"INTELLIGENT ESP" SYSTEM BEING TESTED IN PDO

Cleon Dunham, Oilfield Automation Consulting
Shaikhan al Khadhori and Abdullah al Harthy, Petroleum Development Oman

ABSTRACT

Petroleum Development Oman (PDO), working in close cooporation with several other companines, is developing and testing a remote, automatic, intelligent ESP system for Oman's challenging operations. This progress report describes the system concepts, expected benefits, and current status.

PDO operates nearly 600 ESPs; this number is continuously growing. Many are located in very remote areas; many produce from sandy formations; many produce significant amounts of gas; most use fixed speed drives. These wells must be carefully started and operated to avoid damage from sand, inefficiency from gas, and safe and effective operation within the normal pump envelope. Currently, this is very labor intensive. Due to remote locations, it often results in excessive, hazardous desert driving, inefficient use of manpower, significant production deferment, and excessive operating costs.

To optimize these wells, PDO is developing a system that includes downhole instrumentation to measure pump pressures and other key variables, a real-time sand production monitor, an automatic well-head control valve (for wells with fixed speed drives), and a full production automation (SCADA) system.

The wells must be started and/or restarted slowly to avoid sand production problems or gas interference. Production must be ramped slowly enough to avoid these problems, but rapidly enough to avoid downthrust or excessive motor heating. ESP Technicians are able to interact with the system from the field or corporate offices to optimize operational parameters and troubleshoot faults and shutdowns.

Major benefits are expected to be up to 80% reduction in desert driving, significant improvements in production and equipment life, major reductions in deferment and ESP operating costs, and wider application of ESPs in preference to beam pumps and gas-lift.

Initial field tests are underway in the Wafra Field in PDO. Implementation on more wells in PDO is anticipated when the field tests are successfully completed in early 2003.

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In 2000, six people lost their lives in desert driving-related accidents in PDO. Many of the ESP wells in Oman are located in very remote areas, often two or more hours drive from the Production office. And, many of these wells produce some sand or gas. Typically, to start these wells, they must be beaned up very slowly by starting with a small choke setting and gradually increasing this setting if sand or gas production is not excessive. Each step in this process requires hours of hazardous desert driving.

The typical start-up cycle is:

- Trip #1: Check out the well and its pumping equipment.
- Trip #2: Manually start the pump and establish initial production. If the pump runs correctly and the well starts producing, begin production on a small choke setting.
- Trip #3: Allow the well to pump for one - two days and then catch a sample. Take the sample to the Production Lab and have it analyzed to gauge the sand content.
- Trip #4: If the sand or gas production is not excessive, return to the well and open the choke enough to increase the production rate by approximately 50 cubic meters (about 300 barrels) per day.
- Trip #5: Take another sample and have it analyzed.
- Trip #6: Repeat the cycle until the well is fully beaned up, or until an unacceptable level of sand or gas production is reached.

What's wrong with this picture? To successfully start an ESP well, or to restart it after a shut down, six to ten round trips to the well site may be required, over a period of from several days to a few weeks. This causes:

- An excessive amount of hazardous desert driving, with an unacceptable exposure to accidents.
- An excessively long start-up time during which much production is deferred.
- An excessively high risk of well and/or pump damage since the time from the incidence of high sand or gas production, to its detection, to the chance to take appropriate corrective action, can be three to four days.
- A reluctance to use ESPs except in those cases where there really aren't acceptable alternatives. Yet, effective use of ESPs could potentially lead to much higher production rates and ultimate recoveries than alternative forms of artificial lift.

To overcome these problems, PDO is embarked on a comprehensive project to develop and test a remote, automatic, intelligent ESP system that can dramatically reduce the need for desert driving, shorten the time required to ramp well production up to full potential, and reduce the incidence of shortened run lives and equipment failures due to excessive sand and/or gas production.

INTELLIGENT ESP SYSTEM — SYSTEM CONCEPTS

Figure 1 illustrates the primary concepts of the remote, automatic, intelligent ESP system.

1. An electrical submersible pumping system that is designed to produce the full potential of the well in terms of cubic meters (barrels) per day.
2. A downhole instrumentation package that can measure such key downhole variables as pump intake pressure, pump discharge pressure, motor temperature, and pump vibration.
3. An on-line sand monitor that can accurately calculate the sand production based on (cumulative) metal loss measurements from an erosion probe. (Typically, readings are taken about once per hour; they can be taken more frequently during start-up operations.)
4. An automatic wellhead control valve (for wells with fixed speed drives), or a variable speed drive controller, to control the backpressure on the ESP or the speed of the ESP.
5. A comprehensive production automation (SCADA) system, consisting of a well-head remote terminal unit (RTU) and a remote SCADA computer system, to permit remote monitoring and control of the well and pumping system.

