Enhanced Applications for Energy Management Control Systems

Roger Mosier, Portland Energy Conservation Inc., Portland, OR
Karl Stum, Portland Energy Conservation Inc., Portland, OR

ABSTRACT

Today's commercial energy management control systems (EMCS) are substantially more powerful than past models. The evolution of direct digital control (DDC) and telecommunications technology have led to the development of EMCS applications for non-traditional functions. This paper gives an overview of the following applications:

- ***Maintenance Control***, including filter control, water treatment control, and runtime tracking.
- ***Security Applications***, such as integration of card key access control systems with centralized EMCS.
- ***Industrial Applications***, including manufacturing line optimization and precision environmental control.
- ***Retail Applications***, including customer traffic analysis and evaluation of marketing activities.
- ***Miscellaneous Applications***, including environmental compliance, indoor air quality monitoring, and noise control.

To assist in the practical application of these functions, this paper provides checklists for use as screening tools. Estimates of the resources and EMCS features required to implement non-energy functions are also be presented. Where appropriate, conclusions will be drawn as to the associated profitability or expected benefits.

This information will assist the facility manager and owner in making decisions on enhanced EMCS applications, expanding the scope of traditional energy management, and achieving enhanced productivity, reliability, and functionality.

Introduction

By definition, an energy management control system manages energy. However, as more powerful systems are developed and installed, EMCS capabilities are expanding to include non-traditional functions. The EMCS is, at heart, a computer program. It can process virtually any information as long as it has the proper sensors and transducers. Its actions are not limited to the traditional tasks of building systems. Enhanced applications tap the vast capabilities of EMCS.

The applications described in this paper are not yet common practice. This is mostly because both building owners and EMCS vendors are usually focused on traditional applications for EMCS, which often take the form of generalized "canned" strategy routines. Vendors may have little knowledge of the security, maintenance, or industrial systems of the building, and owners may not be fully aware of the potentials for the EMCS in their building. In addition, many EMCS installations are constrained by first cost, and there is a lack of case studies and cost-benefit analyses of enhanced applications in the literature. This paper will provide information and general guidelines to increase awareness of opportunities for EMCS applications.

Resource and Technology Requirements

Many of the applications discussed in this paper will be appropriate only if the proper technology is available. In virtually all cases, direct or distributed digital control (DDC) systems will be required. DDC gives power and flexibility in terms of information exchange between the central processing unit (CPU) and any additional components that are required. In most cases, the control system must be expandable such that additional inputs and outputs can be added and configured.

The resources for implementing these applications will vary with the complexity of the task. In general, unless an expert is available on staff, the facility staff will need to work with the controls vendor to implement the enhanced strategy. However, a savvy on-site building operations staff will ultimately be the driver of an advanced project.

Stand-Alone Controllers

"Stand-alone" controllers are electronic modules or computerized systems that are specifically designed to handle a particular task. Often, a stand-alone controller separate from the EMCS is available to implement particular enhanced applications such as security, maintenance, industrial processes, and more. It may be valuable to integrate the enhanced application into the EMCS rather than purchase and maintain a stand-alone controller, but there are pros and cons for both situations. A commercially available controller dedicated to a particular function may be able to perform its designated task better and more flexibly than an EMCS, especially if that function is particularly complex.

For example, for facilities with unusually large or complex maintenance requirements, a stand-alone computerized maintenance management system (CMMS) is often the best way to handle and track maintenance tasks. EMCS can generally be adapted to handle aspects of special tasks, but usually not at the same depth. However, an enhanced EMCS application is often a quick and inexpensive way to implement some component of the stand-alone controller function.

Advanced stand-alone controllers are often more expensive than creating an application for the EMCS. In fact, the cost of a stand-alone control system can approach that of the EMCS itself, but this is because the top-of-the-line stand-alone controller is highly evolved. It is designed to obtain eager acceptance and use by facility staff, particularly in the case of maintenance management. It can be part of a product line and will usually be accompanied by technical support and future upgrade options similar to an EMCS. However, for a focused task, the EMCS is an excellent tool to implement an enhanced application as described in this paper. The cost is usually that of a series of monitoring points and some control code programming.

Maintenance Control

Building managers can use the totaling and counting functions of their EMCS trending capabilities to construct duty logs. A duty log offers valuable information about equipment: how much it is used, how much it is cycling, how well it is following assigned schedules, and more. With such a log, maintenance personnel can more readily determine if maintenance is due or if equipment needs preventative repair or replacement.

