ESP systems enhance reliability in challenging environments

A case study from offshore Brazil

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The Jubarte field is located in the northern Campos basin block BC-60 in approximately 1,300 m (4,260 ft) water depth 70 km (44 miles) offshore the state of Espírito Santo, Brazil. Discovered in January 2001, the field is owned and operated by Petrobras.

Commercial feasibility of the field was confirmed in December 2002 with a pilot production well. Phase-I development started in late 2006 comprised of four producing wells connected to FPSO Juscelino Kubitschek (P-34), which had a processing capacity of up to 60,000 b/d of oil. The artificial lift arrangement for this phase included one well with an electric submersible pump (ESP) installed on a pumping module at the seabed, one in-well ESP and two gas-lifted wells.

Phase II development started in December 2010 comprising 15 producing wells and seven injection wells connected to the FPSO P-57, which has capacity for 180,000 b/d plus 2MMm³/d gas. Current production is more than 130,000 b/d. Stepout distance of the producing wells to the FPSO is between 2.5 and 8 km (1.6 and 5.0 miles). All 15 of the producing wells in the Jubarte Phase II project require ESP systems to boost flow, making Jubarte the largest subsea ESP project in the world since the Liuhua China project in 1996.

Petrobras awarded Schlumberger the contract to supply the ESPs for the Jubarte Phase II project in October 2009, and equipment delivery was expected to begin in less than one year later. This was a major challenge, as ESP systems matching the demanding requirements of the field did not yet exist. Schlumberger quickly established a project team co-located in Brazil and the company’s global engineering, manufacturing and sustaining (EMS) centers to support the design, development, and delivery of artificial lift equipment that would meet Petrobras’ requirements. Meanwhile, Petrobras established a technical team that participated throughout the development and delivery of the equipment, and jointly developed with Schlumberger a comprehensive test regimen that would ensure a high level of reliability.

Artificial lift challenges

The 1,500-horsepower ESP systems were to be located in sealed watertight structures known as caissons or MOBOs (a term derived from the Portuguese for “boosting module”) approximately 50 m (164 ft) under the seabed and 200 m (656 ft) from the production wellheads. Reliability of the subsea ESP systems, operating at 1,400 m (4,593 ft) below sea level, was critical as remediation costs in both time and money would be high. The operating environment of the seabed caissons is defined by dramatic swings in temperature and pressure. Reservoir temperature of the heavy crude is approximately 80° C but temperature at the seabed is around 4-6° C, which is therefore the fluid temperature at startup of the pumps. The heavy crude can contain 30-40% gas. Reservoir pressure is about 270 bar, and to keep the oil mobile and avoid excess gas production, the systems are designed to keep pressure at the sandface above the 180 bar bubble point. However, pressure is always below bubble point by the time fluids reach the pump. At the seabed it is 150 bar but when starting the pumps, it can drop to as low as 40 bar.

Typical seabed pump installations have comingled flow from multiple wells after separation of oil, water and gas. For Jubarte Phase II, each seabed caisson is attached to just one well, and the pumps must handle all the liquids and gas. Each ESP is typically handling 4,500–5,000 m³ of fluid per day. At production startup, before water breakthrough, this equates to about 3,500 m³ oil and 1,500 m³ gas at the pump intake. Water-cut is currently about 40% on average, with wells producing up to 60%. The Jubarte oil is known to favor stable emulsion and the viscosity increases exponentially due to the water-in-oil emulsion formation at this water cut. This creates challenging starting conditions after a shut down. In addition, hydrate formation can occur when water and gas are at a low temperature. Some wells have more gas than others at the pump intake, and flow can be irregular. Gas locking can be an issue when stopping and restarting pumps.
proved successful on smaller pumps in other equipment in the Bartlesville EMS center.

Early and thoroughly trained with the ESP ample, key field personnel were identified leading up to the first installations. For experience were made the focus of efforts tools, techniques, procedures, training, and installation, leveraging experience from other commercial ESP systems, that would increase reliability and eliminate some time-consuming operations that would enable faster rig-up on site. As much work as possible was performed onshore prior to installation. Examples include pre-filling the motor and protector with lubricating and cooling oil, completing factory shimming of the assembly, and utilizing plug-in potheads with individual connectors to deliver 3-phase electrical power to the ESP motor. Pressure-testable flange joints were also provided – a first for ESP construction.