The system is designed to manage the well and pumping system through the various phases of its operation:

1. Pre Start-up. During pre start-up, the system checks all system components and the interfaces between all components to assure proper installation, configuration, communication, and operation.
2. Initial Start-up. During initial start-up, which is done with an Operator on location at the well site, the system assists in operating the wellipump system at the desired initial start-up rate, and in monitoring all system variables to assure proper and safe operation. Normally, the initial start-up rate is close to the "minimum" production rate defined by the pump company to avoid downthrust.
3. Bean-Up, Restart. During the initial bean-up phase, and during any restart after a shutdown, the system moves the well/pump system through a series of steps. At each step, which may be based on a desired or target production rate, pump intake pressure, or fluid level above the pump, the system produces the well at the desired condition for enough time to achieve stability. It only moves on to the next step if the wellipump system is fully stable and if no fault criteria such as excessive sand or gas production have been exceeded. It continues the bean-up process until the target optimum production rate, pump intake pressure, or fluid level is reached, or until a limit such as high sand or gas production is reached. Through out the process, the system continually checks to avoid

under production that could risk downthrust or motor overheating, or over production that could risk upthrust.

4. Normal Operation. During normal operation, the system continually keeps the wellipump system producing at its optimum rate. It does this by controlling the pump backpressure or speed to meet a target production rate, pump intake pressure, or level of fluid above the pump. Through out normal operation, the system continually checks for too high or too low production, excessive sand or gas production, or any shutdown faults.

5. Shutdowns. The system recognizes seven shutdown modes and reacts to each accordingly. The seven modes and associated reactions are:

- Manual Local Shut Down (MLSD). Pump is manually stopped at the well site. It must be restarted manually, either locally or remotely via the SCADA system.

- Manual Remote Shut Down (MRSD). Pump is manually stopped remotely via the SCADA system. It must be restarted manually, either locally or remotely via the SCADA system.

- Automatic Local Shut Down (ALSD). Pump is automatically stopped at the well site by the local wellhead logic in the ESP controller or the wellhead RTU. It must be restarted manually, either locally or remotely via the SCADA system.

- Automatic Remote Shut Down (ARSD). Pump is automatically stopped remotely via the SCADA system. It must be restarted manually, either locally or remotely via the SCADA system.

- Power Failure Shut Down (PFSD). Pump is stopped due to a power failure. It may be automatically restarted when the power is returned.

- Non-Critical Trip Shut Down (NTSD). Pump is stopped due to a non-critical trip condition recognized by the ESP controller. It may be restarted automatically when the reason for the trip has cleared.

- Critical Trip Shut Down (CTSD). Pump is stopped due to a critical trip condition recognized by the ESP controller. It must be manually restarted locally after the reason for the trip has been investigated and cleared.

Whenever the well/pump system is restarted, the system uses the full bean-upirestart process to bring it back to normal production. However, as experience is gained with a well and pumping system, the bean-up parameters may be adjusted to permit the bean-up process to proceed as rapidly as is consistent with safe, effective operation. The long-term goal is to minimize bean-up time, to minimize production deferment, while maintaining complete operational safety of the well and pumping system.

INTELLIGENT ESP SYSTEM — EXPECTED BENEFITS

Based on careful analysis of current operations in PDO, we expect the following benefits from this project. We hope to be able to fully evaluate and document the benefits that are actually achieved and report on them at this conference next year. Early test results in the Wafra Field are supporting these estimates.

1. Reduced Driving. We expect to reduce the need for hazardous desert driving in PDO's ESP operations by 80%. (This will amount to approximately 40% reduction in overall desert driving in these fields.) This translates into a reduction of 600,000 kilometers (375,000 miles) per year. This will mean a reduction of 7,500 hours of driving per year. This will have several profound effects.

    - Safety. This significant reduction in desert driving will greatly reduce our exposure to risk of accidents.

    - Cost. This will reduce the costs associated with operating and maintaining vehicles.