DDC systems can track and display information such as last time ON/OFF, daily equipment run-times, monitored data from analog inputs, energy use, and hardware performance. DDC systems can also accumulate and display monthly scheduled and unscheduled run-times for each piece of equipment controlled or monitored. Duty logs could show change-of-state for major loads for review on a daily basis if desired.

For equipment driven by motors, run-time is the basis for scheduling preventive maintenance. For filters and heat exchangers, pressure drop is the basis for scheduling maintenance. System operators can assist maintenance personnel by preprogramming instructions that associate maintenance schedules with equipment and report skill levels and tools needed for maintenance tasks. Furthermore, automatic sequencing can be used to equalize run-times. For example, with a lead and lag pumping arrangement, the lead pump can automatically be switched once per month (or other interval) to equalize run-time.

Some EMCS have complete add-on computerized maintenance management systems (CMMS) or can interface with a standalone CMMS. Some systems are module-based, where energy management and maintenance management modules are available as needed. This feature greatly enhances the automation and connection between facility operations and equipment maintenance. CMMS can be extremely advanced in terms of data tracking of problems, repairs, equipment downtime, and performance. Customized reports can be generated for use in communication between maintenance staff, management, and other departments.

Maintenance control for commercial buildings is among the most widely used and is commonly applicable. Building owners who have or are installing an EMCS and desire automated maintenance management, but are constrained in terms of budget, may want to implement some maintenance management features in lieu of a full CMMS. The following enhanced applications are fairly simple to program, install, and maintain:

- ***Filter Control.*** Primary and secondary air handling unit filters can be monitored with differential pressure switches, so that when the filter reaches a certain pressure across the media it triggers a maintenance alarm at the DDC operator's console(s). This alarm can be linked to a message that gives the maintenance person information on what size and quantity of filters are required. This strategy can save staff time as well as improving air quality and distribution.
- ***Water Treatment.*** Water chemical feed for cooling tower basins and for boiler systems may be administered manually or by a local specialty feeder. An EMCS can be programmed to perform this function automatically, adjusting the feed rate based on other information to which it has access, such as blow-down or bleed-off rates.
- ***Run-time Tracking.*** EMS totalization features can accumulate the total hours of on-time for any piece of monitored equipment. Alarms can be programmed to notify facility staff when equipment has run for a given number of hours and requires service. Fan motor belts, bearing lubrication, pump seals/packing glands, etc. can be scheduled for maintenance by either total run-time or calendar dates. The DDC system can trigger maintenance alarms and be linked to messages. Run-time can also be used to alternate redundant pumps, chillers, boilers, and other equipment.
- ***Sewer Fee Control.*** Cooling towers lose water through evaporation and require make-up water as well as some periodic blow-down or bleed-off of water to keep mineral build-up under control. If utility sewer rates are high and cooling tower flow rates are large enough, it may be cost-effective to install water meters on the make-up since the

sewer company may assume that all building water, including makeup water, goes down the sewer. These meters will calculate the actual amount of water going down the drain to the sewer, allowing for possible reduction of the sewer bill, as the evaporated water is now not being billed for.

Certainly, a full CMMS is the most advanced computerized method for addressing maintenance management. However, the above tasks or similar facility-specific initiatives can provide automation at a relatively low cost.

Security Applications

Security is of premium importance to most building owners. Some sectors, such as the federal government, are required to maintain certain levels of security. Other organizations, both public and private, perform sensitive work requiring security clearances and access control. For these reasons, most commercial buildings operate under a form of secured or restricted access. There is often an opportunity for integration of security systems with EMCS and other building systems such as HVAC and lighting. This could take the form of contractual integration, where a single party is responsible for both systems; informational integration, where one-way information flow allows both systems to be viewed on the same workstation; or technical integration, which allows the two systems to function as one (DeLuga & Johnson 1997). Security lighting control has long been a common EMCS-controlled practice. Today's advanced security equipment allows facility managers to further refine security practices by integration with an EMCS and thereby meet their needs more exactly. Monitoring and tracking lighting and HVAC use or other occupancy indicators in critical areas may provide a valuable history in the event of a security breach.

Card Key Access

Magnetic card key systems are a standard form of access control. Their minimum function is that of a lock and key. However, in many buildings, the access cards contain unique digital identification information, allowing for activity in the building to be remotely monitored and stored. For organizations that wish to conduct in-house security analysis and monitoring, particularly during unoccupied hours, card key systems are ideal. For organizations that have less need for security monitoring, the access system vendor will typically store entry data offsite to be retrieved if needed. Although many card key systems can feed data directly to the building EMCS, not all have that capability. It will be necessary to work with the security vendor to determine if the EMCS can communicate with the security system.

