface responses, Fig. 2.

Fig. 2. An all-electric intelligent completion system allows precise zonal control and constant downhole diagnostics throughout the wellbore.

The Halliburton Volta™ all-electric completion system, part of the SmartWell intelligent completion family, streamlines operations by using a single downhole line to actuate valves, collect real-time data, and monitor conditions. Electro-mechanical actuation supports controlled, repeatable movement. Integrated position sensors allow high-resolution, bi-directional, fast, and accurate micro-choke adjustments with digital confirmation of every command.

This design helps simplify installation, accelerate system integration, and avoid hydraulic constraints that can affect response times and operating methods. A notable advantage of the Volta all-electric completion system is that it is paired with Halliburton's field-proven ICV, which has more than 2,000 installations worldwide. This helps support a smoother transition to all-electric systems while maintaining the proven features, reliability, and installation procedures.

OPERATIONAL ADVANTAGES OF ELECTRIC VALVE CONTROL

Electric ICVs allow operators to simplify subsea production control requirements, as all valve control and positioning are performed downhole. This helps reduce function time, eliminates the requirement for hydraulic power units, and streamlines maintenance, troubleshooting, and cleanliness requirements to decrease potential leak paths and offshore handling.

Standardized zonal architecture provides flexible multi-zone configurations without additional control lines or modifications to subsea production and surface equipment. The system can help simplify topside and umbilical infrastructure and can help reduce interfaces and the overall effort required during system acceptance.

Workshop and rig-based preparation can be simplified by eliminating hydraulic calibration and the requirement for hydraulic power units. Teams can focus on continuity checks, device addressing, and functional actuation tests with immediate confirmation.

RIG-TIME EFFICIENCY

Deepwater rig rates often exceed $750,000 per day. Multi-operator studies show that all-electric systems can shorten critical-path installation and commissioning time by up to 60%. These savings help lower pre-production costs and free rig resources for other priorities.

Time reductions can lead to measurable time savings for operators through the elimination of the requirement to flush hydraulic lines, streamlined pressure tests, fewer assembly and testing connections, and faster zone verification. Electric systems have demonstrated the capability to move sleeves up to 200 times faster than hydraulic actuation.

Fewer containerized support systems are required on the rig, which helps reduce offshore material handling and required personnel. These efficiencies can help improve schedule certainty and help reduce CO_2 emissions associated with marine heavy lifts, vessel support, and rig operations. For example, shortened installation time can save up to 81 tonnes of CO_2 per well, through reduced rig and vessel usage in a typical three-zone intelligent completion system.

REAL-TIME ACTUATION POWERS DYNAMIC RESERVOIR MANAGEMENT

Hydraulic actuation can limit the performance of intelligent completions, with response times that range from hours to days. This can discourage frequent optimization and potentially restrict dynamic zonal control. Hydraulic systems must move fluid through long, narrow lines while also factoring in friction, compressibility, and temperature effects. In contrast, electric systems transmit power and control signals and convert them to mechanical motion at the device, which makes the tie-back distance less critical as water depths increase.

Electric actuation can help reduce these influences and potential variability. The Volta all-electric completion system provides fast, high-resolution, and bi-directional choke positioning with direct feedback. Valve adjustments occur in minutes instead of hours, which allows operators to optimize production in real time without shutting in the well. This can improve drawdown management and support both manual and automated control workflows.

Integrated position sensors and diagnostics provide actionable health signals that support condition-based maintenance planning. Use cases include balancing production throughout stacked-pay zones, water coning management, and quick response to gas breakthrough. Faster control also supports structured drawdown sequences for interval assessment and better decisions on operational timescales.

DIGITAL SURVEILLANCE AND CONDITION MONITORING

All-electric designs are inherently digital. Constant feedback from actuators, sensors and gauges delivers production insights and offers detailed system health visibility not achievable with hydraulic systems. Operators can detect flow assurance or near-wellbore issues earlier and conduct trend analysis for proactive maintenance, optimization, and automated workflows.

