The Value of Automation in Khalda Sucker Rod Wells

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Abstract

The need to enhance well performance is driving the growth of well automation and optimization systems. In today’s efficiency demanding business world, producers require systems that are capable of more than simply increasing the rate of production. Producers also desire the ability to decrease system failure rates consequently minimizing well down time and lifting cost by extending equipment running life, thus maximizing total system efficiency.

This paper will present the experience gained through the implementation of Smart Sucker Rod System (SSRS) at Khalda field in the western desert of Egypt. The key operating device of the SSRS is the Smart Well Manager (SWM) which is an electronic device with the state of the art technology to obtain control of the sucker rod well based on analysis of surface and downhole data. Moreover, this paper will show the contribution of SWM to: reduce the frequency of well interventions, predict and accelerate the detection of well failures and decreased associated downtime, faster production optimization for new wells, and save on energy demand. Taking advantage of the SSRS, we feel we are maximizing the benefits of Sucker Rod as an artificial lift method.

Introduction

Khalda Petroleum Company is a joint venture between EGPC (Egyptian General Petroleum Corporation) and Apache Corporation. Khalda is spread across nearly 2 million acres about 250 miles west of Cairo, see figure 1, in the western desert of Egypt. The Khalda complex holds two dozen oil and gas fields producing from 58 sandstone reservoir units in seven formations from one mile to three miles below the desert. The successful drilling program pushed daily gross production to approximately 150,000 barrels of oil per day in August 2005.

After discovering Khalda field in 1986, ESP was initially used as an artificial lift system. By 1989 Khalda had 27 wells which were equipped with ESP’s in Salam, Safir, Khalda, Hayat & Tut fields. Today, Khalda have 25 fields with 250 wells produced with ESP (main artificial lift), natural flow and sucker rod pump. By the end of the year 2000 it was observed that some of the new development wells, mostly producing from BAHARIA reservoir, showed very low productivity (around 150 BFPD at the maximum possible drawdown) with high depletion rate. As the goal of every operator of artificial lift
systems is to maximize production and minimize operating costs, Khalda started intensive efforts to study all the available Sucker Rod system combinations (surface units, rod strings and down hole pumps) which are capable to produce rate of 200 BFPD from depth of 6000-7000 ft. Early in year 2001 Khalda selected and ordered the most appropriate Sucker Rod System for its wells. In March 2002 Khalda started the first SR system in well Renpet-1X and currently Khalda is running 49 Sucker Rod wells in Salam and Sumpetco fields in the western desert. The depths of the wells range between 5600–9200ft equipped with Lufkin surface pumping units (C912D-365-168, C640D-305-144 and C456D-256-120) and downhole pump size of 1.25”–1.75”. The producing rate is from 45 to 300 BFPD using the SR system with total production of around 5000 BFPD. Some of these wells were ESP and were changed to sucker rod and others started with sucker rod system. Khalda is the pioneer in Egypt in implementing the Smart Sucker Rod System where all of its sucker rod wells have Smart Well Managers since the first day of operation.

The Smart Well Manager (SWM)

The basic purpose of the Smart Well Manager (SWM) is to determine when the fluid level in the well bore is pumped down to the point where pump intake pressure is no longer sufficient to completely fill the pump barrel with fluid during the upstroke. Incompletely filling the pump barrel reduces the efficiency of the pumping operation and the resulting “fluid pound” causes extra wear and tear on pumps, rods, tubing, and surface equipment.

The SWM is a pre-programmed device mounted at the well site that gathers, processes, stores, and analyzes analog data obtained from a load cell mounted between the clamp and the carrier bar at the polished rod and digital data obtained from Hall Effects (two digital position sensors at the motor for RPM and the crank arm). The SWM uses the data from these input devices to monitor and control the operation of the pumping unit and to display graphic data on a LCD display or portable laptop computer in a format easy to understand.

The SWM also uses this information to detect malfunctions and problems with the pumping unit. Current information about pumping activity can be obtained on demand. Historical data at the well site can also be obtained at any time, and this data can be plotted and produced on reports.

The Polished Rod Load Cell (PRLC) and Hall-Effect transducers combination of input sensors, see figure 2, is preferred for downhole percent fillage control and in-depth analysis of the pump cards when accurate surface dynagraph data needs to be obtained.

The PRLC provides a quantitative measurement of the load on the rod string. It is mounted on top of the carrier bar under the rod clamp. The PRLC directly measures the weight of the rod string and fluid column on the pump plunger. A spherical washer set between the PRLC and the carrier bar ensures concentric loading even if the carrier bar is tilted.
Two Hall-Effect transducers are used. One transducer measures precise motor speed and the second transducer marks the crank arm passage at the bottom of each stroke. These two digital signals, coupled with precise pumping unit dimensional data (from the controller’s database), allow the SWM to accurately calculate surface stroke position. In addition to accuracy, the two Hall-Effect transducers offer the advantage of being able to monitor for belt slippage and to instantaneously shutdown the pumping unit when a “locked rotor” equipment failure occurs.

