PLC BASED ENTERPRISE ENERGY MANAGEMENT SOLUTIONS

By:

Jeffery MacKinnon, P.Eng., Power Engineer;
Scott Warnick, Automation Engineer;
Jesse McDaniel, PE, Principle;
H2E, Incorporated

ABSTRACT

Modern production facilities can potentially have very large electrical loads which translate to expensive production costs. It is recognized that there is value in understanding the primary cost contributions so that a facility can properly manage these resources and refine the operations.

The Enterprise Energy Management (EEM) Technology offered by H2E provides for a customized adaptation of standard OEM power metering integrated with a standard OEM PLC platform. The uniqueness of the H2E technology is the ability, via the use of a PLC, to fully customize features specifically to the way a client manages and operates their facilities. The technology has the ability to integrate with any of the standard OEM meters and any of the common OEM PLC platforms.

The EEM Technology enables the ability to customize facility specific features such as:

- *Breaker Status Time-stamping*
- *Billing Information*
- *Predictive Alarming (i.e Peak Demand)*
- *Custom Calculations, Production Data, and Reporting*
- *Enterprise and HMI Connectivity*

The EEM Technology, with the critical PLC component, provides for a more “in depth” and detailed capability to capture power distribution data at the wave form level and to report.

This paper will address methods to use PLC data monitoring, high speed 52A breaker monitoring, IRIG-B time synchronization, and utility integration to accurately predict real time billing and cost information, and to predict demand cycles within sufficient time for facility operators to react.

INTRODUCTION

With rising energy costs, energy management is critical to the success of a large facility. Cement production in particular is an extremely energy intensive process. To meet the increasing requirements for energy efficiency, the implementation of a system that will allow the dynamic measurement of energy allows the ability to assess usage and departmentalize costs with greater granularity.

By utilizing a PLC based EEM system, engineers and integrators have the ability to create an EEM system that will work as an efficient tool alongside, or integrated with their existing plant control systems.

In order to effectively operate large production facilities, close coordination among management, maintenance, engineering, and facility automation are critical. Each of these separate departments are looking for different information in order to properly maintain and manage their specific responsibilities. Maintenance personnel are looking for different information on electrical loads and equipment than a management group might be. All this information, however, can be determined and displayed in such a way that it is tailored to each individual group’s needs a centrally managed PLC system. The information can be displayed graphically and/or in tables for immediate review; it can also be outputted to data tables for further inspection.

To this end, the EEM systems must be designed with the needs of each of these distinct groups in mind.

VARIOUS SYSTEMS

There are a number of ways to implement an EEM system to satisfy the requirements of the strategy. For example there is the manual approach using existing equipment, a separate power system that is not integrated into the greater control system, and a system that is integrated into the existing control system.

The main advantages of the separate system or black box, is that it is commonly sold by a single vendor and will have the majority of components required to monitor and record energy usage. The disadvantage is that the facility is typically locked in with the initial vendor and there may not be flexibility within the system to develop a strategy that will meet all of the needs of the plant.

This is the greatest advantage of using a system that is integrated into the controls of the plant. It allows unlimited flexibility with the inputs and outputs of the system, while using only OEM parts. The EEM can be integrated with the plant's HMI system to allow direct control and alarming in a familiar manner allowing operators to modify processes in a manner that will add efficiency.

PLC INTEGRATED SYSTEMS

The primary purpose of utilizing an integrated system is to expose the internal components and architecture of the system in its entirety, such that the behavior, structure, and interfaces can be improved and updated with the rest of the facility as it evolves, in ways that most OEM 'black box' energy management systems cannot approach. Integrated systems utilize connections at many levels in a plant control system, including SCADA connections, PLC control system integration, HMI interfaces, and connections at the enterprise level for reporting and management functions.

The advantage for a PLC integrated system is that it can integrate with the existing plant SCADA systems, existing power monitoring, and have customizable alarm and display screens to precisely match the energy billing system and predictive demand calculations in the PLC system. Existing PLC information in the plant control system may also be incorporated into the energy management system, as the PLC calculations take place at the plant control network level.

Existing historical data infrastructure may be used to track data, and display and alarm screens may be added to existing HMI platforms so operators are not required to interface with third party software and components, easing the adoption of alarm and control strategies based on the EEM system.

