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Authors
Heinemeier, K.E.
Akbari, H.

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EVALUATION OF THE USE OF ENERGY MANAGEMENT AND CONTROL SYSTEMS FOR REMOTE BUILDING PERFORMANCE MONITORING

Kristin E. Heinemeier and Hashem Akbari

Energy Analysis Program
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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ABSTRACT

Monitoring of building energy consumption, operation, and weather variables is an important part of an energy consumption evaluation project. However, effective monitoring can be quite expensive. In this report, we discuss five case studies that were carried out to investigate the current feasibility of using a building's existing Energy Management and Control System (EMCS) for gathering some or all of these required data, rather than installing dedicated data-logging equipment, and to identify areas requiring additional development. In each of these facilities, we used the existing EMCS to collect hourly whole-building electricity consumption and outdoor temperature data, without installing hardware, and with only minor software modifications. However, since none of the systems were designed with remote data collection in mind, different procedures had to be used in each case to enable the system to provide the necessary data. It was determined that the process could be greatly simplified if EMCS manufacturers ensured that their software averaged data over an hourly interval and reliably reported them at the end of each hour, used concise and consistent formats for requesting and reporting the data, and provided a simple means of displaying or transmitting the data.

INTRODUCTION AND MOTIVATION

Major energy conservation retrofit and demand-side management (DSM) programs are now going on in several places across the nation, sponsored by governmental agencies and utility companies. Due to regulatory requirements and a growing concern for accountability in conservation programs, there is an increased commitment to evaluation in these programs. Monitoring of building energy performance is an important part of conservation program evaluation, whether the program is monitoring performance before and after a retrofit (see, for example, Turner, 1990) or modeling what the performance of a new building would have been without incentives in place, for comparison with as-built performance (see, for example, Harris et al., 1990).

This performance monitoring can include acquiring facility or whole-building utility data, hourly whole-building data, and hourly submetered data. It can include weather variables and equipment operating parameters, in addition to electricity, steam, chilled water, or other energy consumption data. Most data acquisition is done by installing dedicated monitoring equipment, i.e., equipment whose sole purpose is to perform monitoring for this project.

Dedicated monitoring equipment must include several different types of devices (summarized in Table 1). The first, of course, are the sensors needed to measure the required quantities. Once the sensors have been installed, wiring must be installed to connect the sensors to the datalogger. The datalogger includes software to sample, condition, average, and store the data. There must also be storage devices: short term, volatile memory; and possibly a longer term permanent storage device, such as a magnetic tape drive. The data can often be retrieved remotely, requiring a modem and software for downloading the data. All of this equipment, hardware and software, must be purchased.

Upon reviewing this list of equipment required for monitoring, one will recognize that most Energy Management and Control Systems (EMCSs), used primarily to control a building's systems, include all these same devices. 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 large variety of available peripheral storage devices; and a modem with communications capabilities. Since equipment required for monitoring is likely to be present at a site, it would seem advantageous to make use of it in a monitoring project. Note that the EMCS was designed for control of the building systems; consequently, its application to monitoring may also have some disadvantages. Table 1 illustrates some of these advantages and disadvantages.

We used five case study facilities to investigate how in-place EMCSs can be applied to remote monitoring, and to determine what limitations exist and what areas require further development. The case study approach has been found to be quite useful for this technology. Since remote energy monitoring has not been

		Dedicated Monitoring		EMCS Monitoring
Sensors	-	Must be purchased	+	Existing
	-	Must be installed	+	Numerous points
	+	Researcher can select type	-	Used for building control
	+	Researcher can select accuracy	-	May have to add required sensors
	+	Researcher can calibrate	-	Accuracy and calibration not under researcher's control
Connections	-	Must be purchased	+	Existing
	-	Must be installed	+	Sophisticated networking
	+	No other traffic	-	Other traffic can interfere with monitoring
	+	Can be sized for monitoring	-	Monitoring traffic can interfere with operation
			-	Must be added if expansion needed
Data Logging Processor	-	Must be purchased	+	Existing
	-	Simple processor	+	Sophisticated processor
Data Logging Software	-	Must be purchased	+	Existing
	-	Simple sampling, conditioning, averaging	-	Often simple sampling, conditioning, averaging
	-	Predefined	-	Often predefined
	+	Appropriate for monitoring needs	-	Not defined for monitoring needs
			+	Can be sophisticated computation or calculation
Data Storage	-	Must be purchased	+	Existing
	-	Usually limited size	-	Sometimes must be supplemented
			+	Both short and long term
			-	Sometimes size limitations
Modem	-	Must be purchased	+	Existing
	+	Dedicated to researcher	-	Also used by operator, vendor

Table 1. Comparison of Dedicated and EMCS-based Monitoring

developed as an application by EMCS manufacturers, each EMCS model, and in fact, each site investigated has provided unique challenges. By investigating several manufacturers, and several different sites, we begin to discover generic issues and common limitations.

