ESPS WITH CHEMICAL INJECTION AUTOMATION AND OPTIMIZATION

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INTRODUCTION

The status quo continuous chemical injection systems are labor-intensive. They require operators to manually collect data, interpret that data, and implement changes to the treatment via multiple trips to the well site. This results in higher chemical cost, inefficient use of manpower, greater HS&E exposure, and lag time for execution.

These issues are intensified on electrical submersible pumping (ESP) system wells where higher flow rates require more chemical usage and failure to monitor the treatment program appropriately can result in costly workovers.

A "smart" chemical injection system can make real-time decisions at the well site and remotely transmit data for automatic analysis and reporting. This optimized system will inject chemical on-demand, based on inferred flow characteristics from the ESP motor controller, tracking of on site chemical inventories and reporting through a dynamic web-based monitoring system.

While these basic principles are transferable to any continuous chemical injection system, the focus of this presentation will be on ESP production wells.

Challenges

Maintaining correct chemical injection rates is critical to any oilfield application. This is a difficult problem since well conditions such as pressure and flow rate typically vary over time. It also requires making sure enough chemical is always on location and the system does not run out. Without a proportional chemical injection system, rates must be set at the highest potential production rate to make sure under-treatment does not occur.

Furthermore, manual control of this operation is a highly manpower-intensive process. Rates have to be measured, injection rates calculated and implemented, etc. Additionally most sites are very remote and require travel to access. This process exposes workers to more HS&E risks associated with driving and onsite exposure to chemicals, hazardous environments, etc.

Ideal Solution

The model solution to these issues is a method to instantaneously control chemical injection rates based on the true needs of the produced fluids. Therefore, when production rates increase or decrease, the correct amount of chemical is always injected and ensures proper treatment of the ESP. A proper treatment program can reduce operating costs through increased equipment reliability and less chemical spending.

Remotely monitoring the injection program ensures that the chemical is delivered as the well requires. A robust system allows for implementation of changes to the chemical program and monitor chemical inventory with fewer trips to the well site. Fewer trips increases manpower efficiency, decreases costs, and prevents unnecessary HS&E exposure. This automatic measurement and calculation also allows for standardized reporting and interpretation with fewer man-hours spent gathering and arranging data.

TECHNOLOGY

Chemical Automation Controller

The chemical injection controller consists of a chemical pump control module, which provides an electronic interface and control capability for the injection pump. Integral to the control module is a high-precision chemical flowmeter. The chemical flowmeter reads the actual chemical injection flow rate and is extremely accurate at injection rates as low as two quarts per day. The chemical injection unit is designed for service in explosion-proof areas and remote locations with minimal power availability. The key advantage of this controller is the ability to provide proportional injection of oilfield chemicals to optimize chemical treatment programs.

Tank Level Monitors

Battery-powered tank level gauges accurately measure tank product levels in vented vessels up to 40 ft in height, and send the data to the chemical automation controller using robust wireless technology. Several measurement technologies are available including traditional floats, ultrasonic, pressure, and capacitance.

Variable Speed Drive

The variable speed drive (VSD) has become an indispensible tool for optimizing ESP operations. However for the purpose of this setup, a standard motor controller with basic I/O capabilities would be sufficient. This controller is used as a data collection and interpretation master to serve as a single point interface. Data is constantly monitored from the downhole operating conditions and combined with surface readings such as tubing pressure, casing pressure, the chemical automation controllers, flowmeters, and any other gauges with analog, digital, or MODBUS communications. The VSD has a built-in programmable logic controller (PLC) which can automatically perform any required calculations at the wellsite and transmit new setpoints to the local controllers or change ESP operations to accommodate any limits such as pump intake pressure or surface pressure restrictions. Collecting this data in a centralized location also allows for simple tie-in to a two way supervisory control and data acquisition (SCADA) system.

Flow Metering

Flow metering is critical to both ESP and chemical operations, but is often not given close enough attention. The chemical automation controller requires a flow input to accurately and continously inject the correct amount of chemical, which saves operating costs. Flow rates are important for ESP runlife to ensure that the pump is operating within its recommended limits. There are two main ways to provide a quantitative production rate and two main ways to provide a qualitative production rate for an individual well.

Quantitiative production rates (actual, accurate numbers) can be provided by a dedicated real flowmeter or by a dedicated virtual flowmeter. The real flowmeter should be committed to an individual well and have an analog or MODBUS output for intrepretation by the chemical automation controller and VSD for remote monitoring. This is the most accurate method of measurement, but is also the most costly. The virtual flowmeter is a new development which uses the logic capabilities of the VSD to calculate a flow rate based on the ESP model and actual operating conditions. A series of neural networks are calculated from either 1) tubing pressure and discharge pressure, 2) pump intake pressure, pump discharge pressure, and frequency, 3) pump intake pressure only, or 4) tubing pressure and frequency. These parameters are compared against the calculated IPR data and pump performance from the ESP model to generate a real time calculated flow rate. This flow rate can then be fed into the chemical automation controller for proportional injection and the SCADA system for ESP optimization. This option is often cheaper than a real flowmeter, but in the right applications can provide accuracy acceptable for these tools.

