A UNIQUE WELL MANAGEMENT SYSTEM FOR AUTOMATED SURFACE CONTROL OF ARTIFICIAL LIFT PRODUCTS

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ABSTRACT

In Coalbed Methane (CBM) production wells using Electric Submersible Pumps (ESP), it is common to control fluid levels to the required setting by the use of Variable Speed Drives. However this can cause high harmonics and, as a result, in the Powder River Basin in Wyoming, power companies have become increasingly reluctant to allow the use of variable speed drives and an alternative method of well control had to be found.

A totally new approach to controlling ESPs, and thus the well fluid levels, was conceived. The Weatherford Well Management System0 (WMS) is a self-contained alternative to variable speed drives, which eliminates harmonics problems. It consists of a motor starter, a motor protection system and a microprocessor which controls a surface actuated choke in the flow line. During production operations, fluid levels can be controlled by automatically adjusting the choke.

This paper describes the conception, development and field testing of the Weatherford WMS as a viable alternative to variable speed drives for downhole pump control. This system, which can be made compatible with any communication system, though designed for ESP applications in CBM production, is also applicable to other artificial lift systems and oilfield applications.

INTRODUCTION

In June of 2000 at the CBM Conference in Denver Colorado, a major topic of conversation was the reluctance of the power companies in the Powder River Basin to continue *to* allow Variable Speed Drives to be used due to high harmonics. This phenomenon induces momentary power supply fluctuations resulting in severe voltage spiking which can lead to interruptions in the overall power supply system. In severe cases this can damage domestic appliances and even make clocks run backwards. Since a large portion of the operators in the Powder River Basin were using Variable Speed Drives to help produce these CBM wells, it became clear that an alternative needed to be found.

After evaluating the operational characteristics of the Powder River Basin wells and the flexibility that a variable speed drive offered to the operators, a new concept was developed. What if it were possible to take the basic principles of hydraulic theory and force the well to behave as if it were being controlled by a Variable Speed Drive, without the harmonic issue to contend with. If this could be done in such a way that pumps could be made to operate on a continuous basis at essentially a fixed speed, the harmonics problem would no longer be an issue. An idea was born.

DEVELOPMENT AND TESTING

A long established method of well control is the use of back-pressure to regulate flow. If this basic principle could somehow be harnessed to adjust the production from the well, then something close to a continuous ESP operation might be possible. By using a modern electronic control system in conjunction with back-pressure control, could a viable system be devised? It was decided to test the theory using a combination of extensive laboratory tests followed by field testing on suitable candidate wells. The lab tests proved that the concept could indeed be viable and the subsequent field-testing carried out in the Powder River Basin verified it. The full potential of the concept was realized due to the fortuitous failure of surface monitoring devices necessitating that manual adjustments be made. During initial tests the surface monitoring equipment, providing signals of well performance parameters, was not functioning correctly with the result that all readings had to be taken and inputted to the electronic control system manually. This resulted in a continuous well control concept which was then converted into software, thereby creating a fully interactive device that learns as it operates, controlling the pump and optimizing its operation at the same time. Because of the true interactive, "learn as it goes" mode of operation, the device qualifies as a system that can be patented.

The Weatherford WMS that resulted from these basic concepts consisted of a motor starter and motor protection system combined with a microprocessor. The microprocessor receives continuous signals monitoring well parameters and in turn

sends control signals to the electrically operated surface choke to either open up or choke off on the surface flow line. In essence, the Weatherford WMS looks at programmed information concerning the design of the pump, compares that to the motor amperage, and to surface sensors monitoring flow rates and surface pressure, and automatically adjusts the surface control valve to try to keep the pump running 24 hours per day. The interactive software remembers what is happening and adjusts itself accordingly so that, after a day or two, the Weatherford WMS will literally size the pump output to meet the well's inflow thereby reducing or eliminating gas locking and pump off. All of this is provides more automatic control over a given well and optimizes its performance with little or no additional attention from the operator.

SYSTEM COMPONENTS AND DESCRIPTION

The microprocessor of the Weatherford WMS is a custom designed single board computer with firmware specifically written to optimize wellhead operations on CBM wells. The controller has analog inputs that read the tubing pressure and motor current with 12-bit precision and software filtering of the data. It incorporates a separate relay board to allow the low-voltage outputs from the controller to drive the motor contacter, an electrically actuated valve, and several 120-volt lamps. Downloading a new program serially using the controller's communications port (RS-232) can make firmware changes, there are no EPROMS to bum. All process data, variables, and set points are stored in non-volatile memory which will not be lost should the card lose power. The complete system is powered from a single 120Volt AC source, which is typically a 480/120V transformer mounted in the Pump Panel. A switch on the panel allows manual control of the back-pressure valve, although it is never used in normal operation.