The cases we investigated included three college campuses in Texas, and an office building and a department store in California. Each case used a different brand of EMCS. The case studies are presented in detail in other publications (Flora et al., 1986; Heinemeier and Akbari, 1987; Heinemeier et al., 1991; and LeConiac et al., 1986). Here, we briefly summarize the steps that were required to initiate monitoring, the problems that were encountered, and the solutions to those problems. The primary goals of this paper are to evaluate the entire process of obtaining data from the sites, according to several different criteria, and to recommend changes that would enhance the usefulness of this technology.

EMCS MONITORING ADVANTAGES

Dedicated monitoring systems are the convention for energy performance monitoring. In order for EMCS-based monitoring to even be considered as an alternative, it must match the performance of dedicated monitoring. Assuming it's performance can be made to be comparable, it will have several advantages over dedicated monitoring, making it both more powerful and less expensive.

The most obvious advantage of EMCS monitoring is that it can make use of existing hardware and software. Many larger buildings currently have EMCSs installed; and, as the cost is coming down, EMCSs are more accessible to smaller buildings. Since dedicated monitoring can cost over $1500 per monitored point (see, for example, Claridge et al., 1991), monitoring can be a very expensive proposition. With EMCS monitoring, it is often possible to make use entirely of existing equipment, and to install absolutely no hardware. Since no protocols exist for building energy performance monitoring using an EMCS, each installation is a unique case, and time will have to be spent in learning how to use the existing capabilities and coordinating with building personnel. Time will also be required to ensure that the EMCS is capable of monitoring, and possibly for some reconfiguration. These time expenditures may represent the only costs involved. If EMCS monitoring becomes more routinely applied, and EMCS manufacturers begin designing their systems with remote monitoring in mind, the time and costs involved will be greatly reduced.

Another advantage 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 data logger, and the cost of hardwiring the connections from the sensors to the logger. With an EMCS, however, many points of interest are already monitored in order to control the building, and the network connecting the sensors to the data storage medium is already in place.

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 cooling load or of heat recovery energy savings from flowrates and temperatures, and different kinds of averaging.

With access to several types of data, different types of analysis will also be possible. For example, the EMCS might match equipment hourly runtime with hourly energy consumption to obtain a more accurate representation of energy consumption during equipment operation. Or the status of motion detectors might be aggregated across the building, and used to automatically normalize energy consumption for occupancy.

If a utility can connect to a customer's EMCS to perform monitoring, a vital communication link has been established. Since EMCSs include control as well as monitoring capabilities, this link can eventually be used as a more generalized, two-way communications path. Communications sent between the customer and the utility could include things such as consumption data for billing, troubleshooting, or system operation purposes; requests for customer service; fluctuating prices; interruption notifications; or an electronic newsletter. Monitoring could be just the first step in initiating such a communications path.

Before any of these advantages can be realized, however, the process of configuring existing EMCSs to collect energy performance data and remotely connecting with the EMCS to retrieve the data must be more thoroughly investigated. Once the obstacles to these processes have been removed, the EMCS can become a rich and powerful monitoring tool.

STEPS IN EMCS MONITORING

Dedicated monitoring consists of four steps: measurement, storage, access, and processing. These same steps are used in EMCS monitoring, although they are somewhat altered since the monitoring equipment belongs to the building personnel and must primarily serve their needs.

Data Measurement

EMCSs monitor a variety of control points within a building. To do so, an EMCS is equipped with a large number of sensors. In most cases, these sensors are very similar to those used in dedicated monitoring projects, and can include power transducers or pulse-counting energy meters, as well as temperature, pressure, and humidity sensors (see Table 2). An important figure, used to indicate the size or complexity of an EMCS, is the number of installed points. The term "points" refers to inputs (sensors and meters), outputs (actuators, for example damper motors and valves), and intermediate values (for example setpoints).

