Mitigating Risk using Power Management Systems

by Markus Hirschbold and David Kidd

Executive summary

Because electricity is a key commodity for business it represents significant financial risk. Still, many power management systems remain isolated and separate from the rest of the business enterprise. The result is poor access to incomplete information, with only limited knowledge of risk exposure. An integrated, comprehensive power management system that includes metering, software, and power quality mitigation equipment offers the most holistic, systems-based approach to managing this risk exposure.

Introduction

One of the top priorities for any business executive or senior facility manager is managing or assessing exposure to risk. And because electricity (or power) is a key commodity for energy critical power consumers – those for whom a loss of power can result in serious fines or even loss of life – this risk is mission-critical. Yet, the management and control of this key commodity continues to be one of the least carefully managed.

Extraordinary power costs as well as unexpected disruptions to infrastructure or production facilities always take top priority. According to 2016 World Bank Enterprise Survey data, business owners today find electricity as the third biggest obstacle to their activities.[1] Unreliable power, unclean power, and fluctuating energy prices in deregulated markets represent clear financial risks to any business. These will always have a high priority because the financial impact of these unplanned events can also be devastating.

In fact, the total cost to the European economy from power losses or poor power quality exceeds 150 billion €, while in the US these losses are between $119 billion and $188 billion USD. Still, despite such financial risk, investments in power management or power corrective equipment remain limited.[2]

Managing energy risk requires accurate measurement of the cost, quality, and reliability of the power from the source to the load. A power management system reduces that risk by providing key performance indicators (KPIs) that help managers determine whether critical operating parameters are within expectations (Figure 1). A combination of connected devices – accurate cost/revenue metering, embedded power quality/reliability monitoring, power quality mitigation equipment (to address any power quality issues), and a modern communications infrastructure – delivers relevant, actionable data in a timely fashion.

With a power management system, risk can be managed in terms of understanding what is going on, understanding what will happen if a particular action is taken, and helping make decisions that reduce risk, improve profitability, and maximize the return on the energy investment across the entire enterprise. This not only enables significant energy savings; it also enables a persistent risk strategy for the future.

Power management

A balanced, connected approach includes:

- Software: control and monitoring designed to provide analysis and real-time energy information
- Power meters: accurate, devices that can identify energy savings, increase operational efficiency, and reduce energy costs
- Power quality mitigation: reduce electricity bills, power losses, and process-related voltage fluctuations; mitigate harmonics to avoid voltage and current distortion.

[1] World Bank Enterprise Surveys (2002–16). Data sample includes 139 economies.

[2] J. Manson, R.Targosz, “European Power Quality Survey Report”, Leonardo Energy, 2008

Understanding electricity-related risk

It is not unusual to have management at the VP level of large organizations, or to have risk management as a targeted objective among C-level management. Their mission is to avoid, or at least anticipate, unexpectedly high operating or production costs, avoid low production yields, reduce environmental emissions, improve customer satisfaction, and so on.

Electrical energy is almost always mission-critical and therefore comes with a high risk. For some enterprises, other energy commodities and the energy assets that deliver them may be equally critical to the financial viability of the business: for example, water, air, gas, and steam (WAGES).

For more information on effective WAGES strategies, see White Paper, *Designing a Metering System for Small and Medium-Sized Buildings*.

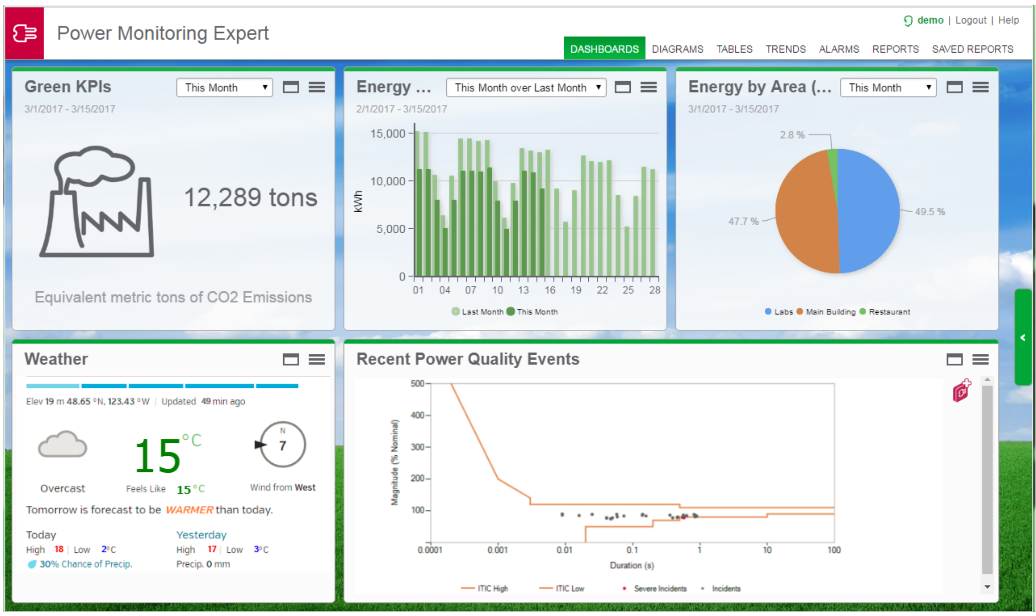

Figure 1

Power management software dashboard highlighting key energy performance indicators for a multi-site industrial enterprise. Such software is a crucial element within a comprehensive power management system.

The true value of energy commodities is a balance between cost, reliability, and quality. Today the majority of underlying technologies designed to deliver the information needed to manage these three attributes often operate *in situ*, or in isolation, if at all. These technologies have traditionally been a mix of metering, billing or power management systems to quantify cost and revenue, supervisory control and data acquisition (SCADA) systems to measure operating parameters of the infrastructure, and dedicated portable instruments to measure power quality.

The result of isolating these technologies is high cost for poor access to incomplete information. The impact is that there is only limited knowledge of the risk exposure due to each business-critical commodity. An integrated, connected, and comprehensive power management system – one that includes metering, software, and power quality correction equipment and can integrate with other operations systems in an organization – offers the most holistic approach to managing this risk exposure.

For more information on the connected systems and the Industrial Internet of Things (IIoT), see the 2017 report reprint: *IIoT EcoStruxure reduces energy use, accesses new business models.*

Risks related to electricity costs & revenue

> A Case Study: A large pulp & paper plant was running the risk of sudden increases in the spot price of electricity for some plants. They needed to track consumption against energy cost from a variety of sources in real time (spot market, on-site generation, load shedding) to be able to make rapid decisions about the most cost effective energy supply. Looking back at the previous month's consumption as provided by a conventional metering system was not able to provide accurate, rapid information for business-critical decisions.

Utilities have always had a "cash register" of tariff meters, but now businesses are also demanding the ability to verify billing, verify the quality of delivered power, and to have the information needed to help them avoid utility penalties. This verification is an important application within a power management system, as it often provides a business with their first or most immediate return on investment (and in fact has been known to fully validate the capital investment within the first year).

Figure 2

Intelligent power meters are key components within power management systems, providing accurate billing verification, cost allocation, and advanced power quality analysis.

With the advent of deregulation in some regions, energy cost may be indexed to the market price. It has also become more common to trade off cost against quality and reliability, which may take the form of a supply contract between the consumer and the utility or energy services company.

In terms of financial risk, specific knowledge is needed regarding the amount of energy delivered/consumed. Quick decisions require relevant data on sudden changes in energy costs based on the weather, for example, which in turn affects load and therefore the spot price. The facility manager may choose to switch to on-site generation if costs are too high. This is especially relevant today as the cost of renewable on-site generation continues to decrease.

Conventional energy cost analysis systems will record and track energy consumption patterns in each section or department or area. It is quite easy to do multi-dimensional analysis: for example, compare usage trends for week 1 with week 3, or from Plant A to Plant B. Most systems will offer some kind of cost allocation, utility bill verification, and sub-tenant billing. The best systems even go so far as to integrate real-time energy pricing to allow "what-if" scenarios.

In all of these scenarios, the results recorded by the power and energy meter must be very accurate. In a commercial building with multiple tenants the meter must be accredited for sub-billing. Then, the software for billing or energy cost analysis must be flexible and cost-effect enough to take these data points and create customized reports. A power management system will supply this for the complete enterprise.

*Note: any discussion of an integrated, connected power management system must include cyber security (not the topic of this paper). There has been a dramatic rise in cyber attacks in recent years. For more information on a cyber secure electrical network strategies, see White Paper *Securing Power Monitoring and Control Systems, 2016*.

Risks related to reliability

> A Case study: A utility was unable to confirm that transformers in an old substation were sized correctly for some new tenants in a nearby industrial park that were expected to add a high harmonic load. The conventional SCADA system provided load levels but could not measure or predict the performance and load level for non-linear loads. They were running the risk of equipment damage and losing power to some key industrial customers.

Having a brilliant history of continuity does not guarantee a reliable energy supply in the future. Even with 99.99 percent energy availability, the equivalent interruption time amounts to 52 minutes every year. Plus, there is no piece of electrical equipment in the world that will "never" break down, and the effect of modern, dynamic non-linear loads on power-sensitive equipment is increasingly challenging. Published financial metrics show this to be true, with total cost to the European economy of 150 billion € while in the US these losses are between $119 billion and $188 billion USD .[3] Power quality, furthermore, is not just a question of availability, but is also directly linked to the operation of the power delivery system.

The standard approach to compensate for an unreliable power supply is to buy expensive redundancy (oversized transformers, multiple utility feeds, backup generation, UPS with a room of batteries, oversized power distribution equipment, etc.) and hope for the best. But the redundancy approach may help ride through a power failure or disturbance, but it will not eliminate the causes.

The key to affordable reliability is not only redundancy, but also predictive analysis and maintenance. If you know in advance that a system is likely to fail – or perhaps weakened by damaging disturbances – you can fix the problem before it becomes one.

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[3] S. Bhattacharyya, S.Cobben, "Consequences of Poor Power quality – an Overview", Power Quality, book edited by Mr Andreas Eberhard (Ed.), ISBN: 978-953-307-180-0, InTech, 2011.

So the challenge becomes one of understanding the potential impact of problems relating to poorly grounded/earthed distribution systems, natural disturbances such as lightning, or disturbances that originate within: from equipment switching, excessive harmonic frequencies, undersized neutral/return cables, and phase unbalances on feeders. In fact, 80 percent of disturbances are generated by user-owned equipment.[4] Carefully measuring and tracking sags, swells, transients and harmonics may show how these anomalies can impact the life and behavior of equipment throughout a distribution network or a facility; looking for them after the system has failed is too late.

Reducing risk due to poor reliability requires the ability to predict. This requires data, information, and knowledge about the impact of power quality and loads on the infrastructure, and about the infrastructure's impact on power quality. A power management system will supply this for an entire enterprise.

Risks related to power quality

> A Case study: A financial data center made a heavy investment in on-site generation and on-line UPS for critical stand-by power. The transfer to stand-by generators was not always smoothly handled, however, and the internal diagnostics did not provide any clues. They were running the risk of putting traders off-line in a volatile equity market.

Figure 3

Transient voltage surge suppressors protect electrical networks from damaging power surges and spikes. Active harmonic filters inject harmonic current to cancel any harmful harmonic current. Capacitors are specially designed for use in networks with frequently switched loads and harmonic disturbances All are key components in a comprehensive electrical distribution system.

The average cost of a data center outage has steadily increased from $505,502 in 2010 to $740,357 today (for a 38 percent net change), with the average unplanned outage duration of 130 minutes)[5], which makes electricity the single biggest infrastructure issue that can influence financial business risk. It also reveals incremental increases in downtime costs. This makes it increasingly common for a supplier to verify its energy has been supplied in compliance with accepted power quality standards. It also makes it all the more important that the business can verify it is receiving what it paid for.

And for both, it lowers financial risk if they can ensure any issues with power quality at the point of delivery can be readily and decisively determined. Waiting for a power quality problem to manifest itself, often seen as equipment malfunction or failure, is sadly still the most common way of finding out that a real problem exists.

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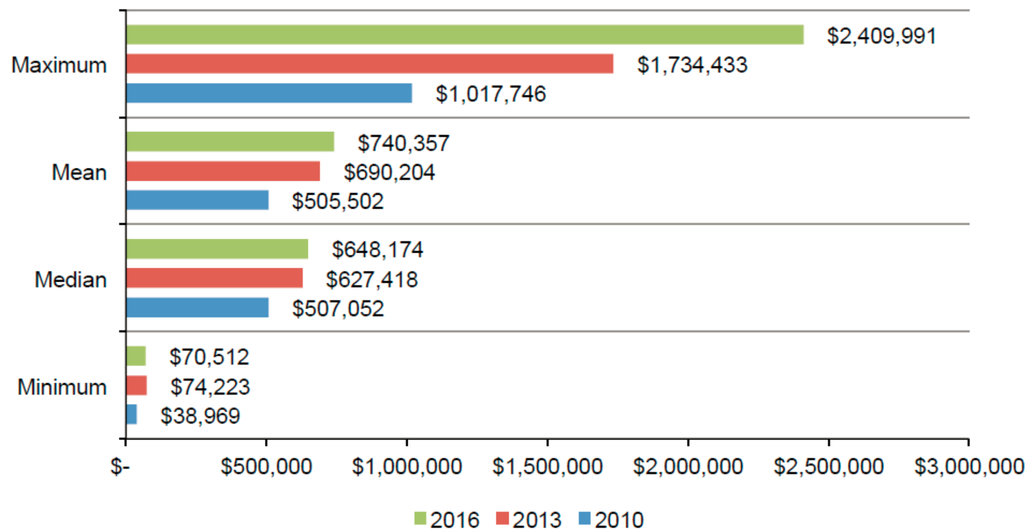
[4] V. Ignatova. "A Framework for Implementing Continuous, Iterative Power Quality Management", White Paper, May 2015.

[5] Ponemon Institute (LLC). "Cost of Data Center Outages", January 2016.

What makes power quality a complex issue is that, unlike other energy-related commodities like steam or gas, the quality of electricity can be influenced not only by the supply infrastructure but also by some of the loads. Electrical distribution networks designed 30 years ago to drive motors and heaters are now driving equipment and tools that feature the latest energy saving and control technologies – typically non-linear loads – that are often a source of poor power quality.

Figure 4

Key statistics on data center outages comparing 2010, 2013 and 2016 figures. Source: Ponemon Institute, Cost of Data Center Outages, January 2016.



As a result, power quality has become an issue at just about every point in the energy supply chain. In fact, power quality is as much an indicator of equipment deterioration as it is a cause of equipment deterioration. In other words, poor power quality can lead to poor distribution equipment reliability, which in turn further has negative effects on power availability and uptime.

Power quality events are often singular or sporadic in nature, and this demands continuous 24/7 monitoring. Portable instruments are useful for troubleshooting known problem areas in greater detail, but can never replace full-time monitoring. Power quality metrics can include:

- Availability (defined as time without an outage)
- Transients (number, severity, duration)
- Current and voltage harmonics
- Neutral currents
- Ground currents
- Neutral-ground voltages
- Crest factor
- Voltage sags/swells
- Voltage unbalance (unequal distribution of single phase loads)
- Flicker (loads exhibiting significant current variations)

The challenge is often to identify the source of a problem and to corroborate these sources over the whole system. For example, if five locations are experiencing transient voltage disturbances at nearly the same time or with a similar signature, there is a good chance the problem has a common source. A comprehensive power management system will supply the information required to identify these sources for the complete enterprise.

The Power Management System

In considering ways of managing cost, reliability and quality of energy, it is clear that there are countless systems claiming to perform monitoring, analysis and prediction for each of these attributes.

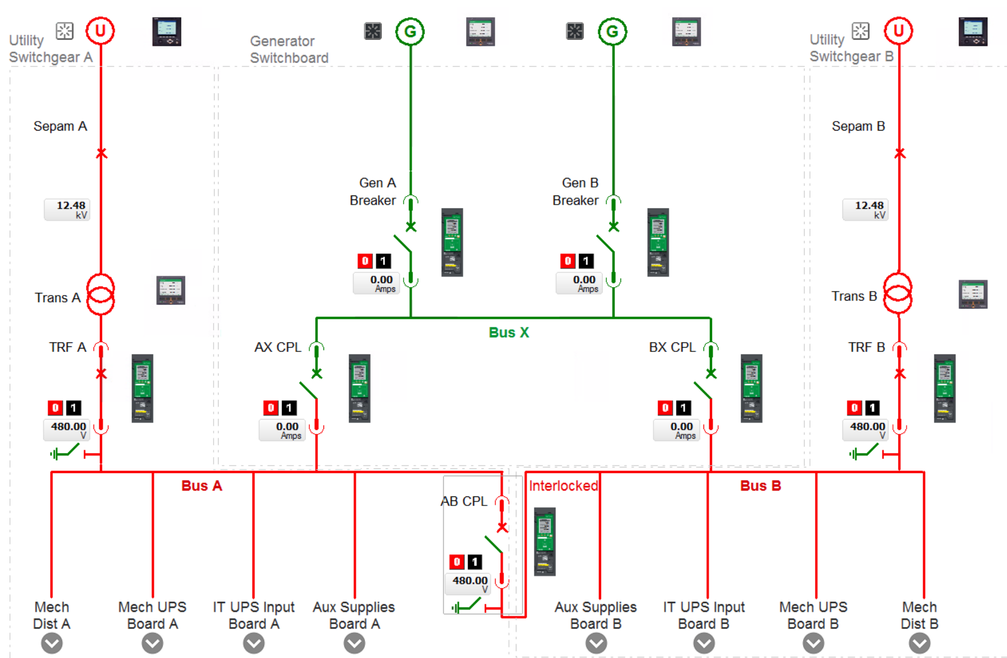
The common shortcoming of these tools is that they cannot provide the comprehensive view to correctly manage all aspects of the electricity delivered directly to the load, measured in terms of the financial risk to the enterprise.

Some examples may illustrate this point:

- Energy usage in a supermarket is a substantial operating cost, and efforts to reduce consumption are usually well established. Nonetheless these efforts are usually made one building at a time; overall profitability of the supermarket chain could be greatly improved by taking advantage of a multi-site capable power management system (including bulk energy supply contracts from competing service providers), or by using local generation. The ability to track relative efficiencies and costs by location, and to compare those to industry benchmarks, can be an invaluable decision-making tool.
- Measuring the cost of electricity consumed for an automotive painting facility defines the amount that electricity costs contribute to the manufactured cost per unit. A logical cost-savings step may be to install high efficiency drying lamps, or even to delay the paint-drying process to off-peak hours to take advantage of lower rates. However, the far greater financial risk to the automotive manufacturer may very well be the risk of the harmonics introduced by high-efficiency lamps: these could generate excessively high neutral currents that will burn out an undersized conductor. These can result in a fire or equipment failure and plant-wide shut down for days or weeks.

Figure 5

An example of a power management system topology.



- Wind and solar farms offer a generation asset that calls for an accurate energy meter at the inter-tie point or step-up transformer so that the operator can be paid. However, the solar or wind farm may be exposed to an even greater risk of high repair costs if switching transients on the grid damage its infrastructure.
- High efficiency compressor motors are an obvious part of a cost savings strategy in a pharmaceutical manufacturing plant. Yet the lighter, electronically controlled motor windings tend to generate harmonics. A room full of these compressors will show dramatic improvement on the energy consumption metrics, but the impact of the resulting harmonics on the stability of neighboring equipment may be even more dramatic. Power system instability resulting from cost savings in one area can lead to poor product quality or reduced yields of a very valuable product in another.

The key is to be able to ensure high reliability and good quality at a reasonable cost. For manufacturing facilities in general, if the energy infrastructure costs less, the risk of reduced yields is higher. For commercial buildings, a weaker infrastructure runs the risk of business interruptions that can be disproportionately costly. Thus, in a chemical plant it could very well be acceptable to reduce yields by 1% if this is required to save 10% on energy costs, but for an equity trading company a loss of 1% of transactions will be completely unacceptable.

Each enterprise – utility or commercial or industrial or otherwise – will have a different risk tolerance for low cost or high quality or good reliability of supply. A number of key performance indicators are needed to help us manage our exposure to risk. These can identify which facilities are out of line, confirm that costs are on budget, identify strengths and weaknesses compared to the competition, and improve the bottom line.

System topology

A power management system must deliver key performance indicators about all mission-critical energy assets and energy commodities; it must provide these indicators in a timely manner (in some cases, milliseconds), and it must provide enough information for useful analysis.

The topology shown in **Figure 2** provides a simple overview of a power management system. Accurate devices for cost-related data (billing metering), reliability-related data (operational metering) and quality-related data (power quality metering) are deployed at every key asset or distribution point.

These devices require embedded intelligence to provide meaningful, actionable information and key performance indicators. A high speed, flexible and open communications infrastructure (Ethernet, wireless, serial links) ensures that information and performance indicators can be passed to the decision makers quickly. The software tools and reports provide rich information in the form of key performance indicators to simplify the decision-making, analysis based on what-if scenarios, statistical indicators, performance trends and so on.

Key performance indicators

A power management system will provide the data and information required to make intelligent decisions about improving the cost, reliability and quality of energy. These decisions improve profitability and manage risk, and will be based on any number of key performance indicators.

Managing energy assets and energy commodities requires tools that allow you to know the condition of the business relative to other reference points. These reference points might be based on industry average consumption levels, production yield, temperature, occupancy, availability and so on.

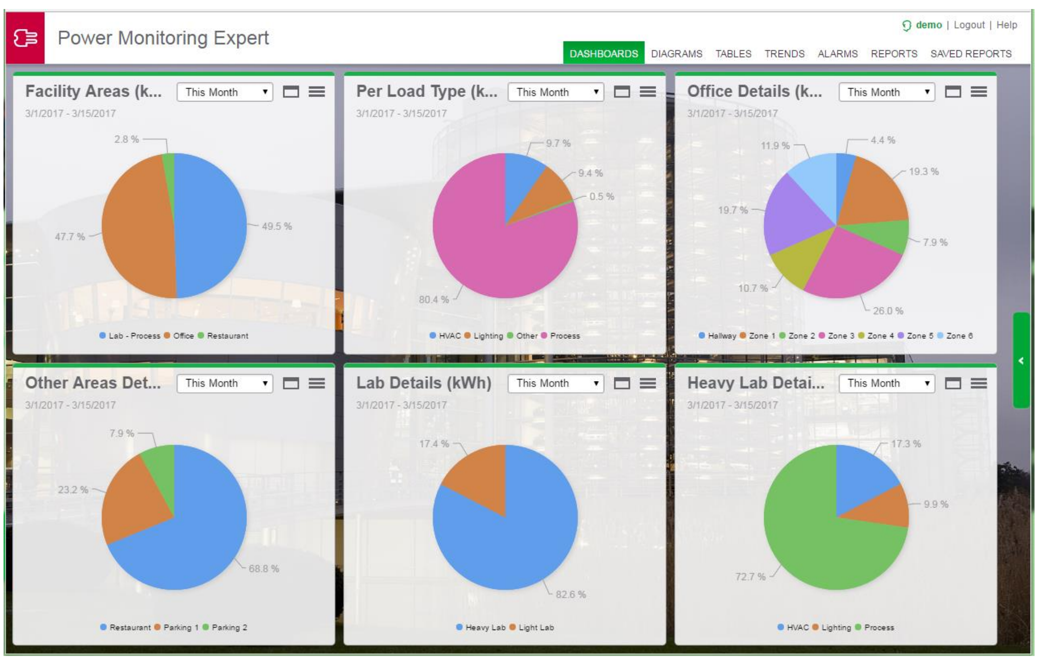
In all of these cases, the power management system is used to deliver key performance indicators that identify areas of potential financial risk. The question "what if?" can be answered by multi-dimensional analyses, delivering the intelligence needed in time for intervention. This helps avoid unexpected costs, unexpected reliability problems, and unacceptable power quality.

A power management system will reveal energy consumption trends per square foot for multiple facilities. Energy managers for supermarkets chains with hundreds of outlets, or any other business with multiple plants or facilities, will be able to determine which facilities are least energy efficient, so that capital costs to save energy can be applied in the most effective manner. The power management system will also record historical load trends, for individual sites as well as aggregated across the enterprise. Armed with this information, facility or energy managers will be better able to project needs, predict maintenance, and even negotiate bulk energy purchase contracts.

Sub-metering across the enterprise and throughout each facility enables the power management system to accurately track consumption levels for each building, tenant, department, process, load type, or other cost centers. This helps ensure commercial building owners are properly compensated for energy used by each tenant. It also supports the normalization of energy costs for different types of tenants, helping plan reliable power systems for new buildings.

Figure 6

Key performance indicators for energy consumption



Trending and prediction data also help a facility avoid penalties from the utility for exceeding high peak demand or low power factor limits. Loads can be rescheduled to “smooth out” a consumption curve, and generators or other equipment can be manually or automatically engaged in response to power management system alarms. And with environmental standards and the potential for hefty fines becoming a substantial consideration for some process industries, a power management system can help normalize emissions levels versus energy consumption to help avoid the risk of excessive pollutants when a plant is not running at optimal efficiency.

In a commercial building, consumption and temperature will be closely correlated, unless there is a large shift in loads – for example, from a new tenant that requires a large server room. Combined with the air conditioning load, the infrastructure may not be adequate in summer months and may require an upgrade. A power management system can deliver the performance indicators a business needs to avoid running the risk of exceeding the capacity of the infrastructure [Figure 3].

All businesses – from data centers or industrial manufacturers to commercial buildings and healthcare facilities – can benefit from auditing and comparing expected monthly energy expenditures to plan. If the actual charges in a given day, week or month are significantly higher than budgeted, this can force changes in business practices, or result in refunds or disbursements. A power management system can accurately “shadow bill” against the utility billing meters to ensure actual billing charges align with those predicted, and catch any utility billing errors by verifying the charges against what is measured by the system [Figure 4]. Beyond electricity, any other commodity such as water, compressed air, gas and steam can be profiled over time and between facilities to identify anomalies in supply or demand [Figure 5].

Figure 7

Key performance indicators for shadow billing

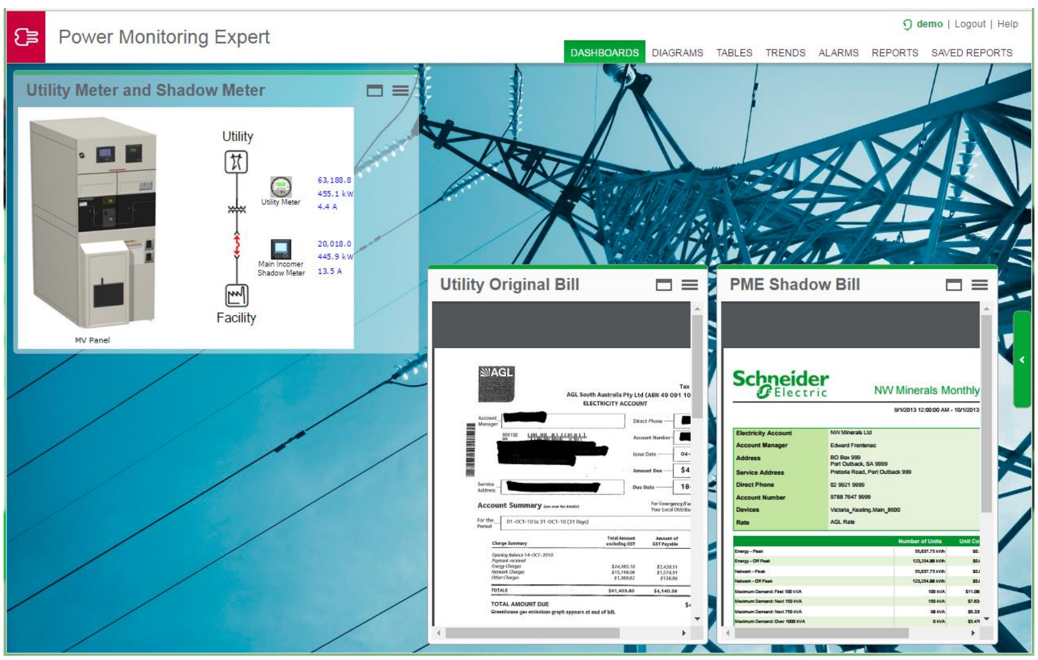
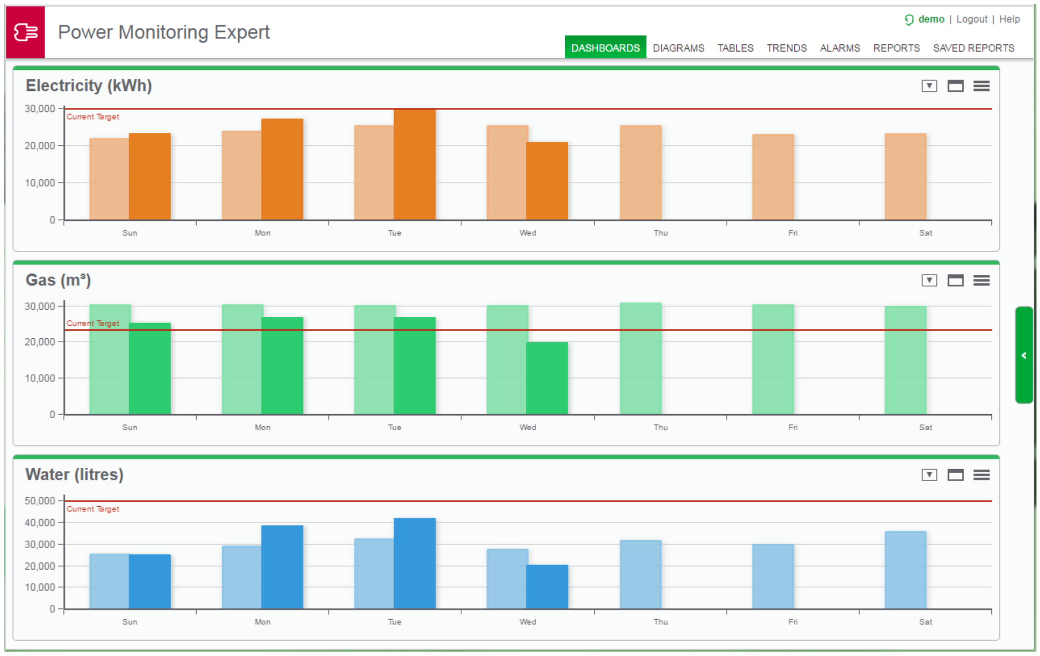


Figure 8

Other energy commodities can be profiled to identify anomalies in supply/demand



A power management system will also provide power availability indicators for multi-site facilities (sometimes expressed as "number of 9's" of uptime, e.g. 99.9999% = six nines). For businesses with critical power needs, such as financial institutions, data centers, or hospital and healthcare facilities, the system can verify if the power is consistent throughout all facilities, and that the substantial investment in mitigation equipment (including back-up generation) is functioning as expected.

When a utility has an obligation to deliver good power quality, as measured against a national standard, it is essential that the pass/fail statistics of each inter-tie point be tracked. A power management system will report on specific compliances, as well as deliver early warnings that make it possible to intervene and preclude non-compliance. **Figure 6** shows an example of a report representing measurements against international power quality metrics.

For more information on power quality metrics, see White Paper *A Framework for Implementing Continuous, Iterative Power Quality Management*.

Ensuring a good return on a power management investment

Any investment in information technology and operations technology (IT and OT) must offer a reasonable total cost of ownership over the life of the system. A power management system should also be flexible and scalable enough that it can easily adapt to new devices and grow with a business as its needs change. In some circumstances, manual meter reading and portable power quality instruments could also provide the data required. Yet the cost of manually collecting, transmitting, storing and processing all that data can be substantial (and even error prone) relative to the amount of information. And this is not a one-time survey; today a full-time, in-depth power monitoring and management strategy is critical to success.

