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Dual ESP completions solve West Africa deferred production

Risks drive innovative design decisions

Offshore West Africa rigs are in short supply. Availability estimates range from six months to a year, and day rates continue to rise. This complicates the scheduling of workovers and drives up their cost. It also defers production.

West Africa's first dual Y-tool, dual electrical submersible pump (ESP) wells, installed for VAALCO Energy Inc., are addressing the risks of deferred production and unplanned intervention. Driven by the desire to maximize return on investment, the company is determined to reduce the commercial and technical risk to acceptable levels to complete and produce the wells.

Early this year, the company began production from two oil producers in its Avouma satellite field, which lies about 10 mi (16 km) south of the producing Etame field offshore Gabon, West Africa. The wells produce to an unmanned platform and are tied back by a subsea pipeline to Etame's *Petroleo Nautipa* FPSO.

Current production at Etame stands at 14,000 boe/d. A new discovery, Ebouri, near the northern boundary of the Etame block, is expected to be tied back to the FPSO in

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3Q 2008. The two Avouma wells together produce 7,200 boe/d of oil and represent a significant portion of the company's total production. Potential production from the two wells has been estimated at 10,000 to 12,000 boe/d.

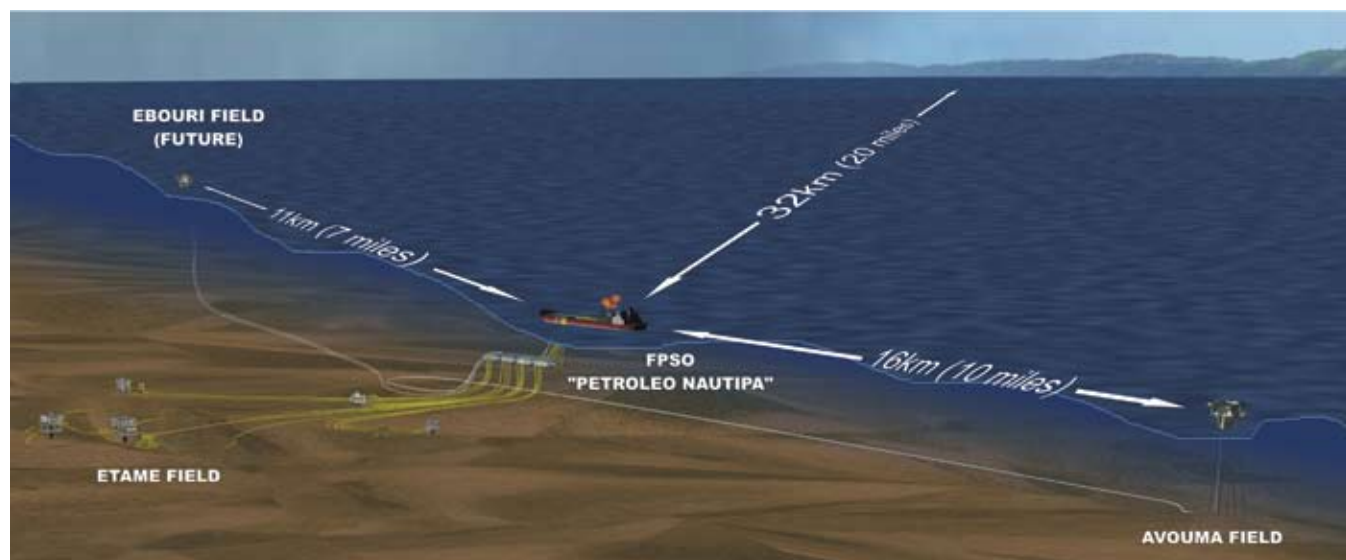
Investigating redundancy

The company launched an intense investigation aimed at assuring continuous, trouble-free production throughout the reservoir's economic life. To maximize return on investment, VAALCO was determined to reduce the commercial and technical risk to acceptable levels and selected Schlumberger as a service partner to complete and produce the wells. One of the most recent success stories for the dual ESP technique, the Avouma completion, borrowed heavily from

positive experiences recorded on more than 30 high-risk installations around the world.

The key feature characterizing the dual-ESP technique is the ability to switch from one pump to the other in a matter of minutes with minimal intervention. With a fully redundant operational spare pump installed in the well, the operator is protected from even a completely unexpected failure. Should a failure occur, the company can easily switch to the backup pump and continue production while it plans and mobilizes workover equipment, services, rigs, etc., minimizing the risk of having to defer production.

VAALCO was not satisfied, however, to simply install a backup. The company wanted to take steps to ensure maximum efficient life from the pumps it had. The company set three goals: minimize the risk of deferred production for prolonged time intervals, provide real-time downhole data for production optimization and reservoir monitoring, and provide ESP surveillance to eliminate preventable failures and provide an early-warning system. Compared to unexpected loss of production from Avouma; the added cost of the dual-ESP solution was valuable insurance.



The Etame block consists of the subsea Etame field, the Avouma platform, and the future Ebouri platform, all tied back to the FPSO *Petroleo Nautipa*.

Methodical risk reduction

The chosen pump configuration was the dual ESP bypass system that features an Auto Y-tool subsurface automatic diverter system with an integral flapper valve. The flapper valve is actuated by flow and requires no mechanical intervention to shift it from pump to bypass mode. The dual Y-tool allows reservoir access through the bypass tubing for conducting sandface measurements or remedial completion services without the need for an intervention.

A methodical approach was undertaken to ensure reliability and performance of the system.