When access is restricted between zones or floors, card key information is valuable for analyzing building occupancy trends. When the EMCS is integrated with the security system, card key readers can act as a form of occupancy sensor to augment zone control with the proper HVAC equipment. This is most successfully and accurately accomplished with an employee "key-in" and "key-out" system. For example, a worker enters her office space by sliding her access card through the reader, either at the main building entrance or at the entrance on her floor. When this occurs, the reader obtains the employee's identification and feeds her data to the EMCS. The EMCS can then look up the location of her office space in a database and subsequently activate lighting or zone-level HVAC at that employee's work space as appropriate. Furthermore, lighting and HVAC can be provided only to nighttime or weekend workers' zones based on a signal from the card key reader. In this way, access control will produce not only non-energy benefits such as enhanced security monitoring, but energy savings as well.

Industrial Applications

For industrial buildings, opportunity for enhanced control applications will exist in industrial process control. Automated process control is typically implemented through Supervisory Control and Data Acquisition (SCADA) or Distributed Control Systems (DCS). Like energy management control systems, SCADA has evolved over the past 30 years (Brinkler, Twidwell & Crane 1998). These systems, through optimization of the industrial activity itself, can lead to significant productivity increases. Industrial engineering consultants are often employed to develop ways to optimize production methods, and the SCADA/DCS is a tool for implementing such strategies. The following are some examples of possible activities for industrial applications:

- Optimizing conveyor belt speed for mass production lines
- Coordinating and integrating different manufacturing lines
- Matching shipping with current production levels
- Interfacing with computerized manufacturing equipment
- Monitoring production at various points along a manufacturing line
- Calculating and storing quality-control or statistical process control parameters
- Graphical representation of processes
- Monitoring raw material inventory levels
- Handling alarms for industrial applications

The ongoing industrial process or activity that is currently managed by a SCADA system may be enhanced by integration with the EMCS. The two systems are somewhat analogous in their structure; both consist of a central processing unit or main terminal unit and both have remote terminal units. Thus, both systems have the computer power and coverage of the entire building required to perform their respective functions. The enhanced application for the EMCS will arise from building environment or HVAC issues that have an impact on industrial processes. Examples include providing extra cooling on demand to high-temperature manufacturing areas, or providing precise environmental control for "clean rooms."

Retail Applications

Retail stores are in an excellent position to receive non-energy benefits through energy management control systems. A critical parameter for stores is that of customer traffic, and the EMCS is a good vehicle for traffic data collection. With the proper motion sensors, the EMCS can measure roughly how many customers are shopping and their rates of entry and exit, as well as when they are shopping. For larger stores, it is possible to determine the areas of highest traffic within the store. A major ancillary benefit of this information is the ability to measure the effectiveness of promotions and marketing efforts. In this case, a direct correlation between the promotion and increases in consumer traffic (perhaps in a particular aisle or area), would provide marketing assessment data. The profitability of these applications comes from the ability to continually obtain reliable data.

Additional benefits are possible for multi-store facilities such as malls or shopping centers. Information about customer traffic has traditionally been gathered by counting cars in the parking lots and garages, usually with pneumatic road tubes. An EMCS can refine car counting for reliability, or move toward people-counting instead. When the ability to determine customer traffic at various levels and locations is available, the following tasks may be implemented:

- Find high- and low-traffic areas
- Evaluate special events
- Compare number of shoppers to number of buyers
- Evaluate business hours
- Analyze seasonal trends
- Determine expected shopping activity by day of week
- Quantify effects of weather on shopping
- Improve traffic to low activity areas

Miscellaneous Applications

Non-energy related tasks are not limited to security, industrial, and retail applications. Creative initiative may yield successful applications for other facilities. Although not yet common practice, the following are just of few of the potential tasks that are known to be implemented across the country.