Point	Temp.	Energy	Flow or Press.	Valve or Damper Position	Setpt.	Status
Each AHU:						
Cold Deck	•			•	•	
Hot Deck	•			•	•	
Precool	•		•		•	
Preheat	•		•		•	
Supply Air	•			•	•	
Return Air	•			•	•	
Mixed Air	•			•	•	
Supply Fan			•			•
Return Fan						•
Zone(s)	•			•	•	
Whole Building:						
Electrical		•				
CW Supply	•	•	•	•	•	
CW Return	•					
CW Delta T	•					
CW Pump						•
HW Supply	•	•	•	•	•	
HW Pump						•
Reheat Supply	•			•	•	
Reheat Return	•					
Reheat Pump						•
DHW Supply	•					
DHW Return	•					
Condensate	•					•
Exhaust Fan						•
Outside Air	•		•			

Table 2. Typical Data Measured By An EMCS

The primary objectives for installing an EMCS are to facilitate better control and simplify day-to-day operation of the building, as well as to minimize energy consumption. Sensors are added to meet the building's objectives, and not a monitoring project's objectives. Hence, while certain variables such as whole-building energy consumption may usually be measured, end-use submetered consumption typically is not. Existing sensors may not be of sufficient accuracy or reliability for the monitoring project's needs. Also, the sensors cannot be easily calibrated or verified by the researchers. Depending on the needs of the monitoring project, it is possible that the project can entirely make use of existing sensors, and require no installation of sensors.

Data Storage

Data collected for immediate use in control applications, (for example in a calculation to determine if more cooling is required), can be either sampled or averaged, and then stored for further analysis. Stored data can be used to determine, for example, how temperatures in a certain zone have fluctuated over the past day, or how energy consumption has changed over the past year. 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." Trended data are stored and presented in a way that was determined by the manufacturer to be the most useful for building operators in running their facilities, not for building researchers; so the format may be somewhat less appropriate for the latter.

Trended data can be stored in several locations in the EMCS. Many EMCSs now 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. The storage medium, the absolute number of points that can be trended, and the number of samples that can be stored for each point vary quite a bit among different EMCSs, although in most cases the hardware capacity is sufficient for remote monitoring needs.

Data Access

EMCSs are usually designed to present trended data in a graphical format or in a numerical report format. The EMCS operator can either look at the data report on the screen of the EMCS computer, print the data to a printer, or write the data to a computer file in order to later read it into another program, such as a spreadsheet or database program.

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 communicating over commercial telephone lines. This remote computer is used to allow operators to check in on the system and control it from another location, or for vendors to troubleshoot problems from their office. Most EMCSs include the required hardware and software for communications, and have a telephone line dedicated to the EMCS use, and these can usually be used by monitoring projects, so long as these monitoring activities do not tie up the equipment when it is needed for other tasks.

Researchers can then use a personal computer to dial up and connect to the EMCS's modem. Most commercial communications program could be used to make this connection. There are then two ways of transferring data: displaying a report on the remote computer's screen, or downloading the data file. In the first method, one uses the remote computer to log onto the EMCS system just as any other user, 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 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. Both procedures could be automated using a script file to watch for certain prompts coming from the EMCS, and to output the proper responses.

Data Processing

Even with dedicated monitoring, some data processing is necessary, in order to translate data from different sources into a common format. In the case of EMCS monitoring, the relevant data are usually embedded in a lengthy text report, and the log files have to be processed to create data files.

EVALUATION OF CASE STUDIES

The key characteristics of each of the case study sites and the findings from our investigations are summarized in Table 3. We were able to obtain data from all five case-study sites, and we have analyzed some of these data to learn about how the sites consumed energy. (For example, the temperature dependency of the hourly energy consumption data from Site D, shown in Figure 1, indicates two different modes of operation. For more detail on data analysis, see, for example, Heinemeier and Akbari, 1987.)

Each site required a slightly different method of retrieval, and none of the systems can be said to be ideal for monitoring, although each had promise. Each system had its advantages and disadvantages. The systems are compared in this section, according to several criteria. One should note that in some cases, limitations are due to the EMCS model itself, while in other cases they are due to unimplemented but available options, or other site-specific characteristics. Almost all limitations are the result of the fact that the systems were not designed specifically with remote monitoring in mind, and could be overcome with minor software changes by the manufacturer.

Accurate Data

Determining the accuracy of the sensors is very important in a monitoring project. Since, essentially, 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 selected by the EMCS specifier, in order to be adequate for control of the building, and the accuracy required for monitoring may or may not correspond with that required for control. The key issue is that the accuracy of the sensors is not under the control of the researcher. The miscalibration of the demand meter at Site D points out the importance of calibrating sensors, or, at least, comparing 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 that which is known to provide false values. This issue of sensor accuracy is quite important, and should be further investigated.

