Optimizing Energy Consumption and Improving Operational Efficiency Through the Use of Smart MCCs in Process Automation Systems

Executive Summary
The escalating price of fossil fuels marked by fierce global competition is driving process industry decision makers to rethink the way their businesses will perform in the future. In order to stay competitive, manufacturers will have to develop strategies to conserve energy and limit their usage of depleting fossil fuel reserves. However, the challenge in achieving this goal is to do so without disrupting production. This is where the integration of Smart Motor Controls (MCCs) into a process automation system can play a vital role in your energy conservation strategy.

In 2005, the Energy Information Administration reported that 80% of the total energy consumed in the U.S. industrial sector is used predominately by the process industries. Sixty-four percent of the energy consumed in a process plant today is used to operate motors.[1] In the future there will be limited energy resources to sustain process manufacturing factories. Your operation will depend on how well your company can manage its energy consumption.

(continued on page 2)

White Paper

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Energy consumption is the second largest operating expense in a plant (after raw materials), and thus optimizing the energy consumption of motors is a logical starting point for improvement. By integrating smart motor controls to monitor energy consumption, the factory can remove wasteful energy expenditure, prevent unplanned downtime, and improve overall operational efficiency. Additionally, with the recent amendment to the U.S. Government's Energy Policy Act (EPAct) in 2005, tax incentives are being offered for implementation of certain energy-savings measures.

The tight integration of motors, drives, and Smart MCCs into a process automation system not only cuts energy consumption, it also enables the end users to reduce their Total Cost of Ownership in an environmentally responsible way that demonstrates results in reduction of installation, commissioning, operation and maintenance costs.

Let's take a closer look.

Introduction

Distributed control systems (DCSs) were designed to provide regulatory control for the process control industry. They were based on proprietary components such as operating systems, networks, hardware, and configuration tools. The standard DCS was mainly designed for communication within system boundaries and was known for analog control and redundancy. Programmable Logic Controllers (PLCs), on the other hand, were designed for high-speed control of discrete devices like motors, pumps, and drives.

In the traditional process plant, PLCs were used to control the electrical infrastructure such as motors, drives and MCCs, while regulatory control was left to the DCS. Since it was not economical to hardwire all of the operating data from individual motor buckets into the PLC, nor to pass this data to the plant's DCS, only minimal amounts of motor performance information was available to the system operator to optimize energy usage. The power consumption information was available locally to the plant electrician, but there was no mechanism to convey the real-time power consumption of the plant to the process operations or Manufacturing Execution Systems (MES). Therefore, it was virtually impossible to determine the energy consumption for each individual process or unit. This prevented the plant from scheduling partial shutdowns to improve energy efficiency or to take advantage of the incentives that electric utilities offer to reduce energy consumption during times of peak demand.

Today, a new class of DCS has emerged that is not only capable of providing the optimum control for regulatory applications, but is also able to integrate and control high-speed discrete devices like MCCs, drives, soft starters, breakers, and power metering devices. Process control systems capable of supporting this integrated approach enable dynamic monitoring of motor performance and usher in a new era in energy management and operational excellence.

Motor Operations

The integration of motor management data directly into the DCS allows the device to communicate its operational condition and status. This can be used for real-time monitoring of motors that can potentially detect motor problems before they occur. The maintenance performed on the motors is no longer reactive. Predictive and preventative measures can now be performed to prevent motor failure and damage, allowing plant operators to extend the life of their motors. Because motors consume approximately 64% of the energy in the plant, monitoring the operating condition is an essential aspect of any energy conservation and maintenance program.

It is estimated that up to 40% of manufacturing revenue is applied to maintenance, and up to 60% of scheduled maintenance checks on valves and motors proves unnecessary.[2] Monitoring motor operations significantly helps the plant operator develop an effective predictive and preventative maintenance program that is focused on maximizing operational efficiency.

Motor Efficiency

Over the past two decades, significant improvements have been made to increase motor efficiencies above the industry averages. Electric motors consume 10 to 25 times their purchase price in electricity each year, so even a 1% increase in motor efficiency can mean thousands of dollars worth of savings in the operation of the motor. Premium efficiency motors cost a little more because of the superior material that goes into them, but the higher cost typically can be recovered in 12 months or less. Significant reductions in energy consumption can be realized by this technique.