The electric ICV system includes integrated pressure and temperature gauges powered through the TEC line. Integrated pressure and temperature gauges powered through the TEC line provide constant measurements that can reduce uncertainty during cleanup and allow rapid diagnosis when rates or water cut shift unexpectedly. Condition monitoring can help reduce interventions by detecting system degradation and delivering planned responses. In deepwater operations, fewer interventions mean higher uptime and lower health, safety, and environmental exposure.

PRODUCTION ASSURANCE ACCELERATES WELL RECOVERY

Electric tubing-retrievable surface safety valves, including all-electric safety valve designs, when used alone or with all-electric completions, can help reduce hydraulic dependencies that can lead to long well-opening sequences after emergency shutdowns (ESDs).

In deepwater and long-offset tie-backs, hydraulic recovery times depend on the time necessary to move and stabilize hydraulic volumes. Electric actuation separates opening performance from these fluid dynamics and can provide more consistent recovery times within various layouts.

A field study demonstrated that the time required for an operator to return wells online was essential to minimizing deferred production during each ESD event, and that regulatory shut-in tests were improved by up to 80% for a 30-km tie-back. This recovery time was consistent within the EcoStar® all-electric safety valve system throughout tie-back lengths, which highlights its rapid response advantage compared to hydraulic systems.

Predictable recovery time supports stronger operational planning and can help reduce deferred production after an ESD, especially in assets with frequent shutdown events. Faster recovery delivers recurring value throughout the asset’s life.

TWO-TRIP COMPLETIONS PROVIDE FUTURE FLEXIBILITY

All-electric completions integrate seamlessly with downhole wet-mate systems, such as Halliburton’s Fuzion® downhole wet-mate connector. This promotes safe, efficient two-trip installations and can help reduce reservoir exposure and well control risk.

Operators can verify electrical interfaces with continuity and functional tests during the two-trip workflow to minimize uncertainty and make faster acceptance decisions. This method also provides a clear diagnostic path, if issues arise during commissioning. Workovers in electric submersible pumps or gas-lift wells become more efficient, because electric systems reduce hydraulic dependencies and improve device-level diagnostics.

The ability to cleanly disconnect from the lower completion after closing valves can help reduce reservoir damage and risk during workovers. This flexibility supports the entire well lifecycle, including during plug and abandonment, by reducing system complexity, streamlining planning, and improving well status verification.

THE FULL VALUE OF ELECTRIFICATION

Electrification can help significantly reduce capital expenditure for subsea umbilicals, risers and flowlines, but the greater value lies in faster cycle times, better production control, and fewer interventions.

Business case evaluations require a clear separation between hardware savings and operational benefits. Hardware cost reductions and operational improvements are identifiable at project approval. Operational improvement gains occur throughout commissioning, start-up, field operation, and optimization. In deep water, where interventions and deferred production often advance economic value, completions that are easier to install, diagnose and optimize can outperform alternatives, even if equipment costs are similar or slightly higher.

All-electric intelligent completions can shorten the time from yard to first oil. They can also improve production with real-time zonal control and help reduce emissions by decreasing offshore time and lowering intervention frequency over the field's life.

CONCLUSION

The industry has spent decades in pursuit of perfected hydraulic completions, and electrification now offers an innovative alternative. All-electric intelligent completions can help simplify operations, strengthen well performance, expand data availability, improve reliability, and help reduce costs and emissions throughout the well lifecycle. This provides real-time visibility and control that support dynamic reservoir management.

Real-time active reservoir management, long sought after in intelligent well design, is now more accessible through electric architectures. Technical maturity is reflected in how these systems are qualified and implemented: modular zone designs, repeatable factory testing, deterministic functional checks, and direct downhole feedback. As a result, completions can operate less like passive hardware and more like engineered control systems to help reduce uncertainty and support faster decisions in complex reservoirs and challenging deepwater environments. **WO**

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