Proposed Guidelines for Using Energy Management and Control Systems for Performance Monitoring

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Monitoring of energy consumption and building operation are important parts of conservation savings analysis, although effective monitoring can be quite expensive. Energy Management and Control Systems (EMCSs) contain all of the same equipment that is usually installed for monitoring, however, and can often be used for this application. Since EMCSs are installed in a growing number of commercial buildings, the addition of conventional energy monitoring equipment can be redundant.

EMCSs are not designed with monitoring in mind, however. The characteristics of an EMCS are determined by the building's control needs rather than by monitoring needs, so EMCS-based monitoring can have several complicating factors. Differences between the EMCS models, the installed options at sites with the same model, or the degree of system utilization at a site can mean the difference between a system that can be used for monitoring immediately, and one that cannot be used at all. In instituting monitoring programs that include EMCSs as tools, guidelines defining procedures and the required system capabilities would be quite helpful.

In this paper, we propose guidelines for EMCS monitoring, based on our evaluation of monitoring procedures in earlier case studies. These guidelines could be used to help in determining whether EMCSs can be used for monitoring at particular sites. The guidelines also discuss how to find out if the necessary elements are present, and what to do if these elements are not present. Finally, we discuss how these guidelines could be used in the development of the EMCS-based monitoring technology, and the advantages that could be realized through that development.

Introduction

Detailed building monitoring is an important part of the evaluation of conservation programs. Most of this data acquisition is done by installing dedicated monitoring equipment, i.e., equipment whose sole purpose is to perform monitoring for the project. Dedicated monitoring equipment consists of several different devices, including sensors to measure the required quantities, and wiring to connect the sensors to the datalogger. The datalogger includes software to sample, condition, scale, average, and store the data. There must also be storage devices on-site: short term memory, and possibly a longer term storage device, such as a magnetic tape or disk drive. The data can often be retrieved remotely, requiring a modem, telephone line, and communications software. All of this equipment, hardware and software, must be purchased and installed. Upon reviewing this list of equipment required for monitoring, one will recognize that most Energy Management and Control Systems (EMCSs) include all these same devices.

Many larger buildings currently have EMCSs installed; and, as the cost is coming down, EMCSs are more accessible to smaller buildings. An EMCS usually includes a large number of sensors; sophisticated interconnections between sensors, actuators, and processors (often comprising a local area network); a powerful processor capable of extensive computation; a large amount of memory; a variety of peripheral storage devices; and a modem and communications capabilities. All of the equipment required for monitoring is likely to be present at a site, so it would seem advantageous to make use of it in a monitoring project. It is sometimes possible to make use entirely of existing equipment, and to install absolutely no hardware. Since the EMCS was designed and configured for control of the building systems, not for performance monitoring, it sometimes takes a little effort to make it work in this new application. But this effort is often well worth it, since the costs for dedicated monitoring range from about $3,000 to over $10,000 per site (EPRI 1989).

Over the past several years, we have monitored several facilities as case studies, in order to investigate how in-place EMCSs can be applied to remote monitoring, and to determine what limitations exist and what areas require further development. These case studies are discussed in detail in earlier publications (Akbari et al. 1989;

Akbari et al. 1986; Heinemeier et al. 1992; Heinemeier and Akbari 1992; Heinemeier and Akbari 1987; and LeConiac et al. 1986). At most of the sites we studied, the EMCS could be used for monitoring with little or no modification. Each system had both advantages and disadvantages. The practical limitations we encountered were due to the EMCS model itself in some cases, while, in others, they were due to unimplemented but available options or other site-specific characteristics. Because of the nature of these limitations, it may be that the technique of using EMCSs, as they are now designed and installed, for monitoring buildings, is better suited to case-study scale monitoring projects, than to large monitoring programs, in which uniformity is of primary importance. However, if some of the limitations were addressed in the design of the future generations of EMCSs, this technique could develop into a very promising technology, even for large-scale projects.

