A PRACTICAL GUIDE TO IMPROVING ELECTRICAL EFFICIENCY IN THE OILFIELD

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ABSTRACT

The rising cost of electricity underscores the importance of operating any business at optimum efficiency. While producers cannot control the cost of electricity, they can reduce the amount that they use. Additionally, production that is unnecessarily down due to electrical events and failures can significantly affect revenue. There are proven methods to reduce electrical energy usage and to minimize electrically related downtime. Often, these methods are not implemented or maintained because their value is not well understood. In the past, with lower electrical costs, these methods may have been ignored or not considered worthwhile to pursue. This paper will outline several simple and tested operating strategies, which improve efficiency, increase uptime and minimize electrical costs.

INTRODUCTION

There are several broad categories, which describe how electrical costs can be reduced and include (1) finding ways to reduce the cost of electricity and (2) reducing how much electricity is consumed. A third related opportunity is improving the reliability or power quality of electrical distribution systems. Finding ways to reduce the cost of electricity is beyond the scope of this document, however it would include, but not be limited to (1) proactive and aggressive strategies to negotiate and secure the lowest utility rate for electricity, (2) consolidating metering points and (3) removing any inactive accounts.

Although methods of reducing the cost of electricity is not included here, it is important to remember that an understanding of applicable tariff structures (the impact of setting demand, etc.) and how electricity is billed is very important to understand in order to perform some of the evaluations that are described later. It is possible that some tariff structures do not penalize users for setting a new demand and there are those where the penalty can be severe and long lasting. Lastly, it is important to have a good understanding of the value and impact of receiving power at secondary meters, primary meters or at transmission levels.

There are several methods of reducing energy consumption such as installing efficient equipment, reducing losses and operating equipment more efficiently. The effectiveness of these methods depends upon factors such as loading, the system design, operating conditions, etc. However, before evaluation of specific solutions, it is prudent to understand a bigger picture of this opportunity. Beginning with an idea of the desired outcome is a good place to start. Ideally, the electrical system should operate at optimum efficiency, with minimum losses and the highest reliability. Such a system will be the lowest cost to operate, have the highest up time and not subjected to penalties for inefficient operations such as power factor penalties. Such a system would ride through severe storms and high winds.

DEVELOP A ROADMAP

With that picture in mind, the first step is to develop a mathematical and graphical representation so that the overall system and the detail of individual components can be examined to determine both the “as is” conditions as well as any future improvements. The tool for this task is a computer model of the electrical system. The model requires information regarding the overhead power lines as well as the loads on the system. Typically, key model elements have their geographic locations via GPS technology input into the model. Some of these elements would include locations of substations, selected power poles, protective devices such as breakers, reclosers and fuse take-offs, line crossings of the same and different systems, capacitors, voltage regulators and individual loads such as beam pumps, esps, compressors, injection facilities and plants.

The mapping portion provides the physical location of all of the important equipment and structures. Then the physical and electrical characteristics are added to the model. The geometry of the power lines such as the height and spacing of poles and conductors, types of insulators and arresters and type of construction provide important physical proximity and dimensional characteristics. In addition, the electrical details of each load are input into the model. This nameplate data consists of horsepower, voltage, current, efficiency, nema code letter, etc. Similarly, protective device settings are recorded. This information is typically gathered by a field survey, which may take a few days to weeks to compile. During this survey, selected power line amp and power factor readings are taken and recorded. This information will be used later to help properly allocate power flow and fine-tune the model to the actual field measurements. Often, during this survey, incorrect assumptions of the system are discovered. Gathering and inputting this data provides many benefits. During the data gathering process, the overall health and ruggedness of the system begins to emerge. The level of maintenance, the system age and any obvious weaknesses begin to surface. The survey provides the groundwork for the model to generate many areas of opportunities for economic evaluation in the form of project lists. The model will indicate if voltage regulators are necessary to keep the system voltage at proper levels, determine optimum capacitor sizing and placement for control of the power factor and calculate fuse and recloser locations and sizing for protective device coordination.