- ***Tenant After-Hours Billing.*** This is an application that allows the property manager or owner to easily track, document, account and bill for the non-standard or "beyond the lease agreement" hours that various tenants may occupy the building. During these non-standard periods, the tenants may require lights and HVAC. These after-hours services may be engaged by scheduling ahead with the facility manager or EMCS operator, by a telephone call override or by a manual switch or card reader override system. EMCSs have been used in such cases to automatically track the precise number of non-standard hours that any tenant may use in a month and generate an invoice from predetermined hourly charges. This greatly simplifies the tracking and documentation required to do the tasks manually.
- ***Greenhouses and Farming.*** Use EMCS to precisely control humidity levels in greenhouses, to schedule plant watering, or to operate irrigation and fertilizing systems.
- ***Noise Control.*** Some facilities may need to monitor and record noise levels. When possible, use the EMCS to ratchet down noise-generating equipment or to activate noise cancellation systems if decibel levels go above prescribed levels. In addition, decibel-level logs may help resolve worker complaints about noise levels.
- ***Environmental Compliance.*** Many organizations must carefully monitor pollutants or emissions. EMCS can handle this job and provide documentation. At hazardous waste cleanup sites, EMCS can monitor soil for toxic contaminant levels and generate alarms as required.
- ***Indoor Air Quality (IAQ) Monitoring.*** Many building owners that have IAQ concerns use EMS to monitor and troubleshoot carbon dioxide, toxic substances, and humidity levels. CO_2 monitoring as a means to control outside air ventilation is common practice. Monitoring information can be continuously downloaded to trigger real-time alarms and periodically archived for future reference. Some building owners have found IAQ parameter data useful to resolve litigation involving air quality.

- ***Animal Farms.*** EMCS has been creatively applied to farming tasks. For example, at a hog farm, an EMCS controller is used to schedule and automate feeding times while opening and closing gates to herd animals to the desired locations.

Screening for Enhanced Applications

Opportunities may exist for facilities that have unusual needs. A "Yes" answer in the following table may indicate areas where enhanced EMCS applications may be appropriate and valuable.

Table 1. Screening Checklist

	Yes	**No**
General/Miscellaneous		
Are there regularly repeated activities that would benefit from automation?	☐	☐
Does the building have noise problems which require monitoring?	☐	☐
Is there a need for information that would be difficult to collect manually?	☐	☐
Are there IAQ problems in the building?	☐	☐
Is an ongoing IAQ record considered valuable?	☐	☐
Is environmental compliance (emissions, toxicity levels) an issue?	☐	☐
Does the facility have a number of tenants requiring lighting and HVAC during normally unoccupied hours?	☐	☐
Maintenance		
Are maintenance tasks performed by in-house staff?	☐	☐
Is maintenance performed without the aid of a computerized maintenance management system?	☐	☐
Could filter pressure drop monitoring and maintenance message generation be implemented?	☐	☐
Would automatic water treatment control be appropriate?	☐	☐
Would equipment run-time tracking be valuable?	☐	☐
Are there significant water evaporation losses in the facility?	☐	☐
Security		
Does the facility have a security card-key access system?	☐	☐
Could the security system be integrated with the EMCS?	☐	☐
Could the card-key system be used to detect occupancy during normally unoccupied hours?	☐	☐
Can the HVAC system be controlled at the zone level for a key-in, key-out security system?	☐	☐
Industrial		
Is there an opportunity to integrate process control (SCADA/DCS) with a central EMCS for control or monitoring purposes?	☐	☐
Is there a need for process data collection or analysis?	☐	☐
Are there manufacturing areas with strict environmental control?	☐	☐

For questions that have been answered "Yes," further investigation is warranted. Consultation with the controls contractor, maintenance personnel, industrial engineer, or other specialists may be required.

Profitability and Cost-Benefit Discussion

The cost-effectiveness of any application will depend on its benefits. Many building energy managers are accustomed to thinking of cost-effectiveness in terms of energy savings and simple payback, but analysis of the EMCS applications presented in this paper are often difficult to quantify in such a manner. Increases in productivity and efficiency should be factored into cost-benefit analyses; other benefits, such as improved occupant relations, full environmental compliance, or enhanced security, may be hard to quantify in dollar amounts.

The following hypothetical examples describe an EMCS application, give some of the costs, and discuss the associated benefits that could be expected.

Maintenance Application

An additional EMCS point consisting of a pressure transducer is added to an air-handling unit to measure pressure drop across a filter. The cost of this additional feature will be $300 - $400 in hardware, plus $50 - $100 in of controls programming, assuming $100 per hour for the controls contractor. The programming cost will be lower if in-house personnel are able to perform the work.

The benefits of this project depend on several factors. First, it has been shown that clean filters save very little energy (about 1%) compared to dirty filters. This is because of the complex system interactions between fan performance, duct static pressure, equipment run time, and coil efficiency (Houghton 1997). Second, the benefits will depend on whether filters were previously changed behind or ahead of proper schedule.