In this paper we bring together our experience from these case studies in the form of recommended guidelines for monitoring. These guidelines lay out what elements an EMCS usable for monitoring should contain, how to determine if these elements are present, and what options are still available if these elements are not present. We also discuss how these guidelines could be used in the development of the EMCS-based monitoring technology, and the advantages that could be realized if it were further developed.

Guidelines for EMCS Monitoring

Monitoring using an EMCS is, conceptually, a very straightforward matter: if all the required hardware and software are present at the site, they can be used for monitoring. In practice, however, it can become more complex. The fact that an EMCS is present at the site does not necessarily mean that it can be used for monitoring. Even if one knows that the EMCS model used at a site is the same as one that was used for monitoring at a previous facility, differences in installed options, or in the degree of utilization of the existing capabilities may prevent the system from being used. In our case studies, we found some systems that could begin collecting data immediately with no startup effort, and others that could not be used at all. In a few cases, it took time to discover whether the system would work or not. Sometimes, if we didn't ask an EMCS operator a question about his or her system's capabilities in exactly the right terms, we did not get the correct answer. Since EMCSs are designed to be highly adaptable, capabilities and monitoring costs often must be evaluated on a site-by-site basis. However, knowing what questions to ask and what the answers mean makes determining a system's capabilities much more

straightforward. Having the requirements for monitoring written down and as clearly specified as possible, in the form of guidelines, should help.

The guidelines presented here can be used by monitoring contractors or monitoring program planners as a yardstick for evaluating whether an EMCS at a particular site can be used immediately for monitoring as is, whether it will require modification, or whether dedicated monitoring equipment must be installed. Some of the steps to be taken in this evaluation are shown in Table 1. The guidelines could also be used as the basis for design specifications for EMCSs with monitoring capabilities, for use in monitoring programs.

Note that these guidelines do not represent the current state of the technology: no system that we have encountered includes all of these functions. They can be thought of rather as a standard for comparison. The fact that a system does not fit these guidelines does not imply that it cannot be used. On the contrary, in most cases, some alternative means of achieving the objective can be worked out, or additional hardware or software might be installed to supplement the existing system less expensively than installing an entire monitoring system. Just as the applicability of an EMCS for monitoring must be evaluated on a case-by-case basis, individualized evaluation would be required to judge what would be involved in supplementing the existing system and what the costs would be.

(1) *The physical attributes necessary for analysis should be measured.*

In most cases, the sensors used in an EMCS are very similar to those used in dedicated monitoring projects. They can include power transducers or pulse-counting energy meters, as well as temperature, pressure, and humidity sensors. Sensors are installed to meet the building's, and not the monitoring project's objectives. Hence, while certain variables such as whole-building energy consumption will often be measured, end-use submetered consumption often will not.

To determine whether or not a system includes the sensors needed for monitoring, the EMCS operator can usually generate a list of all the points (input and output) connected to the system, and display the definition of individual points, including their engineering units, calibration constants, and sampling frequency. Find these points on EMCS or building plans, then tour the building to identify any obvious problems with the sensors. If the necessary points are not measured, you might be able to install your own sensors, while making use of existing

Table 1. *Steps in Evaluating the Capabilities of an Existing EMCS*

1. Decide what points you want to monitor, the sampling interval, downloading frequency, and required data accuracy. As in all monitoring projects, you should decide what you will do with the data before you begin collecting them.

2. Call the person in charge of operating the EMCS to make a preliminary assessment of the system. Ask the following questions:

    *   What is the EMCS model and manufacturer?

    *   Does the system have a trend or history facility?

    *   Is there some way to log onto the system remotely, as a VT100 terminal? Is there a modem and telephone line?

    *   Will the trend facility display collected samples to the screen of the terminal?

    *   I am interested in collecting data at (sampling interval) for (number of points) and accessing it (downloading frequency). Do you think this will be possible with your system? Will this interfere with the system operation?