Variable frequency drives (VFDs) are becoming a popular approach to optimizing energy consumption to control flow instead of using the traditional combination of a fixed-speed motor plus regulatory control valve. By regulating the speed of a drive in order to directly control flow rate, a 50% energy reduction can be achieved in fluid flow control applications.

Motor Control Center (MCC)

Motor control systems have a prominent role in industrial processes. These systems are often housed in an MCC which contains a comprehensive array of control and monitoring devices. Advances in technology and decreased cost of electronic devices have led to a boom in the inclusion of various controls and monitoring devices into the MCC. These devices, like relays, variable speed drives, and soft starters, are capable of providing a wealth of data back to the control system regarding the condition of the motor. This information can be presented in the DCS in a clear and easy-to-read format that can be used to increase productivity, minimize downtime and energy consumption, and improve personnel safety. Figure 1 on page 3 shows the network view of a typical smart motor control center.

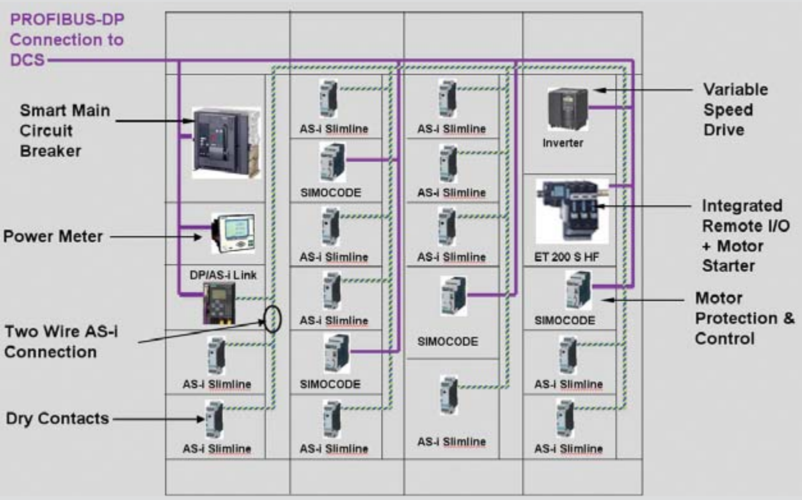

Figure 1 Fieldbuses such as PROFIBUS and Actuator Sensor Interface (AS-i) are the communication backbone for the Smart Motor Control Center

Conventional Motor Bucket
Each combination motor control unit is called a motor bucket. Each motor bucket comes in different dimensions depending on the size of the motor and is the part of the MCC where the power to the individual motor is controlled.

A motor designed to deliver higher horsepower would require a larger size bucket, which means it would need a larger contactor and breaker. This is where the similarity between the conventional bucket and intelligent bucket ends.

In a conventional bucket, an electrical overload switch and a combination of relays would control the power to the motor via a contactor. The relays are usually controlled by the outputs from the PLC, and the feedback is provided via auxiliary contacts to the digital inputs on the PLC.

Making MCCs "Smart"
An intelligent motor management system, such as SIMOCODE from Siemens, can be added to the motor bucket to make it "smart" (see Figure 2). The SIMOCODE motor protection relay controls and protects the motor and acts as an overload switch. The relay has a built-in current and potential transformer to help the SIMOCODE measure line current and voltage. It is capable of sending all information on the motor's operating condition directly to a DCS via a digital fieldbus, such as PROFIBUS. The advantage of using fieldbus versus hardwiring of the signals is that it enables all the data about the motor operation to be transferred into the DCS in a cost-effective manner. For example a single cable (fieldbus) can be used to transfer data that would have required 6-12 separate wire pairs per conventional MCC.

Additionally, integrating power monitoring devices into an MCC, which is connected to a DCS, gives plant electrical engineers a central location where all the information related to production data and to the power system are recorded for analysis and improvement.

Power monitors can record power consumption and power quality data at the same time. There are many causes of power quality problems, such as voltage sags/swells, harmonics, fast impulses, sub-cycle impulses, and neutral to ground high frequency noise.

