The Impact of Power Management on Building Performance and Energy Costs

by Mark A. Chidichimo and Aubrey Oates

Executive summary

Power quality and energy consumption are closely linked to overall building performance. Yet building managers often focus more on mechanical equipment operations. However, power problems are responsible for more than half of equipment downtime in most buildings. This paper reviews how adding power management to BMS capabilities can reduce energy costs and improve building performance while also enhancing occupant comfort.

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Introduction

Power and energy management systems have long been used in power critical applications like industry, data centers and hospitals. Advances in technology now make it easier to utilize such tools in commercial buildings, and at an affordable cost. The benefits of adding power and energy management systems functionality into existing Building Management Systems (BMS) include lower maintenance costs, reduced energy consumption, increased equipment life span, and higher occupant comfort and productivity.

Energy use is an obvious target for improvement in building environments: 42 percent of the world's energy is relegated to buildings.[1] By some estimates, most of that energy – anywhere from 54% to 71% – is consumed by the heating, cooling and lighting systems.[2]

In addition, there is growing evidence that environmental conditions inside a building have a significant effect on worker performance and customer satisfaction. Research by the World Green Building Council[3] finds that employee productivity increases by 11% from better ventilation, and by 23% from better lighting. A 4% reduction in employee performance in cooler temperatures and a 6% performance reduction in warmer temperatures have also been observed.

Most buildings have been outfitted with automated Building Management Systems (BMS) that allow for centralized monitoring and control of heating, cooling, and related ventilation systems. These systems provide building owners and facility managers with a comprehensive view of the mechanical system. However, many of building system managers do not leverage the potential of the system to monitor the electrical system as well.

Power problems are responsible for more than half of equipment downtime in most buildings.[4] This paper discusses how adding power management to BMS capabilities can reduce overall energy costs and improve performance of equipment and buildings, while also enhancing occupant comfort.

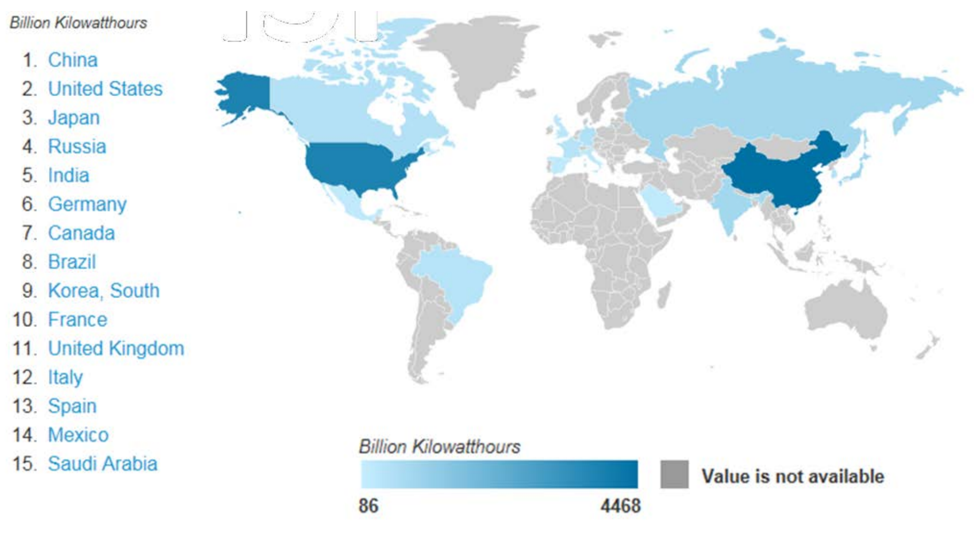

Figure 1
Global electricity net consumption (courtesy of US Energy Information Administration, 2012)

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[1] http://www.iea.org

[2] www.nationalgridus.com/non_html/shared_energyeff_office.pdf

[3] "The Business Case for Green Buildings" World Green Building Council, 2013 http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf

[4] J. Manson, R.Targosz, "European Power Quality Survey Report", Leonardo Energy, 2008.

Why power monitoring is relevant

Power monitoring is a fundamental enabler of reduced energy consumption and lower building CO_2 emissions. The monitoring technology can be applied to measurement of water, air, gas, electricity and steam (WAGES) usage. A monitoring strategy can employ a variety of measurement techniques and many types of measurement devices. Regardless of the specific monitoring strategy, the fundamental outputs include measurement, calculation, collection, display, and sharing of energy data. The information gathered is consolidated in order to make informed business decisions related to energy spend.

Most building operators engage in basic power monitoring, which analyzes the kilowatt hours of energy consumed. This consumption is measured at the main meter and sometimes through additional meters installed around large loads. The information gathered is helpful but limited.

For example, a facility manager might know a chiller is running more than it should (and consuming X amount of energy), but he would have no visibility to the underlying issue that is driving the higher consumption. As a result, the facility manager may need to send in maintenance crews to investigate. If the chiller is failing for some mechanical reason, they would be able to fix it. However if the problem is a power quality issue, this may result in guesswork and money could get wasted on fruitless repair efforts, and / or result in unnecessary equipment wear.

Power monitoring primer

Power monitoring is a specialized discipline focused on managing electrical distribution systems in order to maximize the efficiency and reliability of a facility's electrical infrastructure. It utilizes electrical power metering devices to measure the quality and quantity of power flowing through a given part of the electrical system. It functions much like a BMS, but instead power management helps identify which building systems or pieces of equipment are contributing the most to electrical energy waste. Power monitoring maximizes efficient day-to-day operations by providing visibility into the real-time properties of a building's electrical supply.

Power monitoring enables building management, operations and maintenance teams to see how different building systems and equipment affect the electrical system. It also highlights how different systems and equipment affect each other. This visibility allows facilities staff to detect and resolve problems more quickly, minimize electrical waste, and operate the building more efficiently.

Power management helps to answer the following questions:

- Where is power being used?
- Does the power use signify equipment problems or maintenance needs?
- Is the utility billing correct?
- What does analysis of power consumption reveal?
- Is there a problem with power quality in the building?
- How do similar buildings compare in their power consumption and what do the variations signify?

Given that HVAC and lighting systems, which consume more than half of a building's energy, are affected by power, it makes good business sense to incorporate power monitoring and management.

Power management benefits

There are multiple advantages to monitoring and managing power consumption and quality. Following are some examples of how power management can reduce costs, enhance performance, and improve occupancy comfort:

- **Maximized equipment performance** - Power problems such as transients, swells, and under/over voltage can have a harmful effect on HVAC equipment. A large motor drawing unbalanced power will run hot or inefficiently, leading to wasted power and possible equipment breakdown. Power quality management identifies the problem early so that damage and downtime can be minimized.

- **Avoided loss of capacity** - Harmonic distortion, a power problem caused by non-linear loads, is a common electrical problem that can cause damage to electrical components. In the case of a transformer, for example, a mere 5% harmonic distortion can result in a 25% loss of capacity. A power quality monitoring system allows for the setting alerts on key equipment so that notifications are sent out when harmonic distortion exceeds a certain level.

- **Verified energy bills** - The majority of energy billing errors occur on the administration side of the utility, not the meter. Most facilities receive a bill that only provides a bottom line power usage figure and provides no means for the user to verify. Power management provides the intelligence to read kilowatt hours and compare with tariffs published in the contract. Information such as power usage peaks, overall usage, and time of use are all detailed.

- **Tracked electrical loads** - Tracking load profiles through a power management system can identify early signs of trouble. For example, a typical power load might peak at midday and drop off at the end of the day and on weekends. If that profile changes, it may indicate a problem. A compressor might be malfunctioning, or an employee might be leaving an electrical heater on overnight. The power management system will be able to track down the cause and correct it before the problem becomes severe.

- **Managed assets and capacity** - Power management improves overall asset management and avoids catastrophic failure. In a typical scenario bearings may begin to show signs of wear or chiller motor might be in need of repair. This can be detected on the mechanical side because in-flows might be less efficient. The usual response is to crank up the system. However, when can be observed via changes in the electrical profile, the problem can be identified earlier and with more accuracy and appropriate actions can be taken earlier.

- **Facility comparisons –** The increase of high quality information from the power monitoring system allows for more accurate comparisons between various facilities and campuses. For example, it might appear that a particular maintenance team is performing below par (due to higher costs, poorly functioning equipment), but examining power consumption and quality might reveal that the problem is in the power, not in the people.

- **Applied analytics** - Power monitoring produces large amounts of data. This data can be mined with analytics to reveal hidden trends that are not visible in common, everyday reports (such as hard-to-see correlations between power and equipment). Analysis requires specialized professionals with specific competencies in power quality, electric installation and equipment, who are capable of correlating power quality disturbances with equipment damage, malfunction, or electrical installation downtime. This capability may be provided by the BMS vendor, and can even be embedded to some extent in the BMS dashboards.

See the **Appendix** for a complete list of power quality problems, their impact and their causes.

A new opportunity for efficiency in buildings with non-critical power needs

Traditionally, power management has been used in facilities such as hospitals and data centers where power use and availability are highly critical. The fact is, nearly half of the world's buildings are non-critical, such as educational campuses, retailers and office buildings ("Global Building Stock Database, 2011-2021," Pike Research, 2014). Now building owners and operators of less critical buildings can use power management embedded with BMS for HVAC systems to create business value and positive ROI.

System components

A power management system can operate either as stand-alone or embedded within a BMS depending on budget and needs. Such systems consists of meters for monitoring power consumption and quality; software for viewing, reporting and analyzing power usage; and integration (optional) with building management systems to provide a unified and holistic view of facilities.

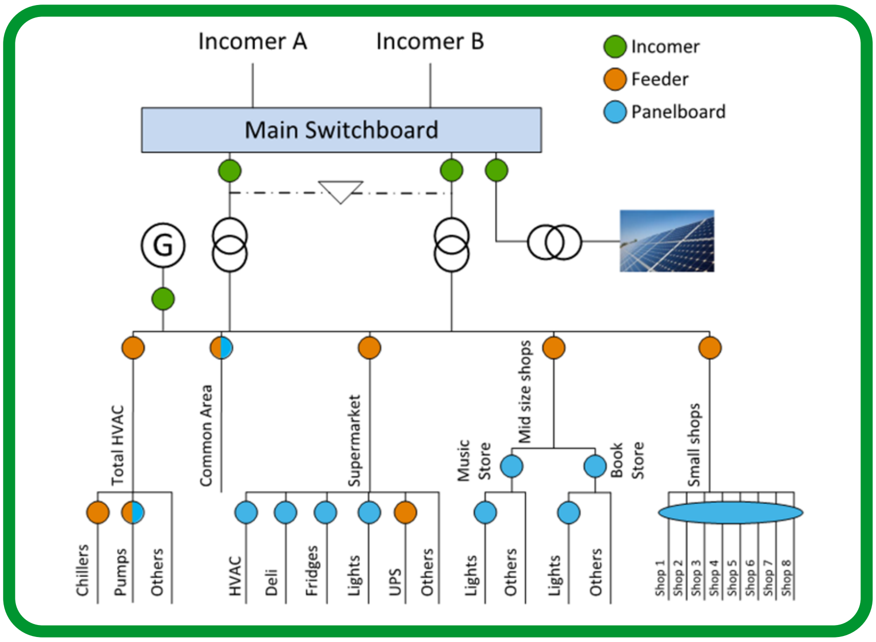
Meters

Power meters measure the quality and quantity of power flowing through a given part of the electrical system. There are many types of power meters available, but they can be divided into two general categories: power consumption meters and power quality meters.

- **Power consumption meters** measure the quantity of energy flowing through a system. They correlate energy use to equipment performance, and identify energy consumption trends. They also identify anomalies in energy use that could signify developing problems, and verifying energy bills. These meters can be installed in one or two locations for basic energy monitoring, or throughout a facility. For example, they could be installed near key equipment components such as chillers and boilers. At the very least, a meter should be placed at the main power incomer.
- **Power quality meters** monitor the quality of the power, not just the quantity. Most consumers assume that power flows into a building like water would flow through a faucet. In reality, a variety of power quality anomalies exist such as voltage dips, harmonics, and transients, all of which can have negative impacts on electrical systems and equipment. These impacts include power outages, damaged devices, equipment overheating, equipment failure, degraded performance, and reduced equipment life.

From 30 to 40% of all unscheduled HVAC downtime is related to power quality problems and up to 80% of the time these disturbances are generated by user-owned equipment.[5] As with power consumption, power quality can be measured in one location or many, depending upon the needs and constraints of each building.

Figure 2
Power meter selection example



Power meters are available with different combinations of the capabilities (see **Table 1** for a partial description). A power management consultant can help determine which meters are appropriate given the configuration of the facility and the available budget. For more information on common power meters applications and the best meter for each need, please refer to the Power Meter Selection Guide for Large Buildings.

[5] J. Manson, R.Targosz, "European Power Quality Survey Report", Leonardo Energy, 2008

Table 1
Examples of different types of meters

Incomer Meters	Feeder Meters	Panelboard Meters
Monitor connection points with external utility or local power sources, such as solar, wind and distributed energy resources	Monitor main distribution circuits from the main electrical switchboard in a large building, or the main distribution feeder from a campus substation. Also recommended for circuits with important loads or specialty equipment	Monitor power distribution panels (distribution panels, panel boards, sub-panels, etc.) throughout a panel that serves non-critical loads.

Power management software

Stand-alone software - In a stand-alone application, power management software provides centralized visibility of power use and how it relates to equipment performance and longevity. This software can be simple or quite advanced. Capabilities can include dashboards for real-time visibility of energy use, alerts for out-of-norm conditions, reports for compliance and management reviews, comparisons across facilities, and analytics for deeper insights.

Software integrated with BMS - Power management can be embedded in a building management system to provide a single, unified view of building operations. This results in convenience and efficiency if non-electrical personnel will need to view and act on the power information that is made available. In addition, an embedded system makes expert-level power information accessible to mechanical systems staff for a simplified and holistic picture of the building operations.

Power management linked to BMS helps both electrical and mechanical systems to run together better. Mechanical and electrical systems traditionally reside in separate data and operational silos. When power management is embedded into a BMS, managers can monitor electrical systems in the same way they manage HVAC systems, with a single set of data, alerts and reports. Such an integrated system makes it faster to determine if the root cause of an equipment problem is due to a mechanical issue or to an electrical issue.

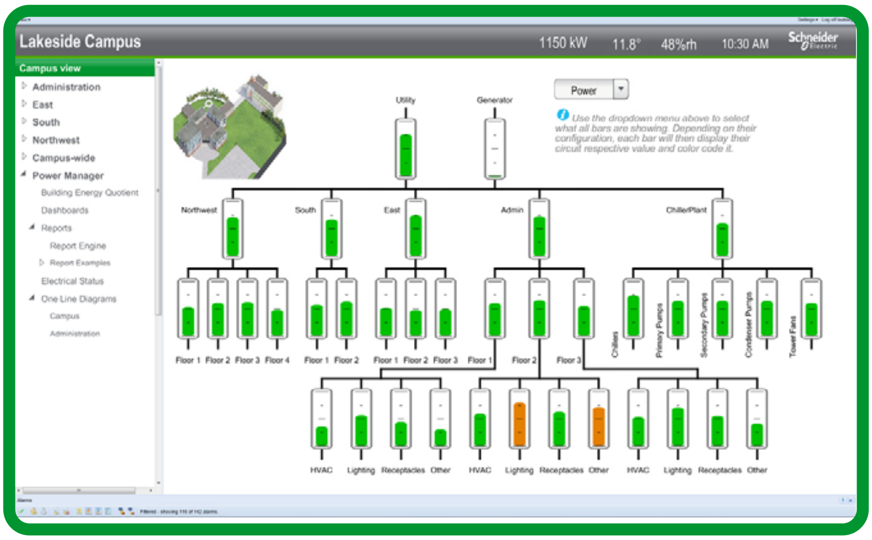


Figure 3
Example of power management software dashboard showing electrical network health summary

Deployment actions

A power management system can be deployed all at once, or phased in over time. The ability to phase in power management makes it affordable for owners and operators tasked with improving building performance.

As a first step, stakeholders need to identify the core areas that need to be measured (see **Table 2**). If accuracy of energy bills is a concern, meters should be placed at the incomer. Placing meters in this location allows monitoring of the power supply and could detect whether problems are coming from the energy provider or are being generated onsite. If equipment performance is the main issue, meters should be added to chillers, boilers, air handling units, and / or pumps. If the priority is to segment or compare different tenants of departments in a given building site, sub-metering should be set up to better understand compartmentalized power usage.

In addition to measurement, the power data that is gathered also needs to be analyzed. An embedded power and energy management system organizes the information into comprehensive, easy-to-understand actionable reports, dashboards, and graphics. This helps mechanical experts and facility managers to make faster, more informed decisions.

Power management requires the establishment of a power policy, as well as defining a baseline, planning of monitoring activities, and performance reviews.

Table 2
A review of existing power management is a first step to improving building performance improvements

Checklist of considerations	Yes / no
Power quality symptoms affecting facility identified	
Power management system already in place	
Power management shortcomings identified	
Utility company billing includes penalties for poor power factor	
Power use being measured	
Monthly energy bill has been validated	
Power meters are installed	
Types of power meters installed are identified	
Power data is being shared across departments	
Electrical power stakeholders within the organization have been identified	
Power reports required have been identified	
Age of equipment has been identified	
Current efficiency measurement methods have been identified	
Current energy expenditures have been quantified	
Energy bill has been audited	
Energy use adjustment methods have been identified	
Power system and building management system are integrated	

A systematic program for power management should include the following steps:

- Establish baselines by understanding the variations and patterns that define "normal operations"
- Set targets/thresholds for proactive notification and exception reporting
- Investigate possible causes of abnormal trends
- Collect information for diagnosis and troubleshooting and propose a response
- Implement a response to the identified problem. Determine which that response should be adaptation/change, mitigation, or equipment replacement

- Establish a procedure for reporting events at the enterprise level, to aid in consistent asset management and development of best practices

Each facility has its own specific power issues, depending on the installed loads, equipment, and the quality of supplied energy. Options to addressing power issues may include add-on equipment that mitigates the power disturbances; modification of settings; design and architecture changes; or even selection of new equipment that is less sensitive to power disturbances.

Conclusion

Most building owners with non-critical power needs have some power monitoring equipment (such as meters) in place, but do not have electrical experts on staff to interpret the energy data that is gathered. Yet they still want visibility into their electrical system for better incident response times and lower energy spend.

Energy use is a major facilities management concern, and buildings have been identified as the largest energy consumers. Yet most building owners and operators fail to measure and manage power. Even BMSs only partially address this issue.

The power system can have a major impact on HVAC efficiency and reliability, as well on energy use and costs. An investment in power meters, when linked with a BMS, provides much-needed visibility into how power relates to equipment performance. Readers interested in delving more deeply into the electrical issues involved are referred to the Schneider Electric white paper “Framework for Implementing Continuous, Iterative Power Quality Management”.

With proper planning, facilities managers can leverage power management to improve energy use, enhance occupant comfort, reduce maintenance costs and emergencies, and continuously optimize building performance.

About the authors

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Appendix

Disturbance category: Short term	Effects	Possible causes
Transients	Equipment malfunction and damage	Lightning or switching of inductive / capacitive loads
Interruption	Downtime, equipment damage, loss of data possible	Utility faults, equipment failure, breaker tripping
Sag	Downtime, system halts, data loss	Utility or facility faults, startup of large motors
Swell	Equipment damage and reduced life	Utility faults, load changes
Disturbance category: Long term	**Effects**	**Possible causes**
Undervoltage	Shutdown, malfunction, equipment failure	Load changes, overload, faults
Overvoltage	Equipment damage and reduced life	Load changes, faults, over compensation
Harmonics	Equipment damage and reduced life, nuisance breaker tripping, power losses	Electronic loads (non-linear loads)
Unbalance	Malfunction, motor damage	Unequal distribution of single phase loads
Voltage fluctuations	Light flicker and equipment malfunction	Load exhibiting significant current variations
Power frequency variations	Malfunction or motor degradation	Standby generators or poor power infrastructure
Power Factor *	Increased electricity bill, overload, power losses	Inductive loads (ex. motors, transformers...)

* Not defined as a power quality problem from standards perspective, but considered as a power quality problem from end-user perspective.