

Integrated Digital Automation System for Production Optimization in the North San Juan Basin

An integrated digital automation system was used to optimize tubing-flow control and plunger-lift installations in the north San Juan basin. The intelligent closed-looped automation system increased gas production, improved equipment reliability, and provided an efficient and inexpensive deliquification method with an almost exclusively remote-controlled operation.

Introduction

Gas-well production tends to decrease over time as a result of depleting reservoir pressure. The liquids associated with the produced gas accumulate in the wellbore. The liquid column creates hydrostatic backpressure on the reservoir, which further reduces the gas flow rate. A minimum gas-flow rate is required to lift the entrained liquid droplets to the surface at a specific wellhead pressure. Several artificial-lift and dewatering methods are available to lift liquid from the bottom of the well to the surface; one is plunger lift. In some marginal gas wells, anticipated production would not justify installing artificial-lift systems such as a sucker-rod pump to dewater wells. In some applications, plunger lift is an economical choice. Plunger lift is an intermittent form of artificial lift that uses the reservoir energy to lift liquids out of the wellbore. Plunger lift has benefited from

improved digital technology. The entire system can be completely monitored and optimized.

Unlike conventional natural-gas reservoirs in which gas production rates tend to be greatest at the onset, then steadily decline over the life of the well, coalbed methane produced in the north San Juan basin progressively increases to a maximum flow rate several days or years after first production. It is a challenge to match and optimize tubing and casing sizes with the ever-changing production rate. Applying optimized tubing-flow control helps to mitigate these challenges.

Integrated Digital Automation

Input/output (I/O) abstraction is the function that defines the connection between physical I/O and the applications or process I/O, or between a calculated variable and a consuming program. An example of I/O abstraction would be to assign an analog input as casing pressure. The programmer could assign the physical I/O to the casing pressure at design time so that "Analog X" is always casing pressure. In an abstracted scheme, the analog input is assigned to the casing-pressure variable at run time so that, if needed, the physical input can be assigned to another process variable if the particular installation did not have a casing pressure.

An example of a calculated value abstracted and consumed by a program is a critical-flow-rate value placed in a common index or array, and then, by use of mapping, that value is called into a subroutine program-organization unit and used to control a plunger process.

Regardless of the language/hardware platform, each functional portion of the application consists of modular routines that use a common set of

interfaces and methods of intercommunicating. A unified application can be created that uses a common application for an entire field of remote terminal units (RTUs) providing production optimization. This standardization allows a single point for upgrading or, even more important, troubleshooting software problems.

Use of a modular design and abstraction layers simplifies the transfer of functions between platforms that use different programming languages. This structure lent itself to the 1,131 languages that support instantiation and allowed a multiwell "pad" control scheme to be created.

Communication with the wells is through microwave radios. Data polling is scheduled between 1 and 15 minutes, depending on the well and the radio. Data capture and archiving occur in several forms. Data are stored at the tag level in a real-time database. Process-specific data are captured in 2D arrays, one of which is the cycle log. Each row in this data set captures values specific to that production cycle such as gas volume, liquid volume, plunger speed, and flow time. Another array captures time- and/or event-based data, such as gas rate and wellhead pressures at a resolution of once per second (adjustable by well).

Well-Control Applications

The well-control portion of the application provides the cycling-well control (plunger or intermitter), tubing-flow control, and wellhead-compression control. Each of these functions can be used alone, or all can be used together on a single wellsite.

Cycling-Well Control

The operation of a plunger system or "cycle" occurs in three distinct steps: after flow, drop, and lift.

This article, written by Technology Editor Dennis Denney, contains highlights of paper SPE 106952, "Successful Application of Integrated Digital Automation System for Production Optimization in the North San Juan Basin," by Peter O. Oyewole, SPE, Michael D. Scull, and Mark S. Downey, BP plc and John B. Herring, SPE, Pure Automation, prepared for the 2007 SPE Digital Energy Conference and Exhibition, Houston, 11-12 April.

For a limited time, the full-length paper is available free to SPE members at www.spe.org/jpt. The paper has not been peer reviewed.

After Flow. This portion of the cycle begins when the plunger initially returns to the surface, pushing fluids to the separator. For a properly tuned plunger system, after plunger arrival, removing fluids from the well results in a reduced backpressure on the formation. Also, the pressure stored during off time will result in increased velocity of the gas traveling through the well system from the producing formation. The velocity allows liquids entrained in the gas to travel to the surface separation equipment and leave the system. The velocity threshold at which the well continues to move fluid or “unload” is called the critical rate or critical velocity.

Plunger Drop. The sales valve is closed, and the plunger, which was held in the plunger receiver/lubricator, begins to fall. The point of plunger drop, when the sales valve is closed, is determined by a selected pressure- or flow-rate-based algorithm. After the plunger reaches the bottom-assembly spring, fluid rises around the plunger. The process will wait a fixed off time and evaluate for lift by comparing pre-defined lift parameters, then lift the plunger by opening the sales valve.

Lift. The sales valve is opened to lift the plunger to the plunger receiver and move the fluid that is above the plunger into the surface separation equipment. After arrival, fluid may continue to be carried to the surface along with entrained liquid vapors. Proper load-ratio calculation ensures sufficient initial velocity to continue the fluid removal or unloading after initial plunger arrival. The closed-looped plunger application repeats the plunger process automatically. This process is termed the plunger cycle.

Tubing-Flow Control

Tubing-/casing-flow control has been used on gas wells with limited success. However, recent advances in technology and automation have proved this technology to be a viable dewatering alternative and wellbore-friction reducer.

In a generic example, the cross-sectional flow area of the tubing string may be small enough to achieve adequate gas velocity to lift liquids from the wellbore. However, these high velocities often result in extra frictional losses that impose an additional back-

pressure on the formation and result in lower production rates. Often, the larger casing (or annular) flow area, which incurs less friction, is too large to permit the gas flow to reach the critical velocity for lifting water from the wellbore.

Flow control allows liquids to be produced up the tubing at the minimum gas velocity needed to lift liquids from the end of the tubing to surface, with additional gas produced through the tubing/casing annulus by use of a control valve.

Enhanced flow-control installations are integrated into the existing automation system with data input from a pitot-tube transmitter installed on the tubing-flow line and the RTU output routed to an electrically actuated control valve installed on the tubing/casing annulus. The existing RTU calculates, in real time, the required tubing-unload rate while differential pressure from the pitot is sent to the RTU and used to calculate actual tubing flow. If the tubing flow is greater than or equal to the critical rate, the RTU sends a signal to open the control valve slowly. If the tubing rate falls below critical rate, a signal is sent to close the control valve slowly. Flow up the tubing is maintained at the appropriate rate for water production, and the well is optimized at the minimum bottomhole pressure, which results in higher overall gas production.

Field Result

With fewer than 40 plunger-lift installations in the study area, high-quality digital automatic control coupled with effective use of plunger-lift data resulted in incremental gas production of more than 4 MMcf/D. The system automatically adjusts plunger-arrival time, after flow, and shut-in time on the basis of a preset operating range to maximize gas production. Thirty tubing-flow control installations resulted in an average gas-production increase of 130 Mcf/D per well. The casing valve automatically controlled gas flow through tubing above the critical gas rate while releasing friction and backpressure on the formation by producing additional gas through the tubing-casing annulus. This operation is a significant departure from traditional means of operating gas wells, whereby multiple full-rig interventions are required to optimize tubing size and the artificial-lift installation. **JPT**