Qualitative production rates (inferred, directionally correct numbers) can be provided by an allocated real flowmeter or an interpretation of the ESP motor amperage. The most common method for flow measurement is an allocated flowmeter which is used at a tank battery to measue flow from individual wells on a predetermined timeframe (most often one-month intervals). This leaves a large gap in production data, which is unacceptable for chemical automation and thorough ESP optimization. ESP motor amps can be used in some situations to infer if the flow rate is moving up or down. This is due to the fact that hydraulic horsepower is a function of flowrate and horsepower is a function of amperage when at a constant voltage.

$$HHP = Q * H * SG$$

Where,
HHP = hydraulic horsepower required
Q = flow rate
H = required total dynamic head
SG = specific gravity of the fluid

$$HP = V * A * \sqrt{3} * 746$$

Where,

HP = three-phase motor horsepower
V = downhole motor voltage
A = downhole motor amperage

These equations can only be combined to give a directional production rate when the total dynamic head, specific gravity, efficiency, and applied voltage do not change dramatically and cannot be relied on for a qualitative number.

Remote Monitoring System

The two components of data integration are getting the data to a centralized point and then interpretation and analysis of the data. There are many options for getting the data from the field to a central database, but we will focus on the two most common. The first option is to use modems dedicated to the service provider to gather the data while the second option uses a broader existing SCADA radio communication system. Using the ESP provider's modems usually allows a higher bandwidth to gather all the necessary data points at a poll rate optimized to the individual operation. Using the existing radio system often requires code modifications and hardware upgrades to accommodate the MODBUS tag list required from an ESP over typical monitored hardware. The recommended list of MODBUS tags that should be pulled from the VSD for proper operational troubleshooting and optimization is approximately 100 registers long. This is a significantly larger data set than supplementary monitored devices such as tank levels, compressor data, or surface transfer pump parameters. These tags are typically polled at 10-minute intervals for good data resolution, but can be increased to five minutes for harsher, gassy applications or decreased to 30 - 60 minutes for more benign applications.

When service company modems are used, the data is often brought into their database and access to this data can be limited. When choosing a service company's monitoring system, be certain to check the tag list, poll rates, data ownership, and historical data availablilty. Many service companies offer a lower price, but one of the aforementioned attributes is compromised. However, most service companies offer web-based interfaces, which allows quick setup and easy access to data with no time commitment on creating, updating, or troubleshooting an internal system. These interfaces also often provide additional reporting and support capabilities beyond in-house capabilities. For chemical automation, inventory reporting includes tank locations, product types, and capacities for any specified time frame. This information simplifies asset tracking and optimizes the number of trips to the field, which saves manpower costs. Graphical usage shows rates of consumption for each chemical and easily indicates how full each tank is. A usage rate calculation can automatically calculate a usage rate to alarm when any deviation occurs. This prevents the production company from injecting too much or too little chemical, which can compromise the treatment program. The usage rate can also predict how much chemical will be used in the future for budgetary purposes. The ESP monitoring system should quickly and easily identify wells that are operating outside of recommended limits, including pump operating range, intake pressure range, and motor temperature limits.

Regardless of which communication option is chosen, there are two additional options for the monitoring and interpretation of the data. The first option provides the data to the operating company's production engineers and field specialists for interpretation and analysis of the data in-house. This method requires more man-hours by the production company and depending on the monitoring system can take more time to get the data in a usable format than is used in the actual analysis. The second option is to use the service company's technical experts to analyze and report on the data. This becomes much easier when they are analyzing with their own monitoring interface. This option requires less work by the company, but often comes at an incremental price. However, depending on the criticality of the application, access to industry experts and specialists may be worthwhile. Some service companies have networks set up across the globe to provide easy collaboration for optimizing and troubleshooting production operations. These collaboration centers allow production companies to use the specialization of chemical and ESP service companies to help bring production up and/or operating costs down.

IMPLEMENTATION

How each of these technologies must be combined will be heavily dependant upon the application and what inputs are available. First, the signal from the flowmeter must be brought into the VSD. If this is brought in on an analog (4 – 20 mA) signal, the scaling must be properly configured between the VSD and flowmeter for accurate results. Second, a signal line must be established between the VSD and chemical automation controller. This will transmit the appropriate flow rate and command signals via MODBUS communications and receive the tags calculated and measured by the chemical injection controller. If motor amperage is used as a qualitative indication of flow, a linear analog scale must be configured based on the pump performance characteristics and coupled with an additional digital relay to indicate run status between the VSD and chemical automation controller. This will allow the chemical automation controller to stop chemical injection when the ESP shuts down. Third, wireless communications must be established between the chemical automation controller and the tank level monitors so that the amount of chemical remaining can be received. Finally, the remote monitoring system must be configured to read all the appropriate registers from the VSD to allow for maximum optimization at an acceptable poll rate with two-way communications. A schematic of this setup can be seen in Figure 1.