Complete system approach

The ESP pumps are just part of a whole system designed to handle emulsion, hydrate, and other potential issues. Solutions include service-line and umbilicals that can inject liquids such as diesel and ethanol (to inhibit hydrate formation) respectively. A complete control system was developed that would take measurements from sensors near the sand face, at the wellhead, at the ESP and at the FPSO. It monitors operations, optimizes operating conditions, and ensures that the equipment keeps operation within its limits maximizing uptime for increased production. The system is automated, and is supported by Schlumberger and Petrobras engineers located on the FPSO and onshore. It includes alarms and trips to mitigate risk of damage or shut-down and enables problems to be addressed without having to shut-down.

System integration testing

As a final check on product quality and to maximize reliability, Petrobras managed a comprehensive program of system integration testing, including extensive pressure testing on potential weak points, such as flanges, to ensure system integrity. The integrated project team developed a rigorous set of test requirements to be completed before delivering each ESP system. A key component of these requirements is a suite of 14 tests that make up the system integration test (SIT) designed to mimic Jubarte II operating conditions. The SIT is conducted on every ESP downhole system—including the motor, protector, and pump—in a vertical test well in the Bartlesville EMS facility after standard factory acceptance tests are completed on individual parts of the equipment. The SIT test requirements were designed to ensure the highest product quality and separate connections improves reliability by enabling lower operating temperatures. Improved reliability is also enabled by creating longer path to ground for the conductors. A key aspect of the design approach was to provide “plug-and-play” type features in the equipment during manufacturing and installation, leveraging experience from other production facilities.

Leveraging ESP experience

Experience from new designs that had proved successful on smaller pumps in other ESP centers in Edmonton, Alberta; Lawrence, Kansas; Singapore; and Grenoble, France. A specialist company provided technical support on its Seapower 02 8kV – 220A high-performance subsea connectors that were subsequently used in the initial stages of the project. The Schlumberger supply chain and manufacturing organization was immediately engaged to begin procurement of long lead-time materials and arranging the anticipated production facilities.

The integrated team concentrated on high reliability in all phases, from the point of service back to product design and delivery. For on-site delivery of the ESPs, installation tools, techniques, procedures, training, and experience were made the focus of efforts leading up to the first installations. For example, key field personnel were identified early and thoroughly trained with the ESP equipment in the Bartlesville EMS center.

(Above) Petrobras P-57 FPSO.
(Right) Schlumberger crew preparing ESP for installation.
program also includes a specially developed subsea umbilical electrical simulator with 3, 4.5, 8, and 10-km cable length stepouts.

**Monitored shipment**

Application of best practices and leveraging lessons learned from prior experience with ESP systems resulted in a key change in the packaging of the equipment before shipment and its monitoring during delivery. A new design of packaging was developed and rigorously checked to confirm that it would optimally protect the equipment from shock damage during transit. Sensors were attached to the equipment and shipping boxes to monitor shock actually experienced during transit and ensure it had not been mishandled.

**ESP performance**

The first ESP system was installed in November 2010 and production started in December. The ESP ran successfully for six months before stopping due to an electrical fault. It was subsequently restarted and ran until October when it tripped again. Gas lift was used to assist production while attempts were made to restart the pump. A workover subsequently found the problem to be due to an electrical connector at the pump hanger. The ESP itself was tested and found to still be in perfect operating condition.

In January 2011, Petrobras announced new record daily, monthly, and annual oil production averages during December 2010, citing two Jubarte wells connected to the P-57 FPSO platform as major contributors to these records. In March 2012, Petrobras announced that the 11 wells connected to the P-57 FPSO platform field were producing about 137.1 Mboe/d and that this was the platform with the company’s highest production.

At that time, eight of the 15 producing wells in the Jubarte Phase II project had ESP systems installed and another three had Schlumberger gas-lift systems. It is planned to install another three ESP systems in 2012, and ESP installation in the remaining four producers is scheduled to be completed in 2013. To date, the longest continuous ESP service in the field stands at 620 days. Based on their proven success in the Jubarte Phase II project, similar high-volume high horsepower ESP systems are planned for installation in several other challenging oilfields.