If filters were changed too frequently, the owner will save on filters and maintenance personnel time by implementing filter monitoring. Assuming $100 for a high-quality filter change (includes filter and personnel), the EMCS application would pay for itself within 5 alleviated filter changes. If filters were previously not changed often enough and allowed to become dirty, the benefits would consist of improved air flow in conditioned spaces, decreased driving force for dirty bypass air, increased air quality, and reduced chance of filter structural damage.

In any case, even if filters had previously been changed on an appropriate schedule, relying on computer-generated filter replacement prompts will lessen the administrative cost of manually consulting a preventative maintenance schedule. Thus, this application will provide a range of benefits at a relatively low implementation cost.

Retail Application

Three motion sensors are put in place to analyze the customer traffic in particular areas of a retail store. The intent is to identify areas of high and low traffic, determine if certain products are under-exposed, and to evaluate the effectiveness of a product display in a particular part of the store. The cost of this application will include the sensor hardware and installation ($300 - $500 each or more, depending on the quality of the sensor), and the control programming (approximately 2 hours at $100 per hour). In addition, it is desirable to obtain marketing consulting expertise ($75 - $100 per hour) in setting up the application if that expertise is not available in-house. Thus, the total cost may reach $2,000.

The benefits of this application will be the nature and reliability of the data, and the avoided cost of obtaining the data through other methods. Without the EMCS motion sensors, the data for examining traffic and evaluating a display would be collected by manually observing traffic and conducting surveys or focus groups. Depending on the number of hours of data collected, the rigor of surveys, and the number of focus groups, the cost of obtaining the data manually would be $2,000 - $5,000.

There are advantages and disadvantages to both methods. The implementation of an EMCS application will give continuous data during all hours of store operation, allowing for analysis of seasonal trends, time-of-day trends, and future analysis for any reconfiguration of product displays. However, this data usually provides general trends rather than exact counts of customers. Manual customer counting is gives a more precise number, but can be intrusive in some cases. Focus groups and surveys, though expensive, will provide not only numerical data but valuable qualitative feedback as well. However, the non-EMCS marketing assessment will be a snapshot analysis rather than a continuous data stream. Note that in both cases, post-data collection analysis by a marketing expert or consultant will often be necessary.

A cost-benefit analysis of this retail application reveals that the EMCS is a less expensive method to obtain numerical data for long periods of time; however, additional human insight and feedback will be gained through traditional marketing analysis methods.

Conclusion

There are many opportunities for the implementation of enhanced applications for energy management control systems, ranging across many different building sizes and types. A state-of-the-art DDC EMCS is capable of functions beyond traditional energy management. Cost-benefit analysis of these projects is difficult, since the benefits will often be non-energy related. For this reason, these projects are not common and are usually considered "high-end" applications. However, those non-energy benefits often make the projects worthwhile: automating mundane tasks can increase employee morale, or improved marketing data can increase sales.

References

Brinkler, V., J. Twidwell, and M. Crane. 1998. "SCADA Systems and Their Application to Wind Farm Performance," http://www.dmu.ac.uk/~vcb/vicky.htm.

DeLuga, G., and M. Johnson. 1997. "Security Joining Building Automation," *Engineered Systems* June.

Gustavson, D. 1993. "EMCS—The Human Dimension," *AEE Globalcon* April.

Gustavson, D. 1993. "It's Not Just a Time Clock Any More," *Contracting Business* October.

Gustavson, D. 1994. "Stacking the Deck in Favor of Quality Energy Management." *In Proceedings of the National Conference on Building Commissioning.* Portland, Ore.: Portland Energy Conservation, Inc.

Gustavson, D., J. Cratty, and R. Williams. 1996. "Energy Management Control Systems," from *Energy Management Handbook*. 3rd Ed. Lilburn, Ga.: The Fairmont Press.

Houghton, D. 1997. "Operating and Maintaining Rooftop Air-Conditioning Units," *E-Source Tech Update* January.

Owens, G. 1992. "The Proper Selection, Care, and Feeding of a Large Centralized Energy Management System," *Energy Engineering*.

Ponds, M. 1995. "NERTs: Non-Energy Related Tasks," *Energy & Environmental Management* Summer.

Sabeff, P. 1991. "Pre-Planning for Integrated Building Management Systems," *AIPE Facilities* May/June.

Sanchez, P. 1995. "Resurrected EMCS Saves Money, Increases Comfort," *Energy & Environmental Management* Spring.

Stum, K., R. Mosier, and T. Haasl. 1997. *Energy Management Systems: A Practical Guide*. Portland, Ore.: Portland Energy Conservation, Inc.