With most plants having a PLC or DCS control system in place, part of the initial costs of an EEM system may be mitigated when implementation is started. There is an added advantage of providing the possibility of staged implementation. The equipment can be installed for a very high level understanding of energy consumption, and as capital funds are available, additional equipment may be added. The greater granularity that is developed in the system, the more accurate the model, and the better suited the system is to meet the needs of the energy program. Alternatively, if there has already been equipment installed to monitor energy use, this equipment can be re-used in the new system. This will offset the capital cost of purchasing new metering equipment.

A PLC based system can provide predictive modeling based on past performance and real time system measurements. This model is one of the most important pieces of the integrated approach. An energy model represents the primary driver for energy consumption based on process data. (John C. Van Grop, 2004) With the model the operator and management has the ability to create scenarios in which the outcomes can be determined based on real data. This can allow the plant to make operation decisions that will mitigate a new demand peak and significantly lower the energy costs.

As PLC systems are highly customizable, any billing rate schedule, alarm requirement, or custom calculation required by the plant EEM system can be implemented. Existing communication ready meters may be added with appropriate integration efforts, and industrial control communication protocols can be used, directly reading information from metering equipment. Process and energy data already monitored in existing facility PLC systems can be incorporated into EEM calculations using simple PLC messaging.

IMPLEMENTATION CONSIDERATIONS

There are four main audiences for data calculated in a PLC integrated EEM system:

- Management
- Maintenance and Operations
- Engineering
- Controls and Automation

Each of these four audiences requires different interpretations of the data gathered and processed by the central PLC system.

1. Management Components

From a management standpoint, there are several steps involved in utilizing a successful EEM system. The steps that are relevant to this paper are: Assess Current Performance, Identify Opportunities, and Evaluate. (Stephen J. Coppinger)

1.1. Assess Current Performance.

Before a facility has the ability to improve it has to measure its current state. Successful EEM systems must accurately measure energy usage with respect to actual fiscal costs. Appropriate rate schedules, fees, and other secondary costs must be accounted for, such that energy and demand measurements captured by the system hardware can be appropriately measured as billing costs. Production departments and other facility units may be tracked separately such that each department can be assessed as a cost center.

1.2. Identify Opportunities

When the existing system is assessed and there is enough data measured and tracked, opportunities will present themselves that will allow the reduction of both departmental and overall costs. A typical example of such reductions often manifests as careful management of energy demand peaking. Demand peaking is often a major billing contribution for facilities that consume large amounts of electrical energy. For example, starting two large motors at the same time, but at different areas of the plant, may consistently cause higher peak demands. Capturing demand peak data and applying fiscal data to it, can identify steps for prevention, either using automation or procedural controls.

1.3. Evaluate

By monitoring your metrics of success, whether they are utility billing data or total energy usage, an EEM system will allow the facility to monitor real time and provide accurate measurements of investment returns. Tracking such information on a corporation wide basis also provides a useful metric of data and cost centers across a large number of facilities, each of which may have vastly different rate structures and energy costs.

Where possible, it is very useful to separately monitor the utility metering data as well as plant owned metering equipment. Identical billing calculations can be performed against each set of energy data, see figure 1. Identifying deviations between the utility and plant measured values allows management to take steps to rectify the situation.