The system includes a 20-key keypad and 2x20-character LCD display, which make it easy to view process variables and alarms and to change set points in the field. The display is rated for extended temperatures, and is illuminated for nighttime viewing. All connections to the board are quick disconnects and the controller board can be replaced in a matter of minutes. For ease of installation, field terminations are made to a set of fused and non-fused terminal blocks on the inner panel of the control enclosure. The controller has a single RS-232 serial port, and communicates using a standard Modbus-RTU protocol. This feature can be utilized to pass information to existing control and/or monitoring systems and the controller is adaptable to existing telemetry systems or can be incorporated in a new telemetry program.

The software has been written to avoid the need for a down-hole pressure measurement sensor. The electrically actuated back-pressure valve will essentially size the pump for the well based on current water conditions, will continuously adapt to changing conditions in order to maximize gas production and can offer a much larger window of control than variable frequency drives. On CBM wells with low water inflow, this system can slow down water production by over 90% in order to maintain an optimal water level without excessive starting and stopping of the motor. In addition to controlling the back-pressure valve, the system will protect the motor from underload and overload conditions. Underload conditions will cause a shutdown followed by a delayed restart, until a maximum number of automatic restarts have occurred, while overload conditions will require a "reset" before allowing the motor to start. Other shutdowns include high and low tubing pressure and a "pumped off" or "gas locked" condition. Because of its' unique ability to adapt, the Weatherford WMS can be used for a variety of well applications and artificial lift vehicles. It has the ability to optimize wells making free gas and keep the pumps from experiencing gas locking or even pump off, all accomplished without downhole pressure sensing equipment.

The Weatherford WMS is typically mounted next to the pump panel. It can not be mounted inside the shed at the wellhead, because it is not rated for Class 1 Division *2* environments. The actuator and the pressure sensor are rated for wellhead installation and can be supplied in explosion proof enclosures. The system is designed to handle standard industrial temperature ranges and can be mounted inside or outside for all weather performance.

FIELD TEST DATA

Three wells were tested as part of the field test segment and the following results were recorded:

The well was being operated with a submersible pump and motor and variable speed drive with gas production of 40 MCF and the pump was cycling (that is stopping and starting) 25 times per day. The only change made to the well was the installation of a Weatherford WMS and after three days operation, the well was producing 250 MCF per day and the pump was running continuously 24 hours per day, maintaining a fluid level 40 feet above the pump.

- This well was producing 50 MCF per day with a variable speed drive controlled submersible pump which was cycling 40 times per hour.. Within 2 days of the Weatherford WMS installation, gas production peaked at 325 MCF per day and cycling was reduced to 4 times per day.

As with the other two case histories, a Weatherford WMS system was installed on an existing well equipped

with a submersible pump. In this case the well was producing 25 MCF per day and was cycling 50 times per hour and was in the process of being evaluated for abandonment. On the third day of installation, the Weatherford WMS had stabilized the well to where its cycle time was reduced from 50 times per hour to 5 times per day and gas production had increased from 25 MCF per day to 275 MCF per day. Over a thirty-day period the well stabilized, consistently making the 275 MCF per day, at which point, a decision was made to shut the Weatherford WMS off to evaluate the results. Within 36 hours, the cycle time increased to 50 times per hour and gas production became erratic, ranging from 20 MCF to 30 MCF per day. After a two-week period the Weatherford WMS was turned back on and, within 36 hours, cycle time reverted to 5 times per day and gas production increased to a stabilized rate of 270 MCF.

CONCLUSIONS

All the field-testing proved the theory was correct and that a product had been developed that was technologically advanced and exceeded the original goals. The ability to adapt to different well conditions and learn as it goes offers interactive capabilities that were not available before. This technology can have a profound effect on the future of well performance where variable speed controls are now used and downhole sensors have proven unreliable. This revolutionary approach to well control offers cost-effective options and unique methods for optimizing well production. It can obviate the need for purchasing add-on accessories to protect the downhole equipment and the flexibility of the system offers unique cost saving features that give the operator better overall control of the wells and better "hands off' well performance.

This product was designed specifically for ESP systems in CBM applications however, it works equally well in oil field applications as well. Due to the flexibility of the system, it can be used very economically on almost any artificial lift vehicle, such as Rod Pumps, Progressive Cavity Pumps and others.