All of these opportunities are summarized in a list of projects. The next step is to perform economic evaluation of the projects to determine each project's value and costs to implement. These projects usually consist of adding and sometimes relocating equipment such as voltage regulators, reclosers, fuses and capacitor banks. The purpose of implementing these projects is to optimize the system. In most all cases, these projects have economic benefits and payouts that are beyond the minimum threshold economic criteria. It should be remembered that the electrical infrastructure is the backbone of most oilfield operations. The machines that generate revenue such as beam pumps, esps, compressors and pumps are powered by electricity. Additionally, electrical costs are one of the largest controllable expenses. Beyond function, it is imperative for this system to be efficient, reliable and to be monitored for optimum operation.

Therefore, it is important to implement the project list in order to gain the value of creating the model. Following the implementation of these improvement projects, the electrical model continues to pay dividends by acting as the foundation for future "what if" scenarios for load expansions and large motor starts. The model also functions as a tool to help maintain the integrity of the system once it is brought to optimum performance, which highlights the importance of maintaining the model over time. As the system changes, the model must be modified to reflect the changes. New wells, changes to existing wells and load additions should be incorporated into the model to maintain the integrity and the value of the model.

INSTALL DIGITAL RELAYS AND RECLOSER CONTROLS

Digital reclosers should be considered where the electrical model identifies the need for a recloser in the system. Modern digital reclosers provide high-speed operation for system protection, unsurpassed flexibility for coordination with other protective elements such as fuses and reclosers, fault location information and valuable event and historical data at quarter cycle resolution. These significant advantages make digital reclosers a clear choice over hydraulic or older technology electronic reclosers. The ability to locate a fault on the system, especially after a storm, is an operational advantage that can get production back online more quickly than any other method. Historically, electricians surveyed miles of power lines looking for the cause of a fault (arrester failures, contact with animals, rodents or snakes, downed lines, etc.). Often, these faults are not apparent without knowing where to look and electricians might select other more destructive and potentially dangerous methods such as reclosing back into the fault and looking for the "fire". Digital reclosers can provide the fault location in conjunction with fault maps that are generated by the model so that precise location of faults can be narrowed to a handful of pole locations. This reduces downtime and improves safety.

A second major advantage of digital reclosers and digital relays (transformer and motor protection) is that these devices also record events like faults and events. Analysis of faults and events can lead to understanding how to move from reactive repairs to preventive measures. The high resolution of data from these relays provides the detail for evaluation. Another advantage of this data is the ability to know the electrical conditions at important locations in the system. Having access to real-time power and event data is a very powerful tool for optimizing the electrical system and knowing the efficiency of the system.

COORDINATE PROTECTIVE DEVICES

A protective device such as digital recloser controls and relays and fuses is necessary to minimize the effect of faults and events in the system. The idea is that a fault at an individual load such as an esp should not affect any other load on the system. Protective device coordination is a management of settings and fuse sizes to minimize the impact and isolate the effects of faults and events. The electrical model is an essential part of device coordination and digital protective devices provide the most flexibility to fine tune settings. A properly coordinated system will help maintain the greatest power availability and uptime to the loads on the system.

MANAGE REACTIVE CURRENT

Oilfields are unique in many ways, but especially in that, the electrical loads are almost exclusively motor loads. This type of load, also known as a constant kva load, presents special challenges to a power distribution system. All motors require current to magnetize the field of the motor. This current is not involved in doing work, but flows through the system and it measured as var (reactive volt amps). Because the load on the electrical system is mostly motors, a large amount of reactive current flows through the system and is usually measured in thousands of var (kVAR) or millions of var (MVAR). This current takes up space in all of the lines and has losses associated with its flow (I^2R losses). These losses are watts of wasted power that can be minimized with the installation of capacitors. Capacitors can provide the magnetizing current required by motors. In the past, these capacitors were installed near the service point (where power is received from the Utility) to eliminate power factor penalties. Most Utilities punish poor power factor with power factor penalties because lower power factors require that the Utility have larger power lines and more generation to provide the current. Installing capacitors, sometimes called power factor capacitors, at the service point is only eliminates the penalty, it does not reduce the losses in the lines.