CONCLUSION

Improved Worker Safety

The chemical automation system reduces the need for oilfield workers to visit remote facilities to check tank levels or to adjust chemical injection rates. Such visits are significant safety hazards during harsh weather conditions. The system reduces incidents associated with traveling to remote locations such as injuries due to slips and falls incurred while riding in automobiles, boats and helicopters, climbing ladders, or tanks.

The chemical automation system reduces exposure to oil and gas that may contain carcinogens and toxic chemicals, and produced water that often contains high levels of NORM (naturally occurring radioactive material). If a system failure occurs, the chemical automation system provides immediate alarm notification and identification. The respondents will know where the problem has occurred and what safety precautions are required.

Production Optimization and Reduced Environmental Impact

The chemical automation system is used to automate chemical treatment to maintain remote equipment integrity and optimize production, such as corrosion inhibitors that prevent internal corrosion. Corrosion failures require large amounts of manpower to remediate leaks and mitigate environmental damage. The chemical automation system uses wireless data communications technologies that eliminate the environmental impact of running wires and cables for SCADA/DCS systems. Solar-powered pumps reduce the load on offshore diesel engine-generator systems and also reduce greenhouse gas emissions of gas-driven chemical pumps.

This chemical automation systems allow oil and gas operators to manage their operations in a proactive manner. The alarm system will identify problem situations before they occur and allow rapid remediation. In the long run, the chemical automation system helps reduce leaks, spills, and safety accidents, resulting in improved overall performance

Safer Shutdown and Startup of Remote Systems

When a shutdown due to a process upset or power failure occurs, critical chemicals such as hydrate inhibitors are injected at shut-in rates automatically to prevent lines from plugging during a shutdown. When conditions clear and production is to resume, chemical pumps can be started and rates adjusted automatically, allowing for gradual return to full-scale production.

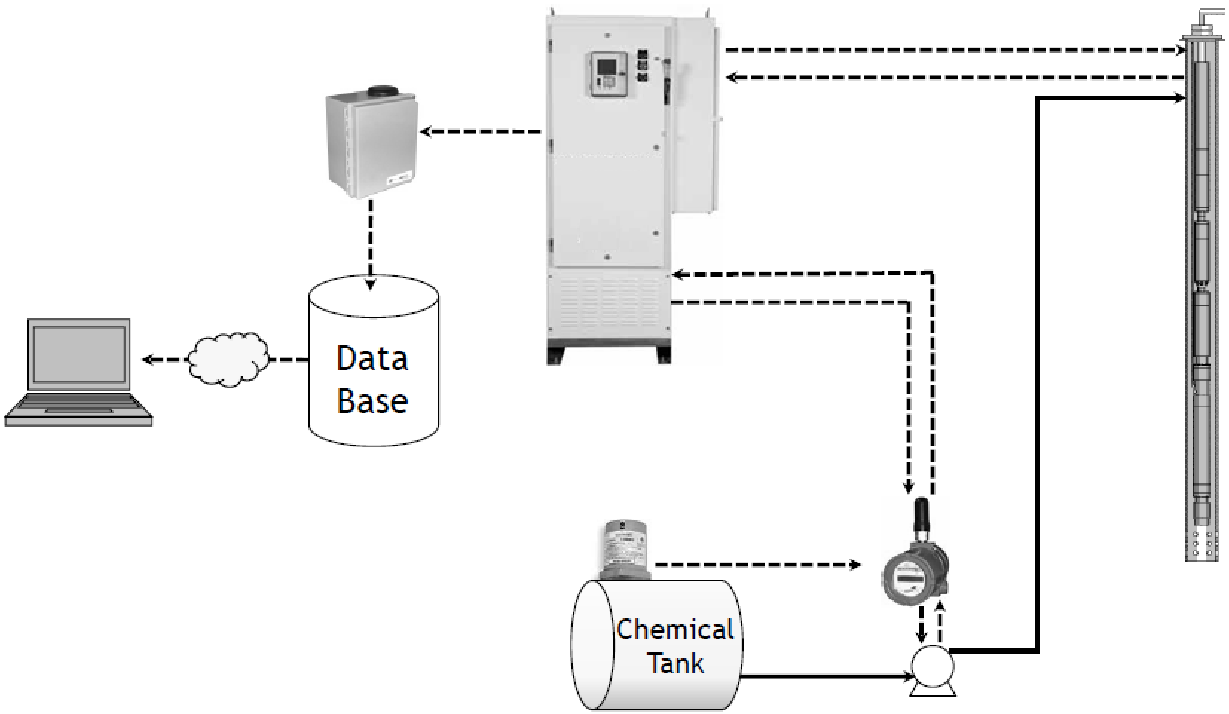

Figure 1 - ESP with Chemical Automation Schematic