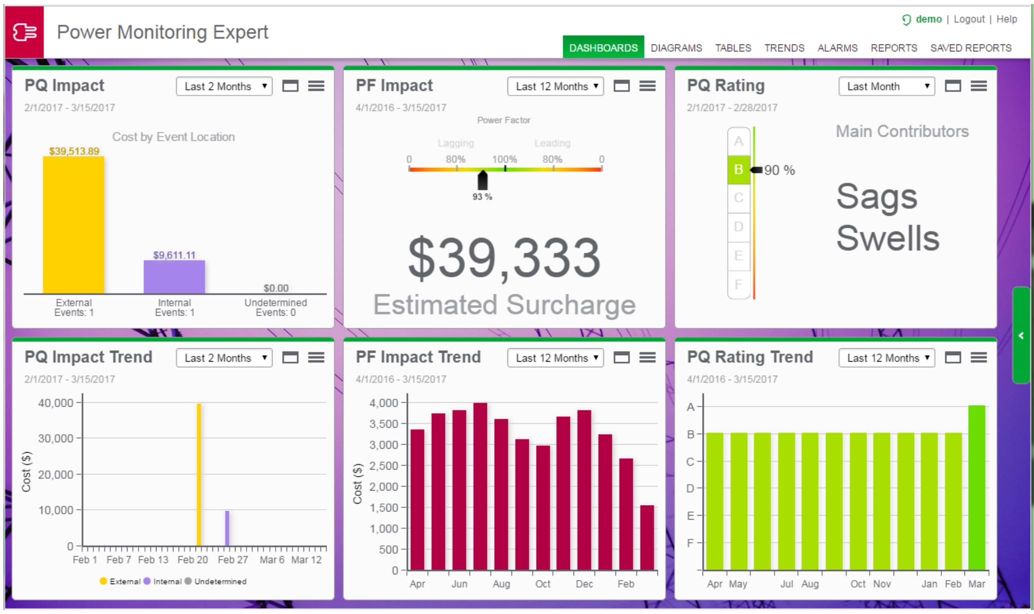


Figure 9

Key performance indicators for PQ compliance

An integrated power management system combines the permanent metering, monitoring, analysis, communications and reporting tools required in a single, cost-effective solution. Some key features required for effective power management systems:

- Energy analytics tools to ensure that key performance indicators can be determined to analyze the performance of the process, the business unit, or the whole enterprise.
- Tariff-class 0.2 or better metering accuracy for energy, demand and usage data to ensure that billing is accurate and correct.
- IoT connectivity to ensure immediate and low-cost access through non-proprietary communication networks that are easy to maintain and scale.
- Support for Internet protocols and web features to ensure that information and data can be accessed easily with commonly available tools (for example, tablets or smartphones).
- Monitoring user-defined quality and reliability metrics to ensure that the supply meets contractual commitments.
- Monitoring compliance in accordance with the IEC61000-4-30 standard, or other accepted standards, to ensure that the supply meets expectations, using recognized metrics.
- PQ troubleshooting tools to ensure that when a disturbance occurs, the capabilities are in place to track down the cause to avoid a recurrence.
- Customized information delivery for each person that needs it – in real time – to ensure that the relevant intelligence is available to make fast decisions to avoid disruptions, equipment failure, and cost overruns.

Conclusion

Energy is a mission-critical commodity that must be managed to reduce the exposure to risk for an enterprise. A power management system can mitigate this risk by providing the data, information, and knowledge required about the cost, reliability and quality of the power supply.

The power management system requires tariff-class accuracy to provide good cost information; embedded analysis capabilities to ensure that useful reliability and quality metrics can be tracked; and a modern, IoT-capable communications infrastructure that makes the system cost effective for large facilities.

A power management system will provide the necessary key performance indicators required to make business decisions that lead to reduced risk and improved, persistent profitability throughout the facility.

About the authors

Markus Hirschbold (P.Eng., CEM, PMP) is the Systems Architect for Schneider Electric's electrical distribution hardware and software. He has held various key positions in R&D, Services, Power Quality, Project Management and Offer Marketing during his 24-year tenure at Schneider Electric. He has been Segment Director for Healthcare since 2009, responsible for the creation of electrical distribution and energy management solutions for Healthcare facilities. Markus holds in excess of 30 patents related to Schneider Electric hardware and software.

David Kidd (B-Com) is the Schneider Electric Launch Leader for EcoStruxure™ Power Management systems, a key element of the EcoStruxure architecture and interoperable technology platform. He is a University of Victoria alumnus and has been involved in the power and energy management industry for 15 years, holding a variety of roles in Application Engineering, Sales, Business Development, and Marketing.

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Resources

Securing Power Monitoring and Control Systems, 2016

How Predictive Maintenance for Circuit Breakers Optimizes Safety, Reliability, and Costs

Enhance Power Equipment Reliability with Predictive Maintenance Technologies, S. Frank Waterer, Schneider Electric, 2012

A Framework for Implementing Continuous, Iterative Power Quality Management, 2015

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