Factors that Affect Motor Performance
The five most important factors that affect the motor performance in any process control system are:

1. Power quality
2. Motor operation
3. Motor condition
4. Load and power consideration
5. Operating efficiency

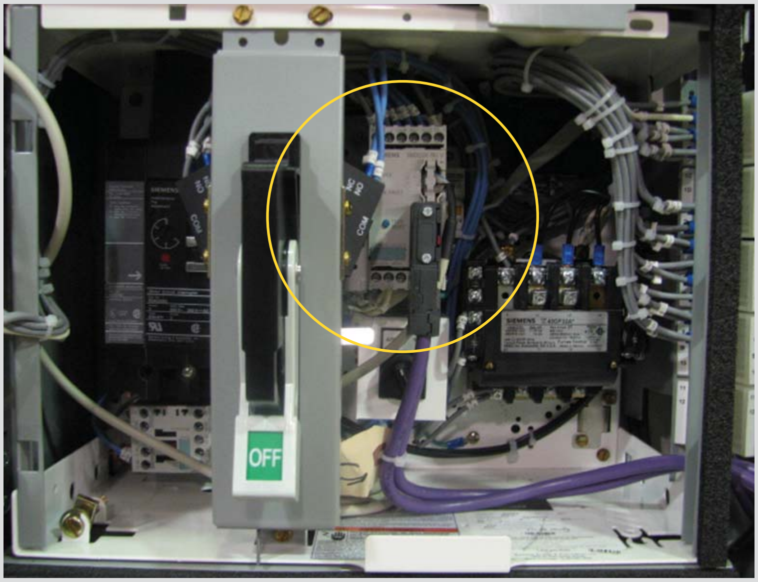

Figure 2 Typical motor bucket with Intelligent Motor Management System

Power Quality
Monitoring the quality of the incoming power is very important for maximizing the lifespan of the motor and for ensuring that it continues to operate efficiently. Some examples include:

- Monitoring the voltage fluctuations to limit the degradation in motor winding
- Ensuring that voltage in the power system is within proper range as to not create iron saturation that can cause excessive heat to build up, resulting in the degradation of the winding insulation
- Lowering voltage, causing excessive current draw that may result in damage to the winding and decrease in the motor efficiency or increased I^2R losses

Inconsistencies in the voltage can be caused by harmonics introduced by variable frequency drives that are being used within the plant or in nearby facilities. A small amount of voltage distortion causes a large current distortion, which in turn will lead to excessive motor currents and the potential for damage to the windings.

Excess voltage applied to the motor causes it to waste energy and operate inefficiently. Data logged in the DCS can help operators identify these situations.

Motor Operation
A DCS that can monitor, log, and notify operations personnel, when conditions require attention, can be used to improve the overall efficiency and performance of the motor. In order to do predictive maintenance on the motor, it is necessary to be able to measure all of the line currents in the motor. Since the heat in each motor winding is a function of the amount of current that flows through it, the motor's potential weakest point is contained in the phase with the largest current (see Figure 3).

Motors typically draw 6 to 10 times their rated current when they are started. This high current can cause the windings to heat up, leading to degradation. Therefore, it is necessary to limit the number of motor starts. An effective predictive maintenance strategy will ensure that the number of hot starts is limited to protect the motor winding (see Figure 4).