3. If the system looks at all hopeful, set up a meeting and request that the following information be ready for your visit:

    *   building or EMCS plans showing the location of sensors you are interested in;

    *   sensor, transducer, and analog-to-digital converter documentation.

    *   documentation on the trend facility, including a photocopy of the manual pages that discuss trend point definition, trend report generation, and file transmission;

    *   the phone number of the EMCS modem, the communications parameters to use in accessing the system (these include baud rate, parity, data bits, and stop bits), a login, and a password.

4. At the site visit, bring a portable computer with you, with generic communications software and a modem, and sit down with the operator to go through a demonstration of the procedure. Use the following steps:

    *   start recording a log file;

    *   dial into the modem and log onto the EMCS, using your login and password;

    *   display point definitions for the points you are interested in monitoring, making sure the definitions include engineering units;

    *   display a list of the points that are already setup for trending;

    *   go through the procedure for defining hourly trend points, trend groups, and trend report (as applicable);

    *   note the time (online, if possible);

    *   request an hourly trend report display or transmission, using a shorthand notation, if available;

    *   note the time again;

    *   logoff and stop recording the log file.

    Keep the log file for evaluating transmission time, determining data processing procedures, defining a script for automating access, and as general documentation. Ask for a tour of the facility, including looking at the sensors.

EMCS networking and data storage capabilities. Installing a few sensors may still be much less expensive than installing an entire data acquisition system. However, due to interference, electrical isolation, and liability considerations, the EMCS operator and building owner should be consulted early on. Alternatively, since EMCSs have access to a great deal of other information on building operation, it may be possible to achieve your

analysis objectives with different input data. For example, monitoring lighting on-time rather than submetering lighting load may provide the information you need.

(2) *Data should be of sufficient accuracy to perform analysis.*

Sensor accuracy is very important in a monitoring project. The required accuracy will, of course, depend on the analysis that will be performed. Since the same kinds of sensors are available for use in an EMCS as in a dedicated monitoring installation, the same accuracy should, theoretically, be possible. The accuracy of the installed sensors is specified by the EMCS contractor, in order to be adequate for control of the building. For those sensors used primarily for control, reasonable accuracy is usually required, and the building personnel have reason to keep an eye on whether or not the sensors are providing believable values. However, other types of sensors are used primarily for indication, and accuracy may not be as high a priority. Recently, more attention is being paid to accuracy in EMCSs. In their Standard 114-1986, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has written guidelines for specifying measurement requirements and recommended methods of verifying accuracy of EMCS instrumentation (ASHRAE 1987). Standard 114-1986 provides typical values for accuracy required for different applications. The suggested accuracies for energy calculation applications are shown in Table 2.

Documentation of design accuracy should be made available by the EMCS operator. The accuracy of sensors, transducers, and analog-to-digital converters must all be considered. The "Measurement and Instrumentation" chapter in the *ASHRAE Handbook of Fundamentals* also provides information on sensor accuracy considerations (ASHRAE 1989). If documentation is not available, it may be necessary to perform on-site tests. Another alternative is to install your own sensors. Again, this may still be an economic alternative to installing an entire data acquisition system.

(3) *Sensors should be in proper calibration before monitoring begins.*

It is important to calibrate sensors, or, at least, to compare EMCS values with some reference to determine their accuracy. This is especially important when data accuracy is not crucial to the operation of the building. In these cases, the building managers may not have incentive to double-check values or replace a sensor that is known to provide false values. In one of our studies, an electrical meter was miscalibrated by a factor of two. Since they