Clearly, the ideal location for providing the magnetizing current or placement of capacitors is at the motor. However, this may not always be the most cost effective location. Small, 480-volt capacitors for loads as beam pumps have a poor reputation for being high-maintenance items and in a large field with hundreds of motors, it could present challenges to managing a large number of these capacitors. One popular alternative is to place banks of capacitors in strategic locations throughout the field to provide distributed centers for motor magnetizing current. The electrical model can perform an iterative process to optimize the location of the capacitors to provide a compromise solution to supplying vars for the motors. These distributed capacitor banks must be controlled with switches and controllers to prevent over voltage conditions when reclosers open during an event or a fault. Installing optimized capacitor banks can significantly reduce system losses, improve the system power factor and eliminate any power factor penalty.

REGULATE VOLTAGE

All electrical devices are designed to operate within specific operating conditions such as a minimum and maximum voltage range. System voltages that are too far above or below the design voltage of a motor can reduce the motor's efficiency or potentially damage insulation systems. The line voltage can fluctuate because of varying load conditions and seasonal changes. Also, since many oilfield power lines are long and sometimes consist of small gauge conductors, the quality of voltage along the power line will vary and suffer the most at the ends of the power lines. The electrical model can predict these effects and provide recommended placement of regulators to help maintain the correct voltage levels in the system. Stable, correct voltage is very important for reliable and efficient operations. Voltage regulators compensate for varying load conditions, seasonal voltage changes and lower voltages on long power lines.

INSTALL LIGHTNING PROTECTION

Effective lightning protection and low impedance grounding are necessary to minimize over voltage, damage and outages caused by lightning induced events. Remote lightning strikes can indirectly cause destructive damage and outages. Electronic devices such as digital relays, reclosers, automation equipment and adjustable speed drives are particularly susceptible to the detrimental effects of over voltages caused by lightning. Additionally, the safe and reliable operation of facilities, esps and beam pumps benefit from proper surge and lightning protection. Lightning and surge protection is almost a science by itself and it can be very confusing to decide what level of protection and types of devices are best. Not all areas of the United States suffer from the effects of thunderstorms. Isokranunic maps and lightning strike reports are useful tools to help gauge the severity in a particular area. Developing a lightning and surge protection plan is a good idea to determine where lightning arresters (power lines and large motors) and surge protectors (smaller equipment and motors) will be installed.

Proper installation and low impedance grounding are key requirements for the proper operation of lightning and surge protective devices. These devices rely on a low impedance path to ground, which means a precision installation is necessary. Grounding conductors must be kept short, direct and without sharp bends. The grounding system should be a single point system, which fully complies with the National Electrical Code (NEC) for safety. Improperly installed systems will not function as intended and can be unsafe.

INSTALL EFFICIENT ELECTRICAL EQUIPMENT

Installing efficient electrical equipment seems such an obvious idea that it is often overlooked completely. Electric motors serve as prime movers for electrical submersible pumps, beam pumps, compressors and various pumping operations such as vapor recovery and water injection. Some of these motors are large motors that run at full load; operate twenty-four hours a day and every day of the year. Transformers offer another opportunity to select higher efficient equipment. Motor and transformer evaluations are important because they are major components connected to the electrical distribution system and the owning cost is significant. Installations with high loads and long run times are usually present the best opportunities for lowering electrical costs by using more efficient motors and transformers.

Premium efficient NEMA frame motors operate with significantly less energy than conventional motors with the same horsepower. Higher efficient or Premium efficient motors may be several percentage points better than an older conventional motor. Today, new NEMA frame motors are available with two levels of efficiency. One level of motor efficiency is referred to as EPACT efficient or high efficient motors (meeting the Energy Policy Act of 1992) and the other level of motors are called Premium efficient (with slightly higher efficiencies above the EPACT ratings). A careful economic analysis will determine where and when to use the Premium efficiency motors for new motor purchases and for retrofits. Use a similar analysis to determine when to rewind motors and when to buy new motors that are more efficient.