**Control methods for the SWM**

The Primary control method is using the pump fillage percentage. This method is based on a downhole pump card using polished rod load and position inputs, and is the most accurate control method. The SWM receives information from the input devices to determine whether sufficient fluid is present in the well bore. If the control unit determines that the well is in a pumped off condition, the control unit turns off the motor control output to stop the pumping unit and places the pumping unit into a downtime mode. Downtime mode allows fluid to flow back into the well bore. After downtime elapses, the control unit turns on the motor control output to start the pumping unit again. Downtime is programmed by the operator based on experience and production tests.

The SWM also performs many secondary control functions to detect pumping equipment malfunction and to help protect equipment against further damage in the event of an equipment failure.

The SWM allows for a programmable number of re-tries when a malfunction event occurs. If the condition continues for the programmed number of re-tries, the SWM shuts down the pumping unit in a Malfunction state that requires the operator to solve the problem and return the pumping system to a pumping state. The malfunction controls include:

- Shutting down the well if the polished rod load exceeds a Peak Allowed or falls below a Minimum Allowed.
- Shutting down the well if surface load on the upstroke falls below a Malfunction set point for programmed number of consecutive strokes. Detects pumping equipment failures such as rod parts, or traveling valve not closing.
- Shutting down the well if the fluid load falls below a minimum allowed level for programmed number of strokes. Fluid load is calculated by subtracting the average downstroke load of the pump card from the average upstroke load of the pump card. Fluid load checking is an alternative method to detect pumping equipment failures, such as rod parts or the traveling valve not closing.
- The SWM will shut down the pumping unit if the measured motor RPM drops below an allowed low limit. Provides protection against stuck pump conditions with quicker response than peak load detection.
• The SWM counts the number of motor revolutions each pump stroke. If that number rises above a set reference by more than an allowed percentage, an alarm flag is set to alert the operator to possible belt slippage.

Gathered Dynamometer Data

The SWM displays a real-time dynagraph trace for on-location analysis of present pumping conditions. The SWM also stores a number of dynagraph cards as an historical record as follows: Five most recent strokes, Single stroke at the last transition from minimum pump strokes to pumping, Last five strokes before a shutdown decision is recorded for each of the last two shutdown decisions and Single-stroke card at the start of the minimum pump stroke well state.

The SWM includes an inferred production algorithm (IPA) to calculate the total fluid production of the pumping unit. The SWM uses measured strokes per minute, programmed surface stroke length and pump plunger diameter, and a pump plunger stroke length inferred from the downhole pump card. The IPA has a K factor to adjust for slippage around the pump plunger and/or shrinkage of fluid volume as gas breaks out of solution in the production tank.

The SWM calculates the polished rod horsepower (PRHP) from the surface card and the pump HP from the downhole card each stroke. The user can enter a reference PRHP immediately after a hot oil treatment. The Smart Well Manager stamps that reference entry with the date and time. The user can also set a peak PRHP limit. If the calculated PRHP exceeds the set peak limit, an alarm flag is set to alert the user that it can be time to treat for paraffin again.

The SWM has separately resettable accumulators, Rodometer and Pumpometer, to keep count of the number of pump cycles for a rod string and a pump. This feature is used as a tool for monitoring the operation and failure analysis of downhole equipment.

The SWM maintains a historical record of the previous 60 days of Run time for the day in percent, Inferred production for the day in barrels, Highest and Lowest values for the polished rod load for the day, and Highest value for polished rod horsepower for the day.

The SWM record polished rod load versus time and save the data for analysis. The analysis feature includes the ability to Record standing valve and traveling valve load values and Calculate traveling valve leakage in barrels per day.

The SWM uses the real-time clock to date/time stamp historical performance actions. One buffer tracks predefined significant events to let the user see the last time that the event occurred.
Case History

In order to show the performance of SWM, statistical comparison was performed between wells equipped with the SWM at Khalda from day one and wells running without control in the field of another company in the western desert. These wells are producing same fluid properties from depletion drive reservoir. The publications of that company, in the western desert, shows very low equipment running lives compared with Khalda which shows only one rod parted over the last four years of sucker rod system operation. All the rod failures reported in the other company were fatigue failure plus coupling unscrew. Fluid pounding and/or gas interference leading to sucker rod parted and pump failures can be easily indicated as the main factors affecting the subsurface equipment failure.

Fluid pound, see figure 3, is generally experienced when the lifting capacity of the pump exceeds the liquid inflow rate to the well. In such cases, the pump barrel is not completely filled with fluid on the upstroke. As the downstroke starts, the traveling valve can not open as it should, and the plunger begins its downstroke with the full load on it. Then, when the plunger hits the fluid level in the pump barrel, the sudden impact force is transmitted to the surface along the rod string. The great dynamic loads occurring during fluid pounding make the rod string experience buckling leading to rod breaks and rod-to-tubing wear. On the surface, the excessive shock loads can damage pumping unit bearings and can lead to instantaneous torques that overload the speed reducer.

The main factors affecting the equipment performances in are highlighted as follows:

- Fast decline in reservoir pressure with production since the reservoir is depletion drive type the fast decline in reservoir pressure was affecting the pump intake pressure. Therefore, the gas and fluid pounding phenomena became serious problems.
- Weak monitoring system, only conventional dynamometer and fluid level shooting device are used once every three months

Figure 4 shows the history of the subsurface pump and sucker rod history for the last nine years in the company mentioned above. It reflects that the average failure per well per year is 3.6 which means the well stops at least once every 100 days. With very simple calculation, if we assumed that the well produces about 200 BOPD with average oil price $50/barrel then the losses per well per year will be $18,000. If we add a service rig daily rate plus replacing the damaged rods and/or pump, the average total cost will be $25,000 per well per year. The field under study has 75 sucker rod wells, which means the total losses will be $1,875,000/year. In case of Khalda, cost of rod parted failure is saved.

Moreover, power consumption is another key factor which can show the great effect of controlling the sucker rod wells using SWM to shut them down in case of low pump fillage.
In addition to optimizing the well performance, good reference for the well production could be achieved with the right adjustment of the SWM K-factor. Khalda compared the test figure calculated by SWM and that measured by well test equipment and found them matching. Where for example; the test of well Hyatt-29 at Salam field on July 6, 2005 by test separator show that well produces 167BFPD where the SWM gave a production of 171.4 BFPD with a difference of 2.3 %. Since SWM gives accurate production figure, Khalda can eliminate the frequent use of test equipment for rod pumping wells where the other companies in the same area still use the mobile test equipment to test their wells. These companies usually use the test separator on wells to test production once per month which means they get only two values for the well production within 30 days period. What about the period between the two tests, how much was the production? In Khalda they get a continuous record of the production by using the SWM.

Balancing the pumping unit is another critical aspect in the performance of the overall system. The conventional method of balancing the unit is by trial and error while measuring the peak amps after moving the crank weights randomly. It usually takes several tries until the unit is balanced. Khalda used sucker rod automation software to aid in deciding the exact required position for crank weights. A surface card is downloaded from the SWM and run on automation software and gives the suggested position of existing counter weights for balancing the unit. This saves time by saving the hassle of trial and error and also leads to accurate unit balancing.

Performance of SWM
Since the installation of the smart system in Khalda, very few automation failures occurred during work over. The load cell failed two times because of improper handling of the load cell and its connector. The load cell cable failed 3 times because of improper handling when disconnected. A modified coiled cable was used to lower the probability of failure. Most of these failures appeared at the beginning of the operation until all parties involved at the well site got used to the system.

Conclusion
Even though the sucker rod is an old method of artificial lift but state of the art technology still participate in the operation of the sucker rod well. It is important to have a controller at each well, whether it has high or low production rate, in order to protect the investment made in the downhole and surface equipment as well as continuous monitoring and analysis of well data.

Automation is a very important component of the sucker rod system but it shares the success with other components. The optimum sucker rod system performance can be achieved after applying the following:

- System Design is very important in order to choose the correct size and material of surface and downhole equipment for each well independently as well conditions are different from one well to another.
- Installation of the surface equipment and Carry, Handling and Running of the downhole items extremely effect the failure probability for the well.
• Monitoring and control are very important for increasing equipment lifetime, managing the well and keep a record of the well history to evaluate the system performance and take corrective actions.

**Things to improve**

In order to download the data from all the wells, the engineer has to drive from one well to another. In some cases that distance is very long where the wells in Sumpetco are 70 km from the office in Salam base. The implementation of a SCADA (Supervisory Control And Data Acquisition) system for remote monitoring, control and analysis will save the driving time required to download the data from each well and also have quicker response to problems. The engineer can easily view the status of all wells and perform analysis at the tip of his finger in the field office. Also the data could be shared with the headquarter office in Cairo over a wide area network.

**Recommendations**

• All sucker rod wells should be automated to help the engineers and technicians to optimize the wells and do their job more efficiently.
• In case of sand and heavy oil, it is recommended to install a Variable Speed Drive (VSD) with the SWM in order to increase and decrease the pumping speed based on pump fillage instead of completely stopping the unit for a programmed downtime.
• With the implementation of sophisticated control systems, personnel’s training is vital in order to utilize the system.
• In case of hundreds of wells, the field automation can start with a pilot project for a group of wells and then implemented over all the wells.

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5. Khalda Sucker Rod System Database
Figure 1, Khalda Location

Figure 2, SWM Installation
Figure 3, Fluid Pound

Figure 4 Average Sucker Rod and DHP Failure per Year