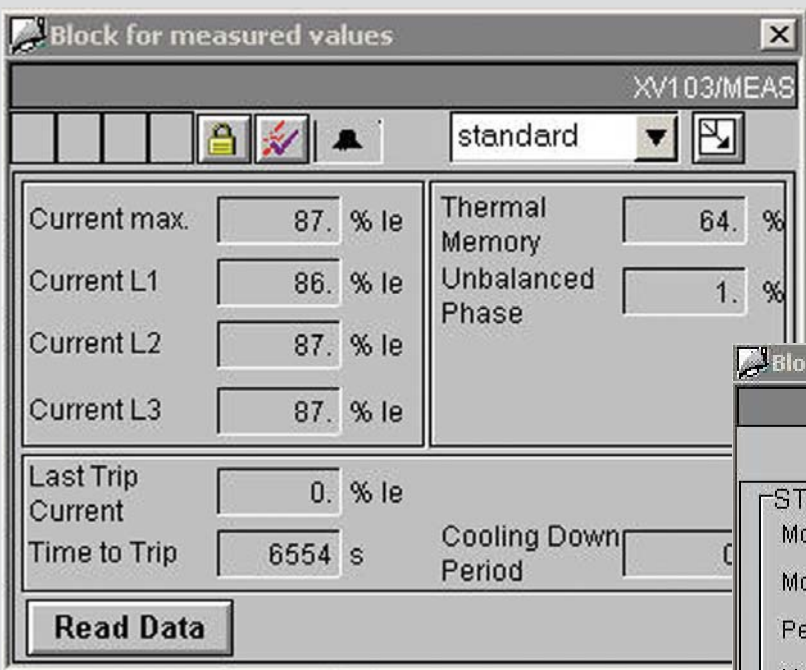

Figure 3 DCS faceplate showing the three line currents and last trip current

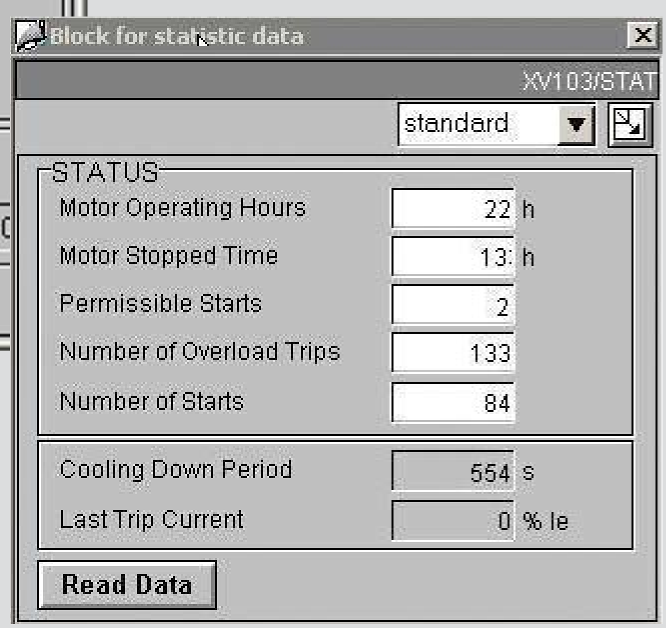

Figure 4 DCS faceplate showing the number of permissible starts and cooling down period

Motor Condition

Tracking, trending, and alarming of motor operating conditions in a DCS is a valuable tool for predictive maintenance (see Figure 5). A motor that draws excessively large current during startup indicates load-related problems. This results in inefficient energy usage and can cause unnecessary burden on the power system every time it starts.

Analyzing trends in the DCS aids in the identification of these types of problems. In Figure 6, the large amplitude spikes indicate when the motor was started. The area on the motor trend marked by the red lines indicates a condition when the energy consumption of the motor increased by 25%. This increase in the energy consumption indicates a change in the motor's operating conditions, which could result from an increased load, unusual process conditions, or a problem with the motor.