Transformer purchases also benefit from an economic analysis. Like motors, transformers have losses in their windings, which are measured as load, and no-load losses. While the first cost of purchasing transformers is significant, other factors such as losses contribute to the total cost of ownership. Although transformers with lower losses may have a higher initial purchase cost, they may have a lower operating cost over time. The intent is not to simply purchase the transformer with the lowest losses, but instead to utilize an economic evaluation to select a transformer with the lowest total owning cost. As the cost of energy increases, so does the importance and justification of performing the evaluation. This method of evaluation is usually referred to as a load loss evaluation, there are several methods used to achieve this analysis, and these are based on calculating an “A” and “B” factor. A general equation for this analysis is:

(Factor “A” X NLL) + (Factor “B” X LL) + (Transformer Cost) = Equivalent First Cost of Transformer
Where: NLL = No Load Losses and LL = Load Losses

Another related opportunity is evaluating phase conductors for losses and economic conductor analysis. The purpose of these methods is to reduce electric energy losses to the lowest practical levels. The electrical model is very useful to perform “what ifs” regarding changing the size of existing or proposed conductors by evaluating the losses associated with the conductors. Long lengths of overhead power lines, long undergrounds to beam pump installations and below grade, esp well conductors can benefit from this analysis. A variation of this method is to perform an economic conductor analysis which will determine the total cost to own and operate various types of line at various load levels. These types of evaluations utilize basic information such as conductor properties, fixed electrical system costs, load factor, demand and energy rate and voltage level.

EFFICIENT OPERATION

Another category of energy savings is that of operating more efficiently. By using adjustable speed drives (ASD), loads can be more economically powered. In particular, fan and pump applications can benefit the most from this technology because the output of an ASD can be varied to meet the capacity required. A typical fan or pump application runs at a fixed speed and is normally designed for peak volume. Opportunities for energy savings may exist where these applications do not operate at peak volume continuously. According to the laws of affinity, volume of flow is directly proportional to speed. Input power is proportional to the cube of the speed so energy savings are realized as the requirement for volume decreases. Cooling fans and centrifugal water injection pumps may benefit from the installation of ASDs.

In addition to surface pump and fan applications, adjustable speed drives have been successfully applied to drive electrical submersible pumps. Recently, more manufactures and end-users, are applying ASDs to beam pump applications. Beam pumps present several different challenges for ASDs, especially how to handle the re-generative characteristics of the beam cycle. In the past, resistor banks were used to dissipate this energy, which was wasteful. However, new control algorithms control the pump without these resistors. Besides getting better control of the beam pump, energy savings can be realized by using more efficient NEMA B Premium efficient motors instead of the high slip, lower efficient NEMA D motors that normally power beam pumps. ASD controls make it possible to use the more efficient motors, which can typically be downsized in HP. The result is a more efficient operation. As with all such opportunities, field-testing and an economic analysis is warranted.

ENERGY PLAN

Because most oilfield loads are powered by electricity and due to the increasing costs of power, it would be constructive to develop an energy plan or policy. Such a plan would act as an umbrella to manage the opportunities and to minimize energy waste. Opportunities can easily be missed without a formal framework to manage and monitor energy usage. The electrical model must be kept up to date and new installations should be scrutinized for energy efficient equipment and operations. A formal guide that outlines strategies that might include: (1) creation and evergreen maintenance of electrical distribution models, (2) guidance for rewind versus new premium efficient motor purchase, (3) assistance with loss evaluating transformers, (4) identification of procurement specifications for premium efficient motors, digital relays and reclosers (5) directions for evaluation of ASDs for fan and pump applications and(6) establishment of installation standards for lightning, surge and low impedance grounding.

CONCLUSIONS

Many opportunities to improve electrical efficiency and reliability exist for oilfield operations. Starting with end in mind, these opportunities are easier to identify and quantify. The investment in an accurate electrical distribution system model will result in identifying improvement projects as well as a valuable tool for evaluating potential “what if” scenarios. Improved, more efficient operations are some of the direct outcomes of hardening the power distribution system by optimizing capacitor placement, coordinating and installing digital protective devices, installing voltage regulators, implementing low impedance single point grounding coupled and installing properly coordinated lightning and surge protection. Additionally, installing efficient equipment and operating more efficiently reduces energy consumption. A structured plan to manage electrical opportunities and monitor usage may be justified depending upon factors such as the size of an operation or the electric bill. Because most oilfield loads are power by electricity and with the increasing costs of power, it would be constructive to develop an energy plan or policy. Such a plan would act as an umbrella to quantify and manage the energy efficiency and reliability opportunities.