    - Personnel Effectiveness. People will have much more time to spend on productive activities - time that is currently spent behind the windshield. We are mounting a significant training program to upgrade people skills to advance field staff from drivers to well analysts.

2. Increased Production. We expect to shorten the time required to bean up and/or restart the average remote ESP

well from ten days to two days, or 80%. Currently, total production deferred due to ESP bean-up operations is on the order of 2% of our total ESP production, or 1,140 cubic meters (7,100 barrels) per day, company wide. We expect the anticipated 80% reduction in bean-up and/or restart time to result in an increase in production of up to 900 cubic meters (5,700 barrels) of oil per day, when the system is fully implemented.

3. Increased Run Life, Reduced Equipment Failure. By closely monitoring sand and/or gas production, and by continuously keeping each well/pump system safely within its operating envelope, we expect to increase average run life by up to 20%.

4. Wider Application of ESPs. Currently, there is wide use of beam pumping, progressive cavity pumping, and gas-lift in PDO. In many cases this is warranted. In other cases, production rates could be increased and more ultimate recovery could be achieved if ESP's could be safely used. With the ability to effectively and safely start and operate ESP's, we expect to aggressively expand ESP usage across PDO. And, we fully expect to see this pumping technology be used more aggressively in other Operating Companies.

INTELLIGENT ESP SYSTEM — CURRENT STATUS

Because the stakes are very high, we are pursuing a careful project design and implementation process. The key parts of this process, and their status, are:

1. Functional Requirements. We met in Oman, in June, 2000, with all participating companies, and with a wide spectrum of PDO staff, to define the functional requirements of the system. We met in Claremore, Oklahoma in September to review the requirements and discuss testing plans.

2. Functional Design. Working separately, each company prepared the functional design of its component of the system - ESP, downhole measurement, sand monitor, control valve, RTU, and SCADA system. We met again in PDO, in November 2000, again with wide participation by PDO staff, to review and coordinate these designs.

3. Detailed Design. Again working separately, each company prepared the detailed design of its component. This is the design used to actually build the system and to assure that all components work together properly. We met in Houston, Texas in February 2001, to review these designs.

4. Testing. We plan at least four levels of system testing and implementation.

- The Shop Floor Test was conducted in Houston, Texas in four phases in April through August, 2001 to verify that all system components were correctly developed, could be correctly configured, and could effectively communicate with one another.

- The second step was a full-scale field test on a ''live'' well in the Wafra Field in PDO. This occurred in mid 2002. It confirmed that all aspects of the system and the system logic work together correctly under "live" well conditions. A few minor problems were detected that need to be finalized before the system can be implemented on more wells. Final testing is planned in early 2003.

- The third step will be expansion of the system to other fieldslwells in Oman. The initial focus will be on high priority wells that are located far from existing Production Stations. This implementation is scheduled to begin in the 2nd quarter of 2003.

- The forth step will be expand use of this system. We anticipate expansion across much of PDO's ESP operations during the coming years.

- The fifth step may very likely be expansion of this system to other Shell Operating Units, and to other companies that use ESP's.

5. Other Project Steps. In addition, we are actively working on four other project steps:

- Documentation. Each company is producing comprehensive documentation and drawings of its component(s) of the system. It is our intent that, in the future, this system can be implemented using any company's components.
- Operator Manuals. Each company is producing comprehensive Operator Manuals, for all levels of staff -

Engineers, Technicians, Well Analysts, Operators, Well Services, Maintenance Personnel, and many others - that must be able to understand and operate all or parts of the systems.

- Maintenance Manuals. Each company is producing comprehensive Maintenance Manuals so that all portions of the system can be maintained and enhanced as needed.

- Training Materials. Each company is producing comprehensive training materials so that each person who must be involved in any aspect of system operation and/or maintenance can receive appropriate initial awareness training, in-depth training, and follow-up training.

INTELLIGENT ESP SYSTEM — WORKING RELATIONSHIPS

This project is the cooperative effort of seven companies. Each of the primary service companies is contributing their time and expertise to make this project a success. This is seen as a large ''win'' for all involved.

- PDO will win by having a very robust system to enhance the safety, operation, and profitability of its ESP operations.

- Each contributing company will have new technology and experience that it will be free to market as it sees fit.

- The industry will gain a new way of operating ESP wells that should improve safety and profitability and should lead to expanded overall use of ESP's in the world.

PDO is very grateful for the contribution, cooperation, dedication, and very hard work of every member of the eight-company project team.

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