Table 2. Data Accuracies Typically Required for Energy Calculation	
Space DBT	+/-0.5 F
Hot Air Supply - DBT	+/-1 F
Cold Air Supply - DBT	+/-1 F
Outside Air DBT	+/-1 F
Dewpoint	+/-3 F
Hot Water - S&R	+/-2 F
Chilled Water - S&R	+/-1 F
Condenser Water - S&R	+/-2 F
Temp. Difference - Water	+/-0.5 F
Temp. Difference - Air	+/-0.5 F
Flow - Water	+/-2.5 % of full scale
Flow - Air	+/-2.5 % of full scale
Pressure - Air Duct	+/-1.0 % of full scale
Pressure - Air Building	+/-1.0 % of full scale
Pressure - Refrig. Water	+/-2.0 % of full scale
Electric Meters	+/-0.25 % of reading

Source: ASHRAE Standard 114-1986.

were only interested in changes from day to day, and not in the absolute value, the building personnel had never discovered the problem. It is important to note that quality assurance is a difficult issue even with dedicated monitoring, particularly in large programs with several monitoring contractors (see, for example, O'Neal et al. 1992, and Halverson et al. 1988). The cost of sensor validation must be figured into the total program cost whether dedicated or EMCS-based monitoring is being performed.

Sensor calibration is often performed at the factory, but many types of sensors should be periodically recalibrated. The frequency with which sensors should be recalibrated depends on the type of sensor. Sensors that are open to the environment, and sensors that include mechanical parts are particularly in need of periodic recalibration. The EMCS operator should have access either to information on factory calibration of sensors, or to documentation of subsequent recalibration. If this documentation is not available, you may be able to field-calibrate the sensors. Since calibration is important for controlling the building, the EMCS operator might be willing to participate in the calibration efforts. If it proves impossible to calibrate the sensors and accuracy is important, then you may want to install your own sensors.

(4) *Software and hardware should permit recording of historical data.*

The current value of all EMCS points is usually available for immediate use in control applications, (for example in a calculation to determine if more cooling is required). These data, then, can be stored for further analysis. Because of the usefulness of this type of data for building operation, most EMCSs have a facility for storing large amounts of data, often called "trending," (trends might also be referred to as archives or history reports).

The EMCS operator should know if the EMCS has a facility for trending, archiving, or collecting historical data. Copies of manual pages summarizing the trend facility may be required to determine if it is really applicable. It is also helpful to get a demonstration of the procedure for displaying or transmitting trend data (see Table 1 for discussion of the demonstration). It is possible that the necessary software is available from the manufacturer, but has not been installed at this site. In this case, the software could be added, although the cost of this software addition will have to be borne by the monitoring project.

(5) *Data should be available in the form of both instantaneous samples and averages over user-selected intervals. Electricity should be reported either as the average power drawn or the total energy consumed over an interval.*

For some variables such as temperature, it might be acceptable to take a "snapshot" of the value once an hour. For most variables, such as power, however, this would be hopelessly inaccurate. We have seen several ways of measuring electrical power. One method uses a pulse counter installed on a utility-type rotating kWh meter. Each pulse corresponds to a certain amount of energy. These systems accumulate pulses--or kWh--and report cumulative energy. One reading is subtracted from the next to determine the total energy consumed over that period. In another method, power is directly measured. This must be averaged to be useful for monitoring. Although a very fast sampling rate would be required to catch quick variations in the load, fairly accurate hourly energy consumption values should be attainable with typical EMCS sampling rates.

If you are monitoring electric power, look at the engineering units on the point definition. If it is shown as kWh, then you will be obtaining average or total energy. If it is kW, then you will need to determine if the trend facility is capable of providing data on an averaged basis. If averaged data are not available, it may be possible to use instantaneous samples, depending on the analysis and the type of point. Some systems have a method of "totalizing" data over certain periods. But whether or not data totalized over an hour can be recorded each hour will have to be determined. Another novel way of averaging, used in some systems, is to record an instantaneous sample, only when the value has changed by some predefined level. This is referred to as Change of Value (COV) monitoring. COV monitoring has the characteristic that when the value is changing quickly, very short interval data are collected; and when the value is changing very little, very long interval data are collected. COV monitoring is discussed in greater detail in Heinemeier et al. 1992.