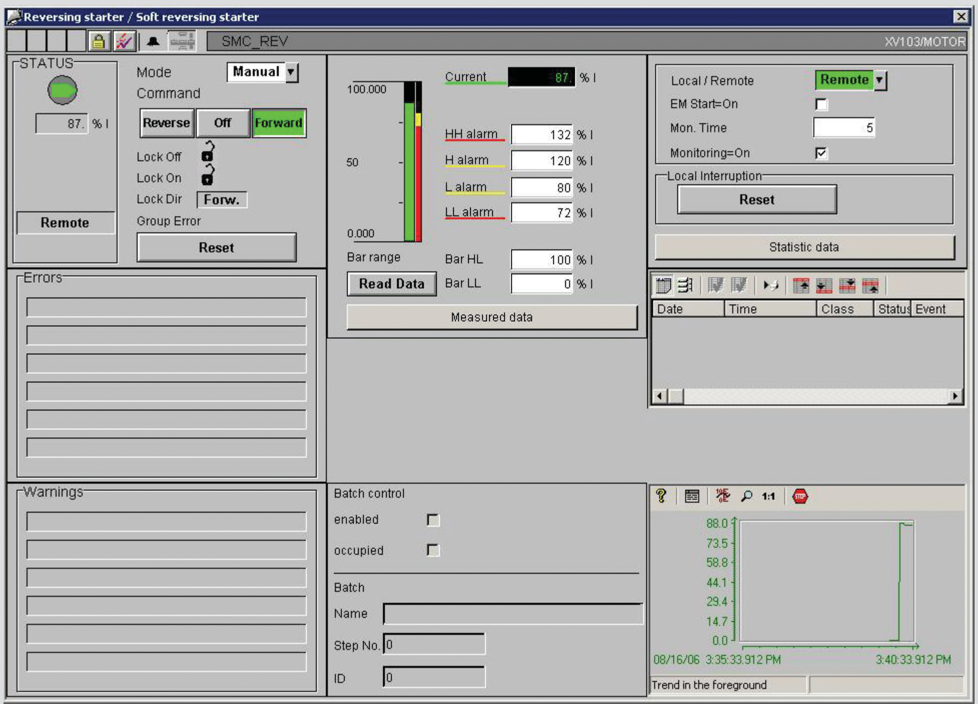

Figure 5 DCS faceplate showing the details of the single motor bucket parameters

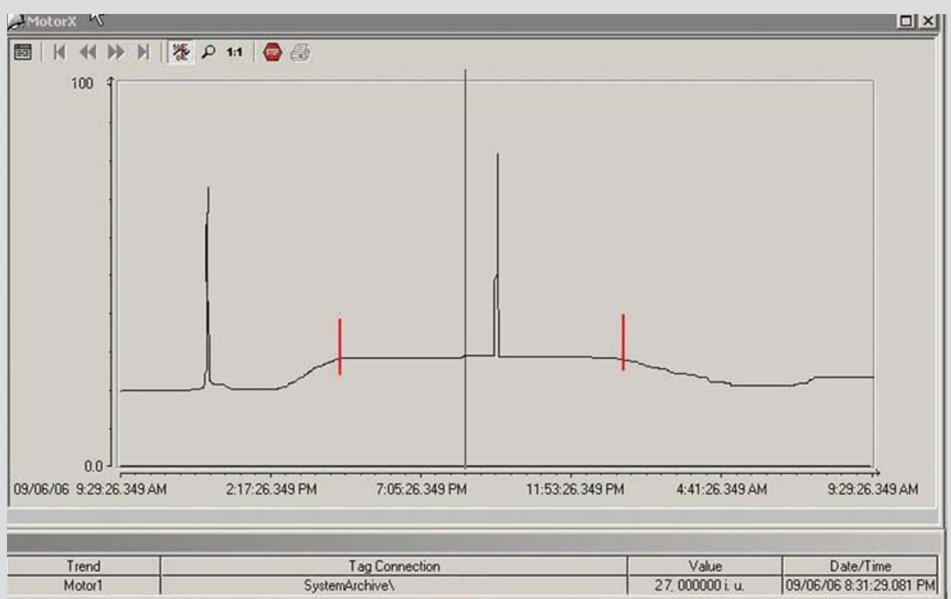

Figure 6 Motor load current consumption trend displayed and archived in the DCS

Load and Power Consideration

Load, percentage of load, horsepower demand, kilowatt usage, and power factor are also important factors relating to a motor's long-term performance. Significant load fluctuations might indicate a potential process-related problem. Many motors continue to operate within nameplate ratings while being forced to carry load demands above their capacity. These excessive load demands cause the windings to run above a safe level. Motors required to operate above nameplate horsepower ratings also suffer from greater torque demands, which can inflict undo stress on the motor's rotor.

Motor efficiency is a measure of the effectiveness with which a motor converts electrical energy to mechanical energy. This ratio of the output power or work done versus the input power is not constant for all load conditions. Motors are optimized to be run most efficiently at a specific load condition; operating the motor above or below that point causes it to run less efficiently. Figure 7 shows the effect of the motor load on the efficiency of the motor. The area on the trend marked between the red lines indicates the area of maximum operational efficiency for the motor.

Figure 8 shows a DCS faceplate displaying the power factor, actual power consumed, terminal voltage, and winding temperature. By monitoring these key operating parameters the motor's condition can be analyzed and alarms can be triggered when they exceed safe levels.