Data Averaging

Beyond measuring the appropriate variables, an important consideration in EMCS monitoring is how the values are stored. For example, at Site C, electricity consumption pulses were constantly totalized to provide a cumulative value. At Sites D and E, the power was averaged over some interval of time. Either of these methods would be sufficient to provide the necessary hourly consumption data. At Sites A and B, however, only "instantaneous" values of power were recorded, which would be quite inaccurate for reporting hourly energy use. In addition, the pulse rate on the energy meter at Site A was too slow to provide very short term data accurately. The EMCS at Site A did have a facility for totalizing values, but it could not easily be integrated with hourly trending. The EMCS at Site D provided information on the performance of the building from yearly to one-minute intervals. All of these intervals are useful, and it is often difficult to obtain both detailed and aggregated data in the same system. Other systems where data storage is a problem might benefit from this method of storage.

Trend Capacity

All of the sites had sufficient trending capacity, at least in theory. In practice, however, both Sites A and C were limited by communication considerations. Both of these sites had several different ways of collecting data, due to the distributed architecture of the EMCSs. These sites indicated that 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. The EMCS at Site D only reported hourly data for the previous day, making it necessary to download data daily. The storage of a year of short-interval demand and temperature data (15-minute) in the the EMCS at Site E made daily or even weekly downloading unnecessary, allowing more flexibility in deciding when to download data. The potential to download demand and temperatures for a number of stores in one access would make this EMCS a convenient monitoring tool, because all the data are in the same format, and time would be saved in accessing the systems and analyzing the data.

Hourly Data, Recorded on the Hour

In order to be compatible with data from other monitoring projects and other buildings within this project, and with weather data, the data available from an EMCS should be reported at the top of each hour. The EMCSs at Sites A and D were capable of doing this reliably. The EMCS at Site E produced 15-minute data, which could easily be aggregated to provide hourly data. The EMCS at Site B could theoretically record data at the top of each hour, although if the system is rebooted, it would not begin collecting at

Site A--see Heinemeier et al., 1991

- A university campus in Texas, with 46 buildings. The EMCS was connected to over 2000 points. All of the buildings were on a central utility electricity meter, and steam and chilled water were circulated to each building from a central plant. The EMCS had a whole-building electric meter and temperature and flow sensors to calculate heating Btu/hour and cooling tons, for each building.
- In Host trending, the absolute limit was 200 points, and 3000 samples per point. In RCU trending, the absolute limit was 400 points, and 64 samples per point. Data could be uploaded to the host automatically. Communications paths in this system were fairly loaded, so the real limitation on data storage was due to communications constraints.
- It was only possible to obtain samples of power data, not averages of energy data, and the data were very inaccurate. One could specify the time for trending to begin, and if the host lost power and restarted, it resumed trending normally; so it was possible to collect data at the top of the hour.
- Remote access was difficult. Trend data could be stored in a disk file, or printed to a printer. However, the disk file could not be automatically transferred to our computer, and the trend data could not be displayed on the screen. The access problem was solved by configuring remote computers to act like printers.
- The trend log file was fairly straightforward to process. Ten datapoints per line had to be time- and date-stamped.

Site B--see Heinemeier et al., 1991

- A large medical research building in Texas, about 811,000 ft^2. The EMCS had 1800-2000 points. The building was split into four mechanical "pods", with one central plant. Each pod had an electric meter and temperature and flow sensors to calculate heating Btu/hour and cooling tons. Weather sensors and condensate meter points were added.
- Data-logging software was installed to allow trending of 999 points. Most data are instantaneous samples, not hourly averages, Data collection begins as soon as the trend points are initialized, which may or may not fall at the top of the hour. If the host lost power and restarted, data collection restarted immediately, not necessarily at the top of the hour.
- Remote access was difficult. Trend data could be stored in a disk file, or printed to a printer. However, the disk file could not be automatically transferred to our computer, and the trend data could not be displayed on the screen. Our solution was to store the data to disk files, and have the EMCS operators move the data files to another computer, and send them electronically via mainframe network. This transfer had a very high transmission rate, and a very high reliability (error checking and correction). However, a human step was unavoidable.
- The files were stored in DIF format. A spreadsheet program was used to translate to a text format. Once in text format, headers and unnecessary information were removed. Some points were reported as accumulating values, so processing included subtracting one value from the next to calculate the hourly change.

Site C--see Heinemeier et al., 1991

- A large medical research center in Texas. The EMCS had nearly 6000 connected points. All of the buildings were on a central utility electricity meter, and steam and chilled water are circulated to each building from a central plant. The EMCS had one or two electric meters, and temperature sensors on steam and chilled water lines in each building. However, there were no flow sensors to calculate heating Btu/hour and cooling tons.
- Host trending was capable of recording data for 50 variables. Data were originally acquired by the RCU, but were then immediately transmitted over the local network to be stored by the host computer. Few of the available trend points were being used at the site, so trend capacity was not a problem. Remote trending was similar to trending, except that the data were stored in the local memory of the RCU, and transferred to the host computer upon request. The limitation on the amount of data collected came from the amount of memory available on the RCU. Archiving resembled Host trending, except data were moved to a more permanent disk file once a day. Only this permanent file could be accessed.