(6) *The system should have an available data storage capacity sufficient for monitoring applications.*

Before data are downloaded to the remote computer, they will be stored for some period of time on-site. Most systems have sufficient storage capacity for this, at least in theory. Capacity is usually specified as the number of points that can be trended, the maximum number of samples that can be stored per point, or the total memory capacity that is available to trend data. In practice, however, some systems may be limited by communication considerations rather than storage space. Many EMCSs have a distributed architecture with networked remote control units (RCUs) and the ability for a host computer to be connected in the network. Data can either be stored on the RCU, on the host computer, or on the host's peripheral data storage medium (hard or floppy disk or magnetic tape) for longer term storage. With this distributed architecture, information other than that being trended for energy monitoring is traveling along the network paths, and one must consider both the impact of energy monitoring traffic on other operations, and the impact of the other operations on energy monitoring. In these systems, networking concerns may be more important considerations than raw data storage space or absolute point limits in evaluating the usefulness of an EMCS for monitoring. Also, at some sites, the available trending capacity is more fully utilized than at others, leaving little capacity free for energy data. Availability of the trend capacity is therefore difficult to predict for a particular site by simply knowing the EMCS model.

You need to find out what absolute hardware and software limits exist, and how much of the capacity is currently in use. The trend manual will have the absolute limits, but the system operator usually has the best knowledge of how fully loaded the system is, and if more points can be added. If there is not enough storage capacity, one alternative is to purchase more memory. Or, it may be

that there is enough space on a temporary basis for short term monitoring. It may be possible to make do with more frequent downloading of data, or a larger recording interval, so that fewer data must be stored. With COV monitoring, a relatively high COV level will result in less frequent data collection, although this will result in reduced accuracy.

Alternatively, it may be possible to install an additional computer in the EMCS network to collect the data. The cost of this additional computer may, in some cases, make EMCS monitoring not cost-competitive with dedicated monitoring. Usually, however, a fairly unsophisticated computer can be used for this purpose. This might be "last year's model," which can often be purchased quite inexpensively as surplus equipment. The cost of this computer would have to be weighed against the cost of dedicated monitoring equipment.

(7) Historical data should be recorded at specified times, not at specified intervals. If the system is restarted, it should begin collecting data at the correct time.

In order to be compatible with data from other monitoring projects, other buildings within a project, and with weather data, the data available from an EMCS should be reported at the top of each hour. Many systems can theoretically record data at the top of each hour, although if the system is rebooted, the data collection time may shift.

One can tell if the system will reliably collect data at the correct times by looking at how the trend point was defined. If it does not ask for the time to begin collection, it might not be reliable. Another way is to look at some collected hourly data. If the data are recorded at strange times, (for example, at 13 minutes after each hour) it has probably shifted. If the system collects data at specified intervals rather than at specified times, the only alternative is to periodically check the data, and reset the trend if it has shifted. This, of course, adds to the difficulty of EMCS monitoring, and may make it impractical in some cases.

(8) The user should be able to connect to the EMCS remotely, using generic communications software.

In order to access the data remotely, one can make use of the fact that most EMCSs allow for a remote computer to be tied into the system's network. This remote computer can either be a "dumb" terminal or a microcomputer, equipped with a modem and communications software, and emulating a terminal (usually a VT100 terminal type). Communication takes place over commercial telephone

lines. Most EMCSs include the required hardware and software for communications, and have a telephone line dedicated to the EMCS use. These can usually be used by monitoring projects.

The demonstration of the system will show that it is possible to connect remotely. If it is not possible to connect to the host computer, it may be possible to connect through an RCU. If there is no way to connect to the EMCS remotely, it may suffice to visit the site periodically and collect the data on a diskette, or to have the operator do this and mail the diskette. While this might be impractical for large groups of buildings, it may be perfectly adequate for a smaller sample.

