

# Meaningful Ways To Interpret Building Data

Building automation systems offer all types of useful data for facility managers and operators, as well as building designers. The challenge is to find more ways to quickly, accurately, and meaningfully interpret the information.

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**O**ur buildings are talking, and we should be listening. We are awash in data and the capabilities to collect, transmit, and store it. If we can find more ways to quickly, accurately, and cost effectively translate all of this information, we stand to achieve many benefits. These include (but are not limited to) increased energy cost savings, decreased failure of components and related alarm incidents, increased occupant comfort and productivity, and more efficient use of maintenance personnel and operations resources.

Consider the following facts about today's building control technologies:

- Control systems are more powerful and a new generation of users is moving in to take advantage of them. New protocols and standardization practices help to make data easier to share within and across platforms.

**We need a short bio of the author.**



- Data acquisition systems capable of capturing short-term data are more prevalent, powerful, and economical than ever.

- Sensors commonly used in HVAC-based control systems cost less and are more powerful and accurate than ever. Prices for accurate controllers (those with

A/D and D/A conversions of 10 bit and higher) are dropping and their use is becoming more prevalent.

- New metering technologies—including those for power, air flow, liquid flow, and thermal energy—are available, affordable, easy to implement, and increas-

ingly reliable and accurate.

• Communications capabilities—such as the Internet, World Wide Web, e-mail, instant messaging, and two-way wireless technologies—allow for real-time transmittal of facility data to those who need it.

Facility managers receive plenty of data in the form of beautiful formats and graphic representations. However, they often complain that they lack the resources to determine what it actually means, and most importantly, what they should do about it. This isn't surprising, considering the shortage of qualified people with the necessary skills to provide these analyses. How many engineers and technicians

have a working background in HVAC applications, facility operations, control systems design and implementation (for products available from over 20 different vendors), and the ability to rapidly look through data from multiple systems and find problems at both the whole-building performance and individual component levels?

### REMOTE MONITORING AND CONTROL SERVICES

In the 1990s, various types of energy information service providers emerged. While these companies offered certain valuable services, their abilities were often limited and they rarely used information garnered from building automation systems.

Today, as communications means have increased, data collection and interpretation has become more sophisticated. As a result, Remote Monitoring and

Control Service (RMCS) centers have emerged to provide centralized monitoring and control of multiple facilities' BAS'. In most cases, RMCS centers are staffed around-the-clock with engineers and technicians who monitor buildings remotely, with a primary focus on alarms and exceptions. These providers are in effect "extensions" of facilities staff, and their contracts often include

with multiple buildings, multiple systems, and real-time alarms. These people face the same challenges as in-house O and M staff—they are responding to alarms and emergencies and do not have the tools or time to analyze long-term system behavior or concern themselves with working systems that may be performing sub-optimally.



### BEYOND ALARMS: AUTOMATED FAULT DETECTION AND DIAGNOSTICS (FDD)

There is no standard nomenclature yet regarding the term "diagnostics" as it relates to control systems. For the purposes of this article, the

a repair service function in response to alarms.

The RMCS business model has advanced primarily in response to the increasing number of BAS' installed in small to mid-sized facilities, as well as to the downsizing of facilities maintenance staffs. It is most commonly used for mid-sized facilities where it is not cost-effective to provide a full maintenance staff trained to commonly interact with the BAS.

The RMCS business model appears to be robust and as operations and maintenance (O and M) staff downsizing becomes more prevalent, remote monitoring and control services may be well positioned to expand to larger facilities, merging in some cases with the more traditional contract maintenance operations already in place. However, one limitation to the RMCS model is that individuals work

term "alarm" refers to a real-time event or condition within the control system that is detected by simple exception logic, such as exceeding a preset parameter, or is triggered by a system component failure.

Alarms require immediate attention by the user and typically offer no diagnostic suggestions as to what the proper course of action might be. A common alarm example might be a zone temperature that has exceeded an acceptable value and has enunciated the "too hot" temperature and the alarm message at the work station. Many systems can be programmed to take certain courses of action for each type of alarm, such as dialing out to a pager and shutting down related equipment or systems.

While real-time alarms are a necessary feature in modern control systems, there are a vast number of other useful messages

hidden in the data flying around our buildings that can be tapped. If properly detected—by either humans performing manual analysis of data or by automated means such as a computer-based analysis—these messages can result in many benefits such as those listed in the beginning of this article (increased cost savings, less failures, better occupant comfort and productivity, better use of resources, etc.).

These messages, herein referred to as anomalies, are the focus of increased interest and research in our industry and could well be the key to unleashing a new era of efficient and lower life-cycle cost facility operation—once they can be detected and reported automatically. This area of research is most often referred to as Fault Detection and Diagnostics (FDD), and consists of a wide variety of approaches and technologies.<sup>1</sup> Those interested in automated FDD development include equipment manufacturers, controls vendors, government laboratories and researchers, industry associations, and private sector firms interested in developing analytical software capabilities and/or using these capabilities to serve their clients.

The computer is the ideal tool to implement automated FDD. It can analyze many systems quickly and consistently and over long periods of time, providing a form of “continuous commissioning.” It can track and account for long-term changes or degradations in performance and find short-term or transient problems that could otherwise go undetected under the manual scrutiny of even the best engineers. This enables human and financial resources to be freed up, so they can focus on implementing solutions to the problems the computers detect.

Once a computational platform is developed for handling

the large amounts of data and performing the analyses, the numbers of diagnostics that can be run against the data sets are limited only by the imaginations of the technicians and engineers coding them in.

#### APPROACHES TO AUTOMATED FDD

If alarms are considered the “tip of the iceberg” in terms of facility performance and control problems, anomalies represent the larger underlying structure from which alarm faults ultimately arise. The key then is to find ways to diagnose the performance of the building systems over time and determine the problems plaguing system performance. Another way to look at it is that alarms represent acute problems—emergencies that have gone too far and need to be identified and corrected immediately—while anomalies are the chronic problems that persist over a long period of time and keep a facility from performing up to its full potential.

There are a number of approaches and schools of thought being taken by those developing and deploying FDD software. Two of the key differences are:

1. Real-time versus historical analysis.
2. Using existing BAS data versus requiring independently acquired data from stand-alone data acquisition equipment.

On the first point, my opinion is that when alarms are detected and reported within the functionality of the BAS (as is currently the case with virtually all direct digital control [DDC] systems being installed today), FDD methods to identify chronic system performance problems can (and should) be done historically. Further, the amount of anomalies that are typically generated by an FDD analysis can result in quite a few work items that—in most real-world instances—would not be performed at the time of diagnosis anyway. In short, my thought is keep acute problems

(alarms) real-time, and let chronic problems (anomalies) be performed, weekly, monthly, or at whatever interval best suits the client's needs.

Regarding the source of data, there are a number of cost and performance issues to consider,<sup>1</sup> but I think the relatively low cost of mining BAS data, coupled with the technology facts listed in the beginning of this article, makes BAS data too valuable to pass over and getting better all the time. Consider also that FDD software/services that use BAS are generating over an 80 percent success rate identifying anomalies.

This is not to say that there is any inherent problem with using data captured by independent metering or data logging equipment, just that in most applications this level of independence is not worth the increased cost. One caveat: Many BAS designs (particularly older installations) can be somewhat “point-shy,” requiring the addition of a few more data points used solely for diagnostics. When there is not room to add these points within the system, short-term, independently gathered data might be cost effective. More information about these viewpoints may be found on-line.<sup>2</sup>

#### REALIZING THE FULL POWER OF BAS FOR FACILITY DESIGN AND M AND V

The potential economic, energy, and environmental impacts of widespread application of automated FDD on our facilities will be significant and cannot be denied. But the BAS has yet further information to offer beyond the diagnostic capabilities discussed above. With appropriate analysis and software tools (and perhaps the addition of a few additional diagnostics and/or metering points in the control system), BAS data can be used as a measurement and verification (M and V) tool and/or as a design and performance characterization tool to track and document



facility performance parameters for the facilities design, management, and O and M staffs. Consider the following examples of ways that BAS analysis software is currently being used in addition to automated FDD:

**BAS Data as a Design Feedback Tool.** Software tools using BAS-based data can provide design engineers and planners with in situ data on actual loads for facility expansions or redesigns. Frequently, invalid design assumptions and rules-of-thumb are applied to renovations of a new facility. For example, designers frequently assume that the chilled water temperature difference experienced by the system is the same as what the coils were designed for (typically around 12 F). Upon analysis, BAS data typically show that the actual temperature difference is much lower. This leads to less than optimum chiller and pump selection, which translates into operational problems. Even if the facility performance data is recorded in some fashion, it is typically so cumbersome to ex-

tract from the BAS that it is usually not readily available to designers or is ignored.

**BAS Data as an M and V Tool.** Software that uses BAS data can facilitate M and V analyses. Some M and V approaches require savings payments based on “microscopic” calculations relating to the use of a specific component, as opposed to the “macroscopic” comparison of the energy bills to a baseline. Software tools can support both approaches. Software can process the data and specifically report the savings based on actual data compared to the baseline. “Actual” data can be actual recorded consumption, or calculated consumption based on a components part-load characteristic or an empirical relation. We refer to these as “virtual meters.” A typical example could include the use of an equation to relate a variable inlet vane’s percentage output to develop a virtual meter representing the fan’s power draw (in kW).

With sufficient baseline data, software can be used to create a baseline based on multi-dimen-

sional parameters. Any recorded parameter can be used as a “dimension.” For instance, a typical baseline can be created based on typical use at a particular time of day, on a particular type of day, and at a particular outside air condition. Once the baseline is created, the software recreates what the energy would have been with baseline conditions, calculates the savings, and summarizes the findings in a report.

#### WHO CAN BENEFIT FROM INCREASED USE OF BAS DATA?

**Facility Managers.** Software tools using BAS-based data can provide facility managers with evidence of optimally efficient operation by providing a consistent “yardstick” by which to gauge facility performance over time. Parameters of interest to the facilities’ tenants, including adequate ventilation and comfort parameters, can also be tracked and documented. Data-based software tools can provide this and other management information in concise summaries.

RMCS and Energy Service Providers (ESPs). These firms usually have a financial interest in making sure their clients' facilities are operated optimally. Frequently, energy measures are disabled or bypassed by local O and M staff members due to temporary requirements or misdiagnosed problems. Even if the disables are justified for temporary conditions, they are often left disabled. With automated FDD and/or M and V software, BAS data can be set up to warn the RMCS of inefficient operation or warn the ESP when the energy performance measures are not being applied optimally. BAS data can be a low-cost source for detailed M and V information to both ESPs and their clients and can be used as the contract vehicle for determining facility performance and tracking savings.

Energy Managers. All functions discussed in this article—from automated diagnostics to M and V and facility performance characterization—are of use to energy managers. Energy managers often complain that efficient operation has been overridden or otherwise compromised in the field by O and M staff members, who are often under separate internal management. Automated diagnostics and analysis can bring the O and M staff together with the energy staff by providing a common and cost-effective way to ensure efficient operation. Energy managers typically find out from a bill analysis or meter data at the end of the month that an energy waste has developed. They then have to figure out why it occurred. In many cases, this will involve manually pouring through BAS trend data, or extensively surveying the systems to find out what went wrong. Automated FDD software will not only identify the waste much earlier, but also should tell why it is occurring and suggest ways to remedy it.

Software can also provide energy managers with the metrics they need to prove that energy ef-

iciency goals are being met and are being maintained over time. Additionally, it can provide a basis for predicting facility responses to future weather conditions and utility price changes.

Engineers and Architects. Engineers and architects can benefit from the data used to control their clients' facilities by learning how the buildings are actually performing. Design engineers often complain about the guesswork and liability involved in design and how the need to design to ultra-conservative parameters can impede efficient performance.

Consider the following example of a recent planned facility expansion I was involved with. The client's facility planners requested a "watts per square foot" (W per sq ft) cooling requirement of 7 (designers are often presented with unrealistic and uncharacteristic internal cooling load design parameters in W per sq ft).

The client's O and M group was using software to perform automated FDD and track facility operating parameters, and was able to take data from the air-handling system and chiller plant to demonstrate that similar facilities currently in-place were not exceeding a total cooling load of more than 3 W per sq ft, even under design conditions representing a summer day.

As a result, the mechanical air-handling system was right-sized and a potential cooling project was cancelled. This resulted in a first-cost avoidance of \$700,000, in addition to the energy savings that resulted from the more efficient use of the chiller plant and the comfort savings resulting from a variable air volume (VAV) system designed to vary across its full range.

#### THE FUTURE: DO WE HAVE THE RESOURCES TO "FIX IT ALL?"

Note from Lisa Murton: Larry needs to write a brief concluding paragraph. Here is his original note:

"The next bottleneck: having the resources to execute the results of the analysis.... Also - could mention Kristin's work on operator issues - I have a different perspective I think - our clients find that the results we provide - "Valve A is leaking"; "Damper actuator B is unstable and hunting" are making their lives easier. I think the difference is that we are taking that final step and giving them the boiled-down result, not a bunch of plots and crap they have to figure out for themselves.)" NC

#### REFERENCES

- 1) Ivanovich, M. and P. Haves. October 1999. "Capturing and Using Building-Generated Data." *HPAC Engineering*.
- 2) Workshop on Building Diagnostics. 1999. Lawrence Berkeley National Laboratory Building Technologies Division. <http://poet.lbl.gov/diagworkshop/proceedings/>.