First, the ESP system and completion were designed to maximize performance and minimize risk. The design included a completely instrumented downhole and surface system, including independent multiphase flow meters on the flowline of each well. Metering provides accurate data on the pump, the production stream, and the reservoir that can be transmitted via satellite to a secure web-hosted surveillance system, allowing well monitoring and analysis to be performed in real time.

Next, an initial load flow study was performed to qualify the system capacity for increased loading. Power factor, line, and load harmonic analyses as well as short circuit and protective coordination were studied to ensure an optimized system. Upfront studies allowed accurate equipment sizing and enabled intelligent infrastructure choices on surface equipment, such as cable sizing, routing, required power distribution equipment and harmonic filtering.

Finally, surface electrical connections were engineered and designed to allow for the pumps to be switched with minimal intervention. Both electrical connections were tied into a common junction box with a contactor to allow for simple switching of the power supply from one pump to the other. In addition, power sensing equipment provides a signal that tells the system which pump is running so pressure and temperature information can be accurately calibrated.

When dual ESPs are employed, the usual approach is to run the lower ESP until it either fails or reaches incipient failure mode, then to switch to the upper ESP. It is not considered good practice to alternate the pumps for any reason. The philosophy is that unnecessary ESP stops and starts could cause damaging electrical loading and shorten the

motor's service life.

Building on experience

Dual ESP completions have been run successfully in high-risk wells around the world.

Experience played a major role in designing, installing, and commissioning this completion. A thorough analysis was carried out on the wellbore, and completion requirements were

Dual y-tool, dual ESP bypass system provides a back-up ESP system and allows reservoir access for conducting sandface measurements or remedial completion services without the need for an intervention.

compared with lessons learned on similar completions. A joint operator/contractor team evaluated other operators' procedures and lessons learned. In addition, well site visits to witness ESP activities and equipment makeup with another operator proved valuable and led to the use of newly developed tools and techniques that further improved reliability.

One such modification improved the way the packer penetrator system works and how it is assembled, which subsequently led to time savings during the installation. The modification also is expected to yield better reliability.

Ensuring quality

An enhanced quality program (EQP) assured 100% inspection of all critical parts. The program also tightened manufacturing tolerances. This type of stringent quality assurance plan has proven to reduce the risk of unexpected events and also contributes to prolonged equipment life. But the EQP was only the beginning. The equipment also had to pass full load tests, again with tightened tolerances, to assure that the system had the best chance of operational success.

As part of the EQP, a power system analysis determined how the equipment would operate at different loads. The study involved the use of a computer model to simulate various platform power loads, motor starting, and harmonic analysis.

This work proved extremely useful and indicated that harmonic heating could be reduced and additional power and life could be

attained if the supply-side harmonics were reduced.

The power quality downstream of the variable speed drive (VSD) was modeled as well. Results indicated that the harmonics created by the VSD could potentially cause voltage overshoots at a specific frequency and that the voltage overshoots could be at least 2.5 times the output voltage. This voltage level exceeds the electrical insulation rating and can weaken other system components, potentially causing a failure.

The solution was to address the issue with a VSD with a 12-pulse cancellation front end that incorporates an output sine wave filter. This solution mitigates the harmonics on the generator as well as the harmonics and voltage overshoots that enter the ESP system.

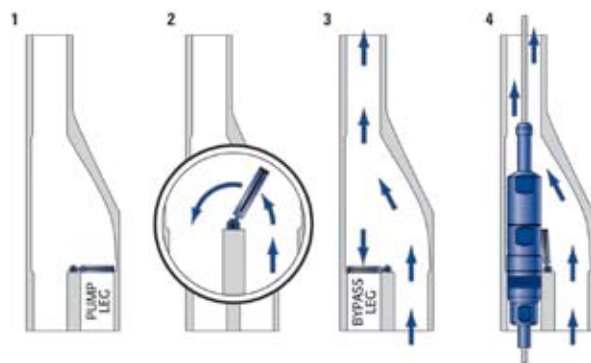
Testing the theories

The solutions looked good on paper, but the real test would be performance in the field.

In addition to the EQP, stringent factory acceptance tests were performed, followed by system integration testing (SIT). Testing has proven instrumental in minimizing or eliminating the risk of premature failure by identifying potential complications. A complete full load string test was conducted at the manufacturing center to assure proper assembly and operation of all ESP components as a complete unit.

All measurements were recorded during assembly to assure proper fit in the field. A thorough SIT ensured that all of the completion components fit together properly before being installed in the well.

The cost measured in time and money to conduct the due diligence, additional quality



The dual ESP bypass system features an Auto Y-tool subsurface automatic diverter system with an integral flapper valve that allows for switching without slickline intervention.

plans, and testing is not insignificant, but it was a small price to pay to reduce the risk of premature equipment failure and the high cost of deferred production.

Sharing the risk

A performance-based contract was con-

ceived to identify key performance indicators (KPI) and to align the objectives according to the project's ultimate success.

Since a key driver was maximum uptime and production, the completion was equipped with a monitoring and surveillance system with associated telemetry to monitor pump and well performance and to allow continuous remote surveillance and control. With this system collaboration among ESP ex-

perts, reservoir engineers and surface operators could identify production, artificial lift, or surface abnormalities and make appropriate adjustments.

As a result, the pumps could be fine tuned to operate efficiently and to optimize production. Life-cycle modeling was employed in the design to accommodate future anticipated production parameters.

Throughout the design and commission-

ing phase, VAALCO engineers took the position that most ESP failures are preventable; therefore, they set out to anticipate and prevent them by a combination of good engineering practice, equipment selection, design redundancy, and thorough testing.

The dual ESP pumps with the dual Auto Y-tools subsurface automatic diverter system have been successfully installed for 11 months. ●