Another alternative is to take advantage of the existing EMCS sensors, while installing your own wiring and data-loggers. One might also be able to take advantage of the EMCS networking capabilities, and collect data from all over the building using a datalogger taking its input from the EMCS.

(9) A mechanism should be available either to display a trend report on the screen of a remote computer that is running generic communications software, or to transmit an ASCII file from the host computer disk directly to the disk of the remote computer.

Simply being able to connect to an EMCS remotely is often not enough. One must also be able to access the EMCS's stored data. There are two ways of downloading data: displaying a report on the remote computer's screen, or transferring a data file. In the first method, one uses the remote computer to log onto the EMCS system, and run the trend utility, requesting that the data report be presented on the screen. The entire session is recorded in a log file on the remote computer, so that while the report is displayed on the remote screen, it is simultaneously recorded on the remote disk. In the second method, the data are stored to an EMCS disk file, and transferred to the remote computer, using some kind of file transfer algorithm. The file transfer algorithm can either be embedded in the EMCS computer software, or can be implemented in a communications program, running in parallel with the EMCS software. If communications software is running in parallel, the EMCS must be on a computer with an operating system that allows multiple processes, and the asynchronous communications must not conflict with the more essential EMCS tasks.

The EMCS operator should know if either of these methods are possible. If the EMCS operator suggests that the first method is possible, make sure the data can be displayed on the screen, rather than to a printer or disk.

In many cases, the data can only be sent to a printer. At one such site, the system was reset so that a remote computer was configured to look like a printer. The EMCS thought it was printing data to a printer, but they were actually being displayed on a remote computer screen and stored in a log file.

Most EMCSs don't have the capability to transmit disk files. If an EMCS in question does have this capability, make sure the remote computer doesn't have to be running proprietary software. If neither of these methods are available, the datalogging functions of the EMCS probably cannot be used.

(10) *The user should be able to request historical data with a simple command.*

When performing case studies, it is not a problem to manually log onto an EMCS to download data. However, in a larger-scale project, a more automated method of data retrieval is needed. Most communications software packages allow the user to create a script file, which can automatically dial the phone, watch for cues coming from the EMCS, issue the appropriate responses, and then move on to the next building. Ideally, after dialing the phone, the script file should only have to provide the correct login name, and then issue one-line commands to request the data. Often, however, one has to specify information such as what points are of interest, what period of time the report is to cover, what recording interval should be used, and where to send the report (to a screen, printer, or data file).

The demonstration will indicate what commands are used to request data. This will give you an indication of how complex the interaction is, and will also help, later on, creating a script. Often, the EMCS will have a "verbose" mode, in which a prompt is issued for each part of the command, and a "concise" mode, in which an entire command is entered on a command line. Be sure to find out if there is a shorter concise command that can be used. A simple procedure is not an absolute requirement, but it makes automation much easier.

(11) *The time required to transmit the data should be as short as possible.*

The amount of time required for transmission of the data is also an important consideration in larger scale projects. Most EMCSs allow a dial-in connection at 1200 or 2400 baud. However, the speed of the transfer will depend to an even greater extent on other factors: whether the data are in a binary or ASCII raw data file, or are embedded in a report; how concise the report format is; and whether or not the report is generated as it is being displayed.

The time required for transfer can be determined from the demonstration, which noted the time before the data were requested, and after the transmission. Using this time along with the number of useful samples obtained (i.e., only the data of interest) and the number of ASCII characters per sample, one can calculate the average number of characters transmitted per second. This can be compared to a reference value of about 240 characters per second at 2400 baud, or 120 at 1200 baud. Ideally, the value obtained from the demonstration should not be less than about a tenth of the reference value. In our experience, many systems meet this criterion, although some systems are significantly slower than this. Alternatives, if the data transfer is too time consuming, are to download less frequently (so that there is proportionally less header information), to use a longer data interval (obtaining fewer samples), to use a higher speed modem (9600 baud modems are available, but may have accuracy tradeoffs, unless a proper protocol is used), or to find out if there is an archive facility that does not generate the report as it is being displayed, and may have less header information.

(12) *Any data transmission errors should be automatically detected and corrected.*

Errors can occur, not only due to faulty or inaccurate sensors, but also when transmitting data from the site. Since data are traveling over commercial telephone lines, noise in the phone lines can obliterate data, or change values.

In systems that have the capability to transmit data files rather than display them on the screen, it may be possible to use a public-domain file transfer protocol, such as Kermit, which can both recognize and correct bad data. Ask if the transmission uses one of these standard protocols, or if the protocol includes error detection and correction. Systems that only allow screen display are susceptible to communications errors. If data checking is not possible, one alternative would be to send the data twice and compare it. If differences are detected, the data should be sent again. This redundancy obviously requires tradeoffs with quick transfer and easy processing.

(13) *Remote access to data should not cause conflicts with control of building or other EMCS operations, or require too much assistance from the EMCS operator. Conversely, the EMCS operator activities should not interfere with data collection.*

With current systems, there is a potential for energy monitoring to interfere with EMCS control operations. In particular, there can be a conflict if the EMCS phone line is used both for remote monitoring and EMCS operation. Also, since operators are working with the same data space, it is possible for them to delete or reset trend data. In some of our case studies, this was a problem.

Asking the EMCS operator is really the only way to determine if your connections will cause interference. Usually, if you make the connection at night, you should be able to stay out of the way. If tying up the system's telephone is a problem, you could consider purchasing an additional phone line and modem. If the system has a distributed architecture, and tying up the host computer is a problem, it might be possible to call into an RCU instead. Another alternative is sometimes to install another computer into the EMCS network, dedicated to your data collection and communications. This cost would have to be carefully considered. Perhaps the best strategy is to develop the best possible relationship with the EMCS operators, so that they will feel comfortable with your activities. Make sure they are aware that the data are important, and should not be deleted without your knowledge. Stay in touch with them so that you can find out early if problems develop.

(14) *Data should be available in an easily processed format.*

Although processing can be done on the remote computer, the easier the data are to process, the more viable this technique will be. The ideal format would be one column for each point. A header should indicate English-like point names and engineering units. Each line should be time-and date-stamped. Columns should be separated by spaces, commas, or tabs. Lines should not be longer than 80 characters. Missing data should be identified as missing, not blank or zero. Finally, each line should be concluded with a carriage-return.

Some additional types of processing that may have to be done are: parsing the date into day, month, and year; parsing the time into hour, minute, and second; subtracting cumulative values to obtain differences, removing the login, command line, and header lines from the log file; calculating the time for each sample, if only the beginning time and sampling interval are known; and inverting the data from rows to columns. Some of the problems we encountered were that only the first 80 characters of a 132 character line displayed, carriage returns were not transmitted, a status line appeared periodically in the middle of the data, the data were not in conventional columnar format, and the data were in COV

rather than hourly format. All of these could be dealt with, but when taken together, made data collection rather cumbersome.

Evaluate the format of the data collected in the demonstration. If the format is not appropriate, find out if alternative formats are available. Sometimes trend data are available in a "spreadsheet compatible" format, which can be easily processed. You will need to make sure this file can be transmitted--often it can only be recorded onto the EMCS disk.

Development of EMCS Monitoring Technology

If remote energy monitoring were developed as a regular application by EMCS manufacturers, many of the difficulties we have encountered would be avoided. The guidelines presented here could also form the basis for specification of future generations of EMCSs that will include monitoring as a basic function, or monitoring modules that can be used to supplement existing EMCSs. In general, these guidelines could be easily met with minor software changes by the manufacturer within their existing trend facilities. Some of the particular provisions that should be made in EMCS software are to allow data to be averaged over an hourly interval, to reliably report data at the end of each hour, to create concise and consistent formats for requesting and reporting data, and to create some simple means of rapidly and reliably displaying or transmitting the data.

Although these simple modifications to existing EMCS software would greatly enhance the usefulness of this technique, a system designed with energy performance monitoring in mind would probably have some fundamental differences. For example, the only way for us to gain access to the data in these existing cases was to have the data displayed on the screen and captured into a log file. However, this is not the most appropriate method, due to the inability to perform error detection and correction, and the time it takes to transmit and process the report. There is also a disturbing potential for energy monitoring to interfere with EMCS control operations, and for control operations to interfere with energy monitoring. Ideally, controls manufacturers should incorporate into their basic software a procedure for transmitting data files to a remote, dial-in terminal, using a standard file transfer protocol. It should also have a separate energy monitoring procedure, which would allow monitoring to take place without either interrupting or being interrupted by control procedures.

It is clearly a problem that the operator must be relied upon for a great deal of the information needed to evaluate the applicability of a system for monitoring. Future designs could address this by more thoroughly documenting capabilities either on-line, or within the system documentation. The more clearly monitoring researchers can define their requirements, the easier it will be for manufacturers to clearly define their systems' capabilities.

One of the advantages of EMCS monitoring is that it is possible to obtain much more information about the building operation than is typically economically feasible in a dedicated monitoring project. In dedicated monitoring, the number of points that can be monitored is usually limited by the number of available input channels on the datalogger, and the cost of hardwiring the connections from the sensors to the logger. With an EMCS, however, many points of interest are already monitored. The EMCS might also be well suited to collecting information on the useful output of systems (in addition to the energy input), and monitoring zone thermostat settings, both of which have been identified as gaps in the field data acquisition system technology (Misuriello 1990).

The computational capabilities of EMCS processors are quite extensive and often underutilized. This provides the opportunity to perform basic processing of the data at the site, before the data are transmitted to the monitoring site. This kind of processing might include things like calculation of heat recovery energy savings from flowrates and temperatures, and different kinds of averaging and normalization.

Several parties would benefit if the applicability of EMCSs for energy performance monitoring were further developed. Building owners and operators would benefit from the immediate feedback that such systems could give them on their building's performance. They would also benefit from the fact that a site that is easily monitored is a more likely candidate for utility and government conservation assistance programs. Utility DSM program designers might include EMCS monitoring in their incentive programs to bolster evaluation efforts. When an incentive is offered for installation of an EMCS (as a conservation or load-management measure), the level of incentive could be increased if the EMCS can also be used for monitoring. Whether or not an EMCS is eligible for this increased incentive could be determined using guidelines such as those presented here. Utilities might then benefit from more cost-effective conservation programs. These utility programs would also present a market advantage for those EMCS manufacturers who offer systems with monitoring capabilities. In fact, controls manufacturers are in an ideal position to perform

conservation services themselves, and to validate savings by using the EMCS for monitoring. They already have a relationship with the customers; through the EMCS specification, installation, and commissioning procedures, they are quite familiar with their customers' facilities; and they have already installed the appropriate hardware and software, and are intimately familiar with its operation.

Conclusions

In earlier case studies, we found that EMCSs can be used for monitoring energy performance. However, due to the fact that EMCSs are not designed with remote energy monitoring in mind, currently each site may present unique problems and require unique solutions. This paper has focussed on the complications that can be encountered in EMCS monitoring, so that they can be dealt with. However, for perspective, it is important to reiterate that it is often possible to gain access to a wealth of information on building operation without installing any software or hardware, by using EMCSs. This paper has presented guidelines to use in evaluating particular sites to determine if an EMCS can be used for monitoring. The guidelines also discuss how to find out if the necessary elements are present, and what to do if they are not. These guidelines represent only an interim step in developing EMCSs for use as monitoring tools, however, and the paper discussed how the guidelines could be used in further development of the technology, and the promise that the technology holds if it is further developed.

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