Site C--continued

- The data reports were defined for a 132-column printer, but the EMCS could display only 80 columns on the screen. Therefore, several columns were truncated and their data were not accessible. Error checking was not possible. Complex user interaction was required, suggesting that automation would be difficult.
- The EMCS used COV (change of value) trending, where the system collected a piece of data only when its value has changed--for example, the time and cumulative energy consumption are recorded when 300 kWh have been consumed. The data had to be translated to an hourly format. Depending on the COV level, this can introduce error.
- The EMCS did not send carriage returns at the end of each line. The log file, then, often consisted of several very long lines. The EMCS display included a status line, which was written to the log file whenever the status line was refreshed. Data were not reported in a straightforward columnar format. One could determine the identity of a value only by where it occurred on the line (see Figure 3).

Site D--see Heinemeier and Akbari, 1987

- A five building complex with over a million ft^2 of offices, restaurants, banks, and computer facilities, located in San Francisco CA. The EMCS had about 400 points. Energy data available in this EMCS included both whole-building demand, and demand submetered into "Central" and "Outlet".
- The computer had access to three disk drives, two of which were used for control, and one to store data. Data storage capacity was not a limiting factor in this EMCS.
- Data were averaged over several different intervals: one could obtain the last 10 minutes of 1-minute data, hour of 5-minute data, day of hourly data, month of daily data, or year of monthly data. Because only the most recent day of hourly data were available, we downloaded hourly data once a day. We automated the data access procedure.
- The EMCS-monitored data differed from utility-bill data by a factor of two. We discovered that the calibration factor on the pulse initiator was incorrect by a factor of two.

Site E--see Flora et al., 1986; Heinemeier and Akbari, 1987; and LeConiac et al., 1986.

- A department store chain on the West Coast. We focussed on one 226,000 ft^2 store near Los Angeles CA. A host computer communicated over phone lines with local computers in each store. Each building was controlled separately but schedules and set points could be changed by the host computer. The monitored data included whole-building demand data and outdoor air temperature.
- The local EMCS averaged data at 15-minute intervals. The 15-minute data were logged for 24 hours, then the host computer downloaded the data from each store to a disk once a day and stored them for a year. The host computer also stored the monthly electrical consumption and peak demand for all stores for about three years. Data had to be retrieved one day at a time, which was slow. We used a script file to automate the data access procedure.
- To look at the most recent data, we called the store's host computer, and the host computer called to interrogate the local RCU. This process used both of the host computer's phone lines, and the host was then unable to communicate with any of the stores for control functions.

Table 3. Findings From EMCS Monitoring Case Studies

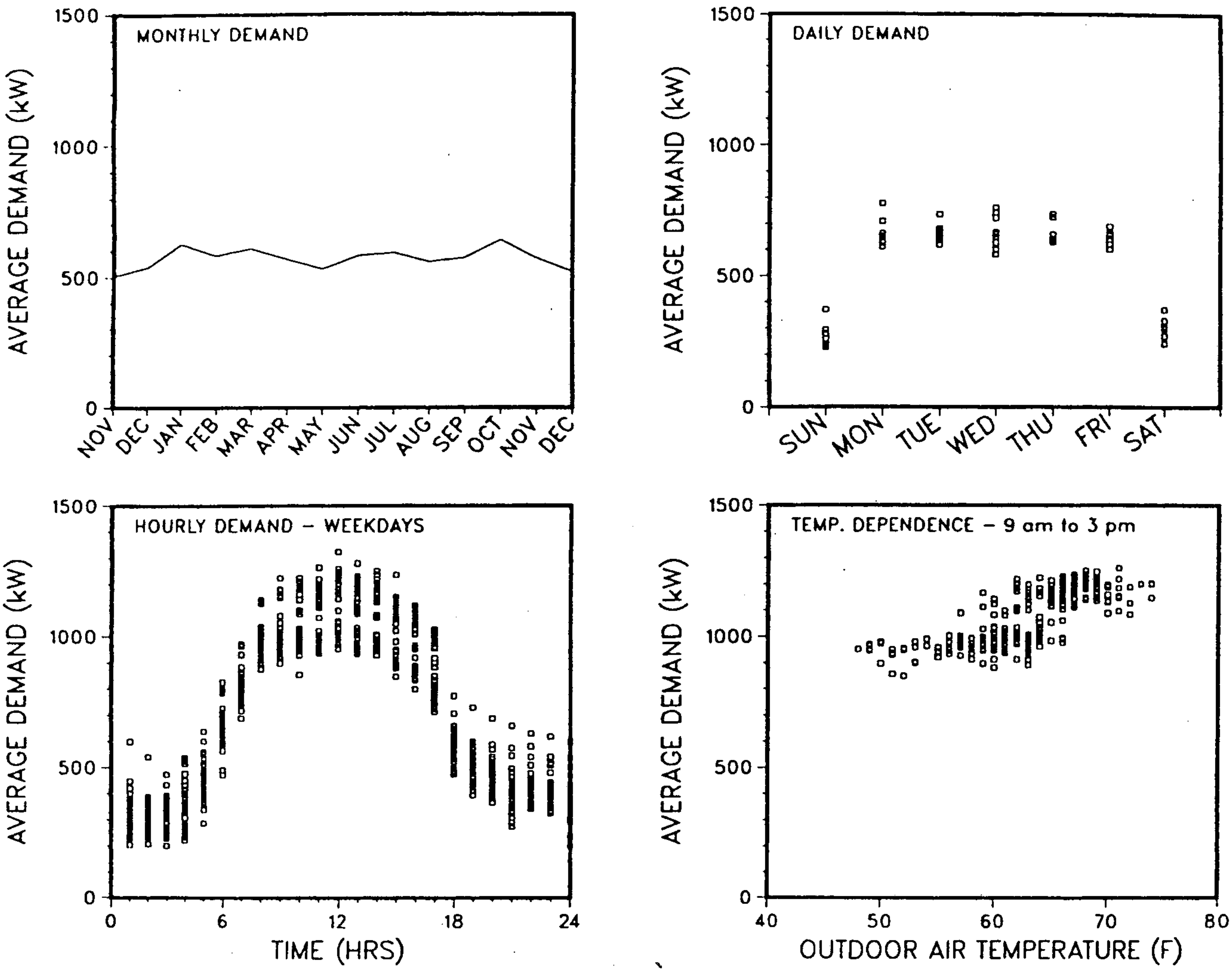

Figure 1. Data Collected From Site D

the correct times, so it could be considered unreliable in this sense. The EMCS at Site C provided data by change of value (COV) rather than on an hourly schedule. The data could be processed to provide hourly data values at the top of the hour. If the COV level is set correctly, little error should be introduced by doing this. COV trending has both advantages and disadvantages, so an EMCS should allow the user to select which form of trending to use for each variable. More recent versions of the EMCS model used at Site C do allow for this facility.

Easily Automated Access

When performing case studies, it is not a problem to manually log onto an EMCS to download data. However, in a larger-scale evaluation project, a more automated method of data retrieval must be used. Most communications software packages allow the user to create a script file, which can automatically dial the phone, watch for prompts coming from the EMCS, issue the appropriate responses, and log the session. The EMCS at Site A was very well suited to this form of automation. After dialing the phone, the script file had only to provide the correct login name, and then issue one-line commands to request the data (see Figure 2, where responses that must be provided are shown in larger type). Interactions with the EMCS at Site C, on the other hand, were more complex. A whole series of questions were asked, and responses had to be provided to request the data (see Figure 3). This could be automated, although it was significantly more complex than at Site A. At Site B, the EMCS operator manually copied the data from one computer to another and then transmitted it over a mainframe network. Since this involved a human step, it cannot be considered automated. From the monitoring end, however, the network file transfer procedure could be easily automated. Data collection from both Sites D and E was automated with a script file. Although, in each case, the transaction with the EMCS was slightly more complicated than Site A, no problems occurred with the process.

Short Transfer Time

The amount of time required for transmission of the data is also an important consideration. 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 the conciseness of the report format, and on whether or not the report is generated as it is being displayed. The data from Site A were in a very compact form. The data from Site C were in a much bulkier report format, which was generated as it was displayed; thus it took quite a bit

```
LOG-IN : XXXX
O,SUM,TRD,VAL,43
O,SUM,TRD,VAL,43,HC4
EXE/IGN (E/I) E (RET)

SYSTEM INFORMATION - TREND VALUE SUMMARY    PGM DAY 5  THU   8 AUG 1991 12:41:02  PAGE:    1

POINT NUMBER :  43                                                          SAMPLE STATUS : BEG
POINT ID     :  H  LIB  - JB COLEMAN     BLG - BUILDING    TON - CHW TONNAGE   SAMPLE RATE   :  1 HR
SAMPLE #     BEGIN TIME : 11:00  ON   8/05/91           END TIME : _____  ON  ______   LAST SAMPLE   :  74
```

SAMPLE #										
1- 10	213.20	188.30	213.50	OFFLINE	186.90	191.20	200.50	182.90	213.80	180.60
11- 20	164.80	165.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21- 30	418.00	OFFLINE	172.00	184.00	190.10	188.70	193.40	150.80	179.40	164.40
31- 40	161.80	169.30	181.70	146.40	182.70	196.20	0.00	0.00	0.00	0.00
41- 50	0.00	0.00	0.00	0.00	254.10	177.50	174.00	172.30	171.50	168.80
51- 60	176.80	181.90	162.20	166.70	180.20	166.70	181.70	143.00	158.70	157.60
61- 70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	262.10	132.50
71- 80	159.00	145.20	154.60	172.20						

```
...END...
QUIT
```

Figure 2. Log File With Data Collected From Site A

```
NAME: ENERGY
PASSWORD: XXXXX

ARCH
SYNTAX ACCEPTED

SYSTEM 600 ARCHIVE PACKAGE
MAIN MENU
1> POINT REPORTS
2> MESSAGE REPORTS
3> DATABASE MAINTENANCE
4> ARCHIVE OPERATIONS
ENTER SELECTION [1-4,Q,H=HELP]..: _1

POINT REPORTS MENU
1> DETAILED VALUES
2> AVERAGE, HIGH, LOW VALUES
3> PERIODIC SAMPLES
4> LONG TERM
ENTER SELECTION [1-4,Q]..:.1

** DETAILED POINT REPORT MENU **
1) MULTIPLE POINTS, DATE AND TIME RANGE
2) ONE POINT, MULTIPLE DATES, TIME RANGE WITHIN DATE
3) MULTIPLE POINTS, MULTIPLE DATES, TIME RANGE WITHIN DATE
ENTER SELECTION [1-3,Q]...: 2
DESTINATION [D,R,P,Q].....: D
GROUP NAME, "<RET>" = NONE: (RET).

DETAILED POINT REPORT FORM...
POINT NAME: GEM2KW
BEGINNING TIME: 0000
ENDING TIME: 2400
DATE
1) 09JAN91
2) 10JAN91
3) 11JAN91
4) 12JAN91
5) ______
6) ______
7) ______
8) ______
9) ______
10) ______
ARE YOU DONE? [Y/N]...: Y
CORRECT? [Y,N,Q]..: .Y

ARCHIVE REPORT INITIATED - COLLECTING DATA
```

TIME	GEM2KW 9-JAN-91	GEM2KW 10-JAN-91	GEM2KW 11-JAN-91	GEM2KW 12-JAN-91
0:50:16				41136.6
1:09:49			37902.3	
1:15:48	23329.5			
2:13:08		34667.9		
4:18:47				41460.1
4:26:12			38225.7	
4:38:53	23653.5			
5:44:54		34991.3		
7:26:45			38549.1	
7:38:21	23977.5			
7:39:54				41783.5
8:21:39		35314.8		
9:21:12			38872.6	
9:28:41	24301.6			
10:08:00		35638.2		
10:30:27				42106.9
10:30:27				42106.9
11:01:15			39196.0	
11:01:15			39196.0	
11:06:11	24625.6			
11:46:32		35961.6		
11:46:32		35961.6		
12:41:25			39519.4	
13:05:01				42430.4
13:26:27		36285.1		
14:21:11			39842.9	
15:03:47		36608.5		
15:33:20	XXXXXXXXX			
15:33:20	33375.2			
15:51:03				42753.8
16:04:18			40166.3	
16:47:03		36931.9		
17:20:02	33697.6			
18:18:37			40489.8	
18:46:26				43077.3
19:02:47		37255.4		
19:42:13	34021.0			
21:20:36			40813.2	
21:56:38		37578.8		
22:01:33				43400.7
22:46:35	34344.4			

```
END OF REPORT
ARCHIVE REPORT COMPLETED
BYE
```

Figure 3. Log File With Data Collected From Site C

longer to transmit. The data from Site B were in Data Interchange Format (DIF), which is very bulky. However, the transmission from Site B took place over a mainframe network at a very high transmission rate. Since the data from Site E were at 15-minute, rather than hourly intervals, there were more data to transfer. Combined with the low transmission rate, it was a very slow process.

Error Checking

Errors can occur, not only due to faulty or inaccurate sensors, but also when transmitting data from the site. In all sites except Site B, data were displayed on our computer screen, and simultaneously stored in a log file. No form of error checking took place, and any noise in the phone lines could obliterate data, or change values. At Site B, the data were transmitted over a computer network, using a standardized file transfer protocol—FTP. This protocol includes both error checking and correction, so transfer was quite reliable.

No Interference with Operation

With current systems, there is a potential for energy monitoring to interfere with EMCS control operations, and for control operations to interfere with energy monitoring. At Site E, there was a conflict when we used EMCS phone lines to interrogate remote stores. An additional phone line and modem in the host computer would have allowed us to access the system more often and for longer periods. It is best to have one phone line that is not needed for control, because it is essential that outside monitoring not interfere with control. There was also a potential for problems at Site A. Once the system was reconfigured to recognize dial-ins as printers, *all* dial-ins were recognized as printers, including operators calling in from home to check on the system, or the regional office calling in to troubleshoot problems. Apparently, this was not a severe problem as there was very little that could not be done with the computer configured as a printer, although the interface was less user-friendly.

Easily Processed

Data should be transferred in an easily processed format. The data from Sites B, D, and E were reported in an acceptable format, and only minor processing had to be done, such as parsing the date into day, month, and year; and subtracting cumulative values to obtain hourly values. With the system at Site A, the log file included a command line, a header, and lines of data samples for each point (see, again, Figure 2). The headers had to be removed, a time stamp for each sample had to be calculated, and the data had to be put in columnar form. Data from Site C required quite a bit of sophisticated processing, due to several factors: only 80 out of 132 columns of data were displayed, carriage returns were not transmitted, a status line appeared in the middle of the data at any time, the data were not in conventional columnar format, and the data were in COV rather than hourly format (see Figure 3). All of these could be dealt with, but when taken together, made data collection rather cumbersome.

No Additional Hardware Required

Aside from a few supplemental sensors at Site B, ***no hardware was added at any of the sites.*** Monitoring would have been greatly facilitated at Sites A and C if a personal computer were added to the system. However, one of the key advantages of EMCS monitoring is that it is capable of making use of existing hardware. Most of the difficulties encountered in this project were related to easily remedied software problems, and few problems with existing EMCS hardware were encountered.

No Software Modifications Required

No major software modifications were made at any of the sites. Site C required no reconfiguration, Site A required a minor configuration change, and a readily available software module was purchased for Site B. However, for all sites relatively minor changes to the software would have greatly facilitated monitoring. For Site A, the system had to be site-reconfigured. The site personnel did not have the expertise to do this, and it would have been much easier to set up monitoring if the software allowed the trend reports to be printed to the screen, or if it allowed the system to have more than one type of dial-in computer. Site B also would benefit from being able to print the data to the screen. Site C would require the least-significant modifications, including the ability to store data by hour as well as by COV (their more recent models do allow this), and a more streamlined report procedure. All the sites would benefit from being able to transfer a disk file using a file transfer protocol, such as FTP or Kermit.

CONCLUSIONS

EMCSs can be used for monitoring energy performance. It is possible to gain access to a wealth of information on building operation without installing any software or hardware. However, due to the absence of protocols for this type of monitoring, and the fact that EMCSs are not designed with remote energy monitoring in mind, currently each site may present unique problems and require unique solutions.

Relatively minor modifications to the available EMCS software could greatly improve this method of collecting data. In particular, EMCS software should be modified to:

- allow data to be averaged over an hourly interval;
- reliably report data at the end of each hour;
- create concise and consistent formats for requesting data;
- create concise and consistent formats for reporting data; and
- 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 technology, a system designed with energy performance monitoring in mind would probably have some fundamental differences. For example, the simplest 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 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.

Several parties would benefit if the applicability of EMCSs for energy performance monitoring were further developed. Building owners and operators would benefit by the 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. Utilities would benefit from more cost-effective conservation programs, resulting, in many cases, in increased profits. They could benefit from the potential for two-way communication with customers that can emerge from this technology. If major conservation programs were to require that whenever an EMCS is specified as a conservation measure, it should be used for monitoring and, to do so, it must meet some minimal monitoring specifications, then controls manufacturers that offer standardized monitoring would also benefit. In fact, controls manufacturers may be in an ideal position to perform conservation evaluation themselves. 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.

Before all of these benefits can be realized, some standardization must take place and specifications must be defined. With funding from the federal Department of Energy and a large monitoring project, we are now working on identifying and outlining such specifications.

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LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
TECHNICAL INFORMATION DEPARTMENT
BERKELEY, CALIFORNIA 94720