WHITEPAPER

Optimizing Data Center Power Management with Advanced Multi-Circuit Monitoring Systems

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Abstract

Electrical metering has become common in data centers over the last decade. Tracking power usage at the facility and component level can help avoid downtime, lower energy costs, and optimize equipment utilization. However, the cost of deploying metering throughout a facility has limited the scope of deployments and prevented most facilities from achieving the full potential benefits. New multi-circuit metering systems (MCMS) can now provide advanced metering capabilities at a lower cost. In this whitepaper, we look at the evolution of metering and where the technology and market stand today, discuss the benefits and best-practices associated with metering deployment in a variety of data center environments, focus on key device attributes and why they matter, and describe how new advanced MCMS products provide a less expensive, easier to install, feature-rich metering solution. With this information, data center organization will be better able to make decisions that will help reduce costs, increase energy efficiency, and prevent unplanned downtime throughout the data center lifecycle.

Introduction

In recent years, the data center (DC) industry has seen an increasing number of metering deployments. The value of metering in data center environments is well established: it provides visibility into equipment and system functioning for monitoring, tracking, trending, benchmarking, and spotting abnormalities. Data captured by metering systems can help DC owners and operators to avoid downtime, lower energy costs, and optimize equipment utilization, among other benefits.

However, not all meter components and approaches are created equal, and one-size solutions do not fit all. If organizations want to get the most impact for their metering investment, there are multiple variables to consider. Specific metering system capabilities and configurations can make deploying devices easier—easier installation, integration, and ongoing maintenance through the lifetime of the DC—all while mitigating costs often associated with these projects.

Installing metering as either a retrofit or new build can be expensive. These costs have often limited the scope of deployment by any given facility. For example, a common deployment consists of simply installing single-point meters within the facility.

By contrast, deploying a multi-circuit monitoring system (MCMS) can provide a significant cost reduction for DCs, and more actionable data compared to single point meters. Newly developed MCMS products offer a lower-cost, more effective deployment option that can help DCs to easily integrate metering to optimize power utilization across the facility. An integrated MCMS can monitor systems at a granular level, catching potential issues and providing early warning, allowing a potential failure to be easily addressed downstream before it becomes a bigger problem upstream. The rationale and use cased for deploying metering in each data center can vary depending on industry, market segment, or application, but the key factors to consider when selecting a metering solution are universal. In this whitepaper we will examine device attributes of traditional and MCMS metering systems and discuss their impact and expected performance, with the overall goal of enabling more informed decision-making for metering upgrade and new build projects.

Why Deploy Metering?

"Tracking and managing data can inform decision makers in the following ways:

1. It helps organizations identify abnormally low-or high-energy usage and potential causes, supporting such practices as peak-shaving. It also facilitates capacity planning around space and power utilization and helps with carbon accounting and greenhouse gas (GHG) reporting.

2. It helps organizations track and manage energy costs, verify energy bills, and prioritize, validate, and reduce energy costs through improved energy efficiency and energy management.

3. It allows organizations to quantitatively assess data center performance and to benchmark it across a level playing field. Benchmarking evaluates the organization's position relative to the rest of the market (cross-sectional benchmarking) or over time in one data center (longitudinal benchmarking). This enables engagement with senior management and other stakeholders to participate in continuous improvement of the organization's energy performance.

4. It helps organizations develop and validate energy-efficiency strategies and identify opportunities to improve energy efficiency by lowering energy and operational costs. These strategies include identifying large energy users and establishing performance metrics (cooling plant kilowatts/ton, air-handling watts/cubic foot per minute, etc.) for monitoring and tracking.

5. Energy performance metrics can also be used to commission and detect faults in physical systems and diagnose their causes."

SOURCE: *Data Center Metering and Resource Guide, U.S. Department of Energy, February 2017.*

Metering Evolution

As the infrastructure underpinning today's vital financial, government, utility, healthcare, transportation, and technology industries, data centers must be able to provide reliable, consistent, and secure performance. Electrical power metering is an important tool for safeguarding operations across all segments of the market, with use cases that extend to:

- Mission-critical data centers (e.g., air traffic control systems, national security, banking)
- Hospitals and facilities that provide 24x7 patient care
- Industrial facilities such as manufacturing and food processing plants
- Residential systems (e.g., apartment facility HVAC)

The idea of electrical power metering is not new, dating from Thomas Edison's 1881 patent for an electrolytic meter to the invention of remote metering in the 1960s. Today virtually every industrial, commercial, government, and residential electrical system in the world incorporates metering in some way—from the national power grid down to the municipal power utility meter on the side of your house. Similarly, data center operators have incorporated meters to track electricity utilization at various points throughout their facilities.

Current Standards

Due to the importance and ubiquity of electrical systems, governmental and industry bodies have developed standards to ensure consistency. These standards help ensure the performance of power systems on behalf of the end-users and public who count on their availability, and enable data center owners and operators to rely on consistent readings and results from the various metering systems, equipment, and components that go into their facilities. "Accuracy is perhaps the most important attribute of high-end metering," and standards provide a means of determining and comparing accuracy of components in the marketplace.

Metering standards established in the data center industry include:

- The American National Standards Institute (ANSI) code for Electricity Metering (ANSI C12.1) and code for Electricity Meters – Accuracy and Performance (ANSI C12.2)
- The International Electrochemical Commission (IEC) standards for Electricity Metering Equipment (IEC 62053)

What Drives Performance Requirements?