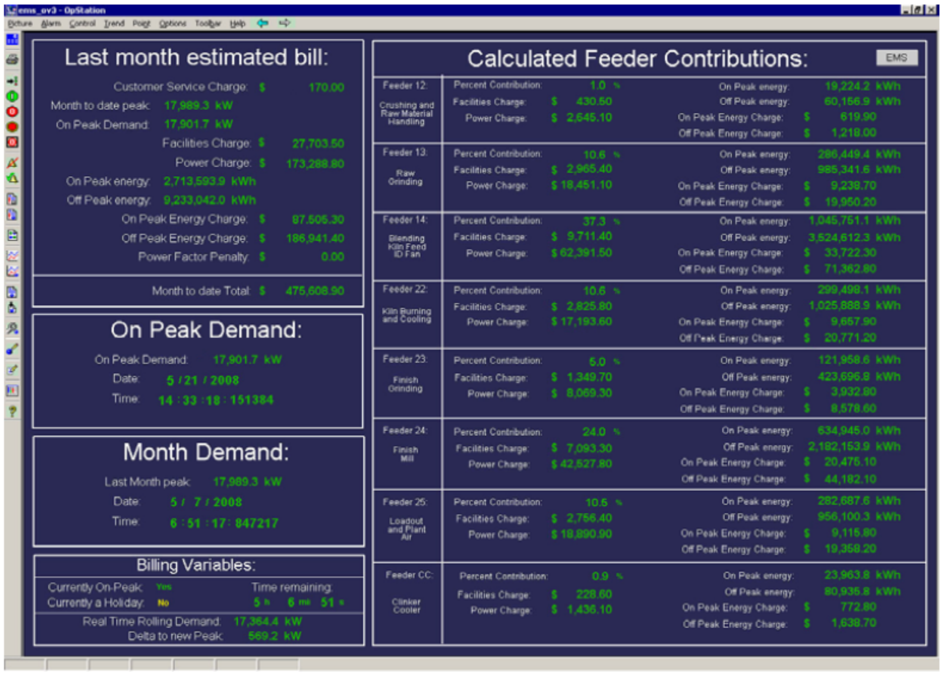

Figure 1: Example billing HMI Screenshot

2. Maintenance and Operations

Maintenance personnel have the ability to measure system energy usage for each large electrical load in the facility in order to monitor efficiency trends over time, to determine uptime, electrical starts, and other measures of equipment economy. Performance trends of equipment will be monitored and accurately measured. Based on this information, scheduled maintenance can be determined effectively.

A carefully designed system must be able to capture energy usage of large equipment, number of starts, and other performance and usage metrics, in order that sufficient data is available for maintenance personnel to properly operate equipment. The system should be capable of monitoring the current energy usage and comparing it to the historical data. If there are deviations, alarms or automatic control can be implemented to curtail new demand peaks or deviation from goals through load shedding or diverting to alternate sources.

The system should continuously measure many energy variables including current, voltage, frequency, kW, kVAR and power factor at multiple points in the system. With this information accurate load flows can be developed based on real time, accurate information. This in turn will help identify where capital spending can be used for power factor correction, motor control upgrades, and other considerations with positive payback.

3. Engineering

Another primary component of a well-designed EEM system is the capability to perform and report on system power quality. The system may include an accurate sequence of events infrastructure and have the ability to perform waveform captures on power quality events in order for qualified engineering personnel to properly analyze system failures or anomalies.

With an unexpected shutdown a system that is properly configured can allow quick analysis of the situation and diagnosis of the problem. This helps to limit downtime and allows the facility to take steps to mitigate the same problem from happening in the future. On a corporate level, with equipment of similar configurations installed, this allows the solution to be spread to other facilities to optimize uptime.

4. Controls and Automation

Over time, a properly maintained and operated EEM system will provide a great deal of information on demand peak control, appropriate schedules for operation heavy loads, and other metrics of efficient plant operation. It is often useful for these strategies to be implemented in a plant-wide control system. A well designed EEM system will have the ability to interface with the facility control system in order to maintain and implement schedules and peak control.

IMPLEMENTATION OF A PLC BASED EEM SYSTEM

A typical PLC based integrated EEM system is based on the following primary components:

- Communication Enabled Meters
- Data Collection
- Time Synchronization
- Billing Calculations
- Demand Peak Processing
- Demand Predictions
- SCADA and HMI Integration
- Waveform and Power Quality Analysis

1. Communication Enabled Meters

The heart of any EEM system is data collection. There are a number of highly accurate meters on the market that are perfectly adequate, and the purpose of this paper is not to determine or recommend particular hardware. Meters should ideally be able to support a reliable industrial networking protocol that includes time-stamping, such as DNP3 or IEC 870-5-101. A properly designed network should allow sufficiently high poll rates to support predictive demand and energy calculations, therefore it is valuable to use broadband network variations of the protocols where possible.

2. Data Collection

Data from each meter, including phase currents, phase voltages, kW, kVAR, kVA, power factor, and energy use variables should all be polled from each metering location. Metering locations are selected in order to provide sufficient granularity for cost center energy distribution. Cost centers, of course, vary from facility to facility and process to process, and sufficient data must be gathered to provide accurate and meaningful data for all cost centers.

Ultimately, all metering data in the system must be monitored by the PLC system and scaled to human readable formats, such that all cost center energy data - and by extension, fiscal costs - can be allocated appropriately to each cost center, as determined by facility requirements.

3. Time Synchronization

To be meaningful, event data from both metering equipment, and potentially from high speed discrete inputs, must be processed and displayed in a central location in order to determine an overall event history. To do so, metering and monitoring equipment should be, where practically possible, synchronized with a high speed time synchronization protocol such as IRIG-B or NTP. Since a network communication protocol such as DNP3 can preserve event timestamps from field devices, the best use of the architecture can only be achieved if all equipment is managed from a central time source. GPS satellite clocks or network time servers are useful sources of time.

4. Billing Calculations

Every facility has entirely different billing philosophies and rate schedules that determine the actual costs associated with energy and power data. The overall system bill generally uses data from only one or two meters connected to the primary power feeders to the facility, and a direct application of the rate schedule produces a quite accurate result. However, it is important to consider how that cost is to be split among cost centers.

Consider that the largest changes to costs over a month billing period occur, nearly always, when new demand peaks are reached. Because of this, it is critical that each cost center account for its contributing portion of that demand peak. It is useful to determine individual cost center costs using an identical rate structure as that of the overall plant feed to maintain context among all cost centers.

The most significant portions of nearly all large industrial rate structures are energy usage and demand charges. Therefore, to arrive at a reasonable cost for each center, the plant rate structure can be applied using the individual energy usage for each cost center, and the instantaneous demand value for each cost center measured at the time that the overall plant last achieved a new peak. Therefore, the peak demand for each cost center may not simply increase over the month as usage is tracked, but may be higher or lower during arbitrary points in the month, depending on what was operating in the facility when the overall facility peak was achieved.

5. Demand Peak Processing

Special attention must be taken to determine the demand period associated with the utility metering philosophy. Different utilities use different means to determine peak time windows, including set windows, sliding windows, and variations in between. It is critical to accurate bill estimation that a PLC based EEM system replicate the utility billing system as close as possible to provide a meaningful basis of comparison. Most utilities will provide synchronization information and detailed information on how their demand periods are determined on request. As a general rule, published rate structures do not provide sufficient granularity of demand window processing, and close coordination with utility personnel may be required to get accurate results.

6. Demand Predictions

There are a number of ways to predict demand and warn operators of potential peak conditions. Often, simply comparing the current instantaneous value to the current demand peak can have value, as it is simple to understand and easy to implement. If the instantaneous value approaches the peak within certain constraints, alarms can be generated to warn operators and/or allow programmed events to occur.

More advanced methods of predictions can also be implemented to capture demand changes over time, including rate of change monitoring, or least squares approximated slope calculations, etc. Based on samples of the instantaneous demand over the demand period, the approximated slope can estimate if a new peak will be reached by the time the demand period is over should the current rate of change be maintained. Additional alarms can be set based on these criteria based on plant requirements.

It is often more useful to plant operators, however, to measure the average demand over the first portion of the demand period, such as halfway or two- thirds through the time period. If the average demand for the first portion of the period is above the current peak, alarms may be generated. Additionally, calculations can be made to let the operator know how much demand must be reduced in such a situation to prevent a new peak.

7. SCADA and HMI Integration

One of the primary purposes of having a PLC base for an EEM system is to make SCADA integration seamless with plant systems. Existing HMI systems may be expanded to include EEM screens so information is easily available to operators in a context that is familiar. It is often useful to display real operating energy costs for operators, so cost context can be associated with operator actions. When starting multiple large loads in a single demand period may cause a visible bill increase due to establishing a new peak, it makes both operations and management personnel start to ask questions about different ways to operate to prevent it in the future.

8. Waveform and power quality analysis software

As significant metering communication infrastructure is required to provide granular cost data, it is often prudent to install software to poll metering hardware for event data, waveform capture data, and other power quality data, particularly in facilities that have significant nonlinear loads. Software for this purpose is highly vendor dependent, and can be considered a separate layer from the PLC and HMI components of an EEM system. However, it is useful to provide waveform data to engineering personnel as another tool to use in conjunction with sequence of event data provided by the PLC system, particularly when time synchronization is used to accurately associate waveform data with captured EEM events.

CONCLUSION

By utilizing an integrated approach for enterprise energy management (EEM), the system is customized to meet the organization's needs while being friendly to all groups within the corporate structure including management, operations and maintenance. By avoiding single vendor options, facilities gain greater flexibility, integration, and usability for their systems.

REFERENCES

John C. Van Grop, C. (2004). Maximizing Energy Savings with Enterprise Energy Management Systems. IEEE Power and Energy.

Stephen J. Coppinger, P. D. (n.d.). DEVELOPING A CORPORATE-WIDE STRATEGIC ENERGY.