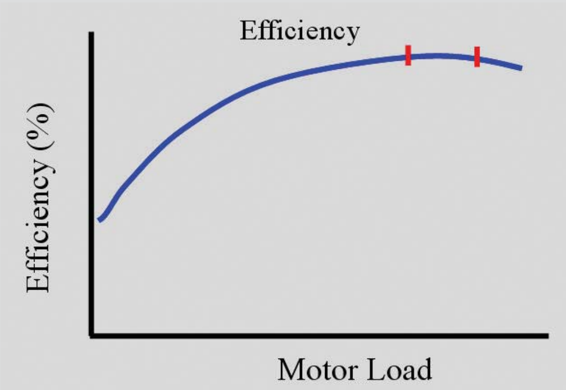

Figure 7 A typical graph of an AC motor efficiency verses the motor load

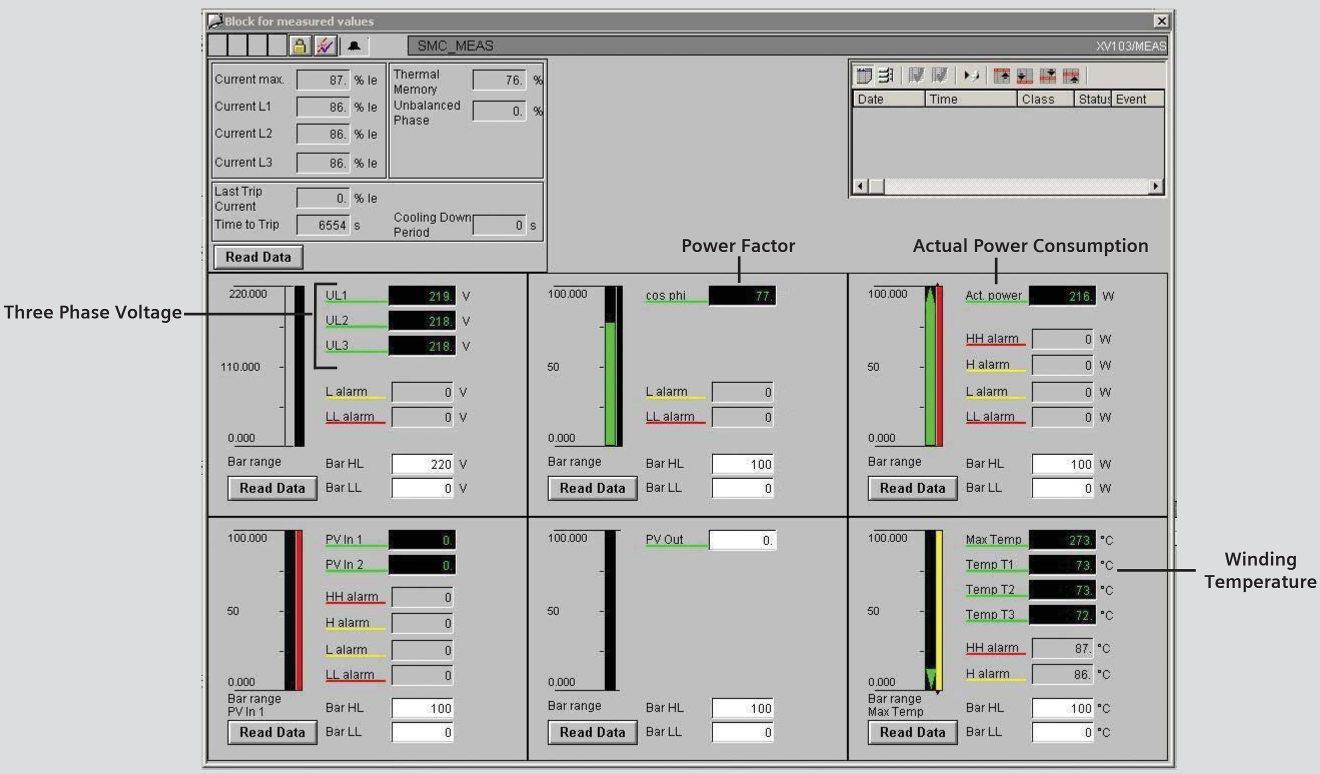

Figure 8 DCS faceplate showing the Three Phase voltages, Power Factor, Actual Power and Winding Temperature

Motor Operating Efficiency
In an effort to reduce a plant's Total Cost of Ownership, each facility should frequently and carefully monitor power usage and operating efficiency of the motors. Motors are often oversized or undersized due to incorrect initial design or from post-commissioning modifications to the process design. Oversized motors have higher initial costs and are typically more costly to repair and operate. Undersized motors perform poorly and suffer from higher energy losses, which can lead to premature failure. Improperly sized motors are less efficient and, therefore, are more costly to operate.

The dynamic motor data logged in the DCS can be very helpful in troubleshooting, repair, and replacement of the motor. Integration of the Smart MCC in a DCS allows the dynamic data of the motor to be logged and trended for the early detection and prevention of costly repairs. It also provides valuable data which can be used to pinpoint and correct problems with the sizing of a motor and its dynamic response to changing process conditions.

Benefits of Integrating Motor Control Data in DCS

Improve Productivity
Engineers can access the parameters of the individual MCC bucket directly from an engineering station in a central location. They can modify operating parameters, analyze performance, and reset faults from the control room. SIMATIC® PCS 7 Asset Management software from Siemens allows parameterization and diagnostics information to be published on the DCS HMI screens, providing easier access to the maintenance personnel (as shown in Figure 9).

Minimize Downtime
Implementation of an effective predictive maintenance program is critical to avoiding unscheduled downtime. It is estimated that over $20B is lost annually due to unplanned downtime, with 38% caused by preventable equipment failure.[3] Any unusual condition, like phase unbalance or loss and excessive current draw, are reported in the DCS. This allows the operator and/or maintenance personnel to take corrective action. Even in a trip situation, the cause and location of the trip can be easily identified and necessary maintenance can be quickly performed.

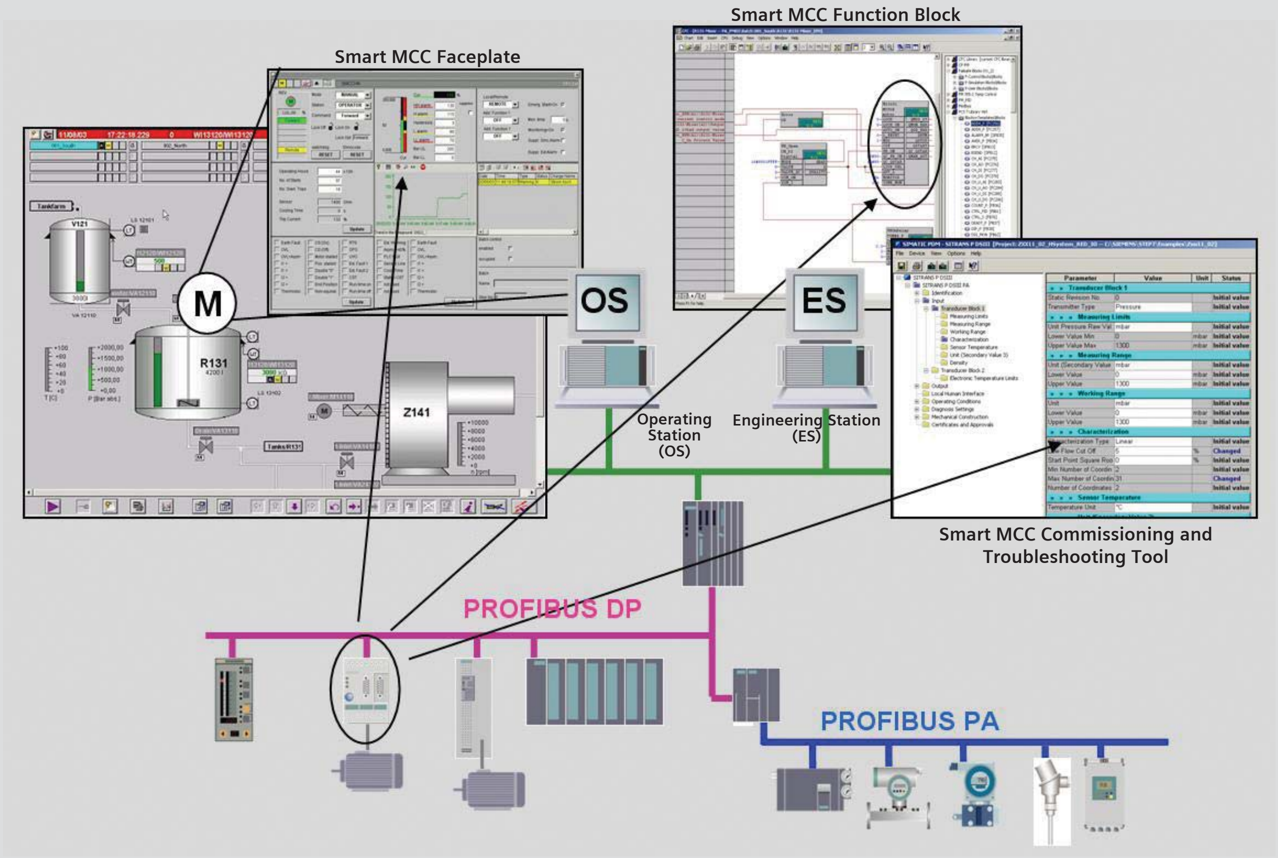

Figure 9 Central access to all devices (including motors, drives, and Smart MCCs) improves process visibility and helps you to create an effective, preventive, and predictive maintenance program for all of your plant assets

Decrease Installation Cost
Using a digital fieldbus like PROFIBUS, motor buckets can be connected to the DCS using a single or redundant cable that is daisy-chained between motor buckets. This allows tremendous reduction in the cost of field wiring, terminations, and PLC hardware. Based on actual project implementation data, reductions in engineering, installation, and maintenance costs by 30% or more are not uncommon.

Improve Equipment Reliability and Efficiency
Fault tolerant communication architectures can be designed to ensure a high degree of availability of the communication between the DCS and MCC. Different physical mediums, such as copper or fiber, can be used to connect the digital fieldbus. For example, a fault-tolerant, redundant, fiber-optic PROFIBUS ring can be used between the DCS and MCCs that are positioned in remote locations.

Improve Personnel Safety
Every time a motor bucket is disconnected from the control system for repairs or maintenance, the change in status of the motor bucket is logged in the DCS. The operator initiating the request can write comments in the operator request area or alarm comment field to inform other operators and maintenance personnel. There is always a central place for operators to look for this information, thereby reducing confusion and improving safety.

Energy Management
Smart MCCs enable the power consumption of different parts of the plants to be collected within the DCS. This information can be displayed for the operator to monitor the KWh consumption of the manufacturing process alongside other key process parameters. The information can be further passed into a historian or an MES for reporting purposes.

This information can be used to implement different energy management strategies, allowing plants to create a strategy which helps to optimize energy usage and production output simultaneously.

Energy Optimization in Process Industries
Understanding where energy is used in the manufacturing process is a key first step in the development of strategies to minimize energy consumption. Distributed control systems that are capable of integrating process and power system information can be a valuable resource to the conservation of energy in process manufacturing. Energy management systems do not replace human involvement in the decision-making process, but should be looked at as a real-time tool to keep energy consumption in check.

Through understanding of the energy consumption for each individual process or unit, experts can create better designs that are focused on improving energy consumption. Process optimization techniques together with real-time energy consumption information all play a part in enabling manufacturing processes to be operated at maximum profitability and with greater energy efficiency.

Optimizing energy consumption and improving operational efficiency are continuous processes that are important during all stages of a plant's lifecycle:

- Design and Engineering
- Installation and Commissioning
- Operation and Maintenance
- Process Modernization/Optimization

During the initial design and engineering phase, an investment in the technologies that enable the optimization to be performed at the later stages can be very helpful. Installation of premium efficiency motors and integrated power monitoring and switching systems lays the foundation on which further optimization can be realized. Pre-engineered libraries of software function blocks allow easy integration of power control devices in the DCS.

The most significant gains in energy efficiency are seen during the operation and maintenance phase. Situations like inefficient operation of the motors can be identified by analyzing the data that is recorded in the DCS. This also provides a powerful tool for the operations management team to understand which operators are good at producing a particular product with the minimum energy input. Those best practices can be transferred to other operators.

Sections of the process control system that do not perform well can be improved using the tools available in the DCS. The data available from the DCS can be analyzed in detail to identify potential process improvements. Using the real, quantitative data, energy efficiency projects can be undertaken resulting in the efficient use of capital resources with high return on investment (ROI).

Conclusion
Saving energy in manufacturing has two significant paybacks: a reduction in green house gases emission and the lowering of the energy cost for the plant operators. Technology, such as the use of Smart MCCs exists today to make process control systems more efficient. By adopting these smarter technologies, manufacturers can not only save energy and reduce their impact on the environment, but also become more competitive economically.

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([1]) U.S. Department of Energy Website, "Improve Motor System Efficiency with Motor Master," http://www.eere.energy.gov/industry/bestpractices, October 2005

([2,3]) "Collaborative Process Automation Drives Return on Assets," Dave Woll, ARC, June 2002.

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