The performance requirements codified in the IEC and ANSI standards were developed in response to complex needs, concerns, and the real-world experience of DC operators. Knowing this context can be instructive for understanding where current metering approaches have blunted the original objectives, and how multi-circuit metering offers a more advanced solution that comes closer to meeting those objectives. As regulations catch up to the latest technology developments and respond to current shortfalls, data centers employing MCMS techniques will already be positioned to meet the next generation of standards and market requirements. The following are leading factors that drive the development and evolution of performance standards.

Federal and state government regulations. The need to comply with government regulations at the regional, national, and state level is a major driving force in standards development. The most significant governmental rules affecting the data center metering industry today include:

- For US-government managed data centers, the 2016 DCOI (Data Center Optimization Initiative) mandated that all agencies "install and monitor" advanced energy meters by September 30, 2018. This mandate had emerged from a process begun back in 2006, when Public Law 109-431 required investigation into datacenters and energy usage. In response, the EPA ENERGY STAR Program conducted an investigation that resulted in publication of a 133 page report

- California Title 24 sets stringent requirements for the metering power distribution systems of residential and commercial buildings (Refer to table 130.5-A in the 2016 standards)

- In the European Union, the MID (Measuring Instruments Directive) sets compliance standards for metering systems. It was signed in 2006 with a 10-year implementation timeline.

Requirements for high-density and mission critical data center operations. The demands of running a high-availability 24 x 7 x 365 data environment necessitate having rigorous system safeguards in place to prevent downtime. Metering is one of those key safeguards that can help avoid an equipment fault or failure when critical production operations—or even lives—are on the line.

Customer requests and an evolving marketplace. With the rise of cloud colocation and hyperscale data centers, there's been a corresponding rise in the need to capture power and other utilization metrics to support business activities as billing and SLA compliance. Within enterprise DCs, there has also been a drive for more metering data. For example, obtaining rack- and server-level metrics can enable operators to implement billback/chargeback or showback practices to better allocate IT expenses to internal user groups within an organization.

Owners and operators are also finding that they need more data at all levels to enable more informed capacity planning and facility management decision making. Increased knowledge sharing—between providers and tenants, between enterprise stakeholders, and between networked facilities around the globe, has also created demand for more widespread and sophisticated metering capabilities.

Industrial and residential applications are quickly catching up. Data centers in mission-critical sectors have moved rapidly towards power system modernization. Recently, those in industrial and residential sectors are starting to catch up. Government regulations have pushed the process along, but operating realities and financial impact have also inevitably led to power system changes. For example, in industrial facilities "dirty power" issues can cause equipment shutdowns. A common response is often to procure or upgrade the facility's UPS system, but strategically applied metering is another piece of the solution that can help detect and prevent electrical irregularities and interference.

A Need for Accurate Specs

In the power metering product marketplace, accuracy standards are often described with verbiage that is not clear and that makes apples-to-apples comparison difficult. ANSI and IEC standards have evolved in recent years giving guidance for metering accuracy and other performance measures.

Customer knowledge of power systems is evolving but many are not fully aware what performance standards they need (or don't need) to meet for specific applications. It's especially hard to make purchase decisions in the face of shifting verbiage used inconsistently by many manufacturers.

It does a disservice to data center customers—and the end-users who rely on them—to perpetuate inaccuracies in system performance and fail to define specifications down to the component level. For example, a spec should not claim "0.2% system accuracy" when the meter is .2% and CTs are .2% accurate.

Customers need transparency and consistent verbiage from power meter manufacturers and suppliers so they can balance costs against actual need and ensure that their systems comply with critical performance requirements. Ideally, the industry can move to standardize its accuracy reporting.

As for Anord Mardix, all of our meter components offer 0.5% accuracy, end-to-end, across the board.

Deployment Options

When developing a plan to incorporate metering in a data center, engineers have four basic installation location options, whether for a retrofit or new build:

1. **Site-level.** Metering general power utility usage as it comes into a site to feed various buildings and other end-use equipment
2. **Building-level.** Metering the utility feed to an individual building, which captures all energy used within that building
3. **System-level.** Metering can be installed to measure whole systems such as chiller plants, lighting, and CRACs
4. **Component-level.** Sub-metering within systems can measure detailed temperature, voltage, and other metrics. This more granular metering—such as at the panel, circuit, PDU, branch-circuit, rack or server level—provides the most data to enable closer energy consumption monitoring and control. Yet this type of detailed monitoring can also be the most expensive to install.

According to the U.S. Department of Energy, "metering only at the site and building level is often the cheapest option, however, it is generally insufficient when trying to determine system and facility performance. And if a DC has just site or system level monitoring, or is relying on traditional branch-circuit monitoring to track system performance, that leaves an information gap.

To date, metering engineering specifications for mission-critical facilities have typically focused on high-level power quality metering (PQM). For example, some DCs use switchgear and high-level meters to measure overall power quality and waveform capture. By contrast, branch circuit monitoring (BCM) has focused more on low-level components, measuring watts and other granular data. The power of an MCMS is that it can provide PQM-quality data at the branch circuit level. This is accomplished not by simply adding more meters, but by adding the right, integrated metering systems.

Only by integrating both upstream data (site, building, switchboard level) and downstream data (circuit, PDU and rack level) can operators have a full picture of the power flow at a DC facility—and be able to detect and prevent potentially critical downtime events before they occur. Traditional metering hardware and software solutions have not bridged this information gap—and some vendors do not even acknowledge that there is a need to address it. Both PQM and BCM level data are invaluable, but when they are only available in isolation the resulting knowledge gap leaves vulnerabilities in the power infrastructure.

The lack of integration and the limited features and capabilities of most currently available monitoring hardware and software systems results in significant impact for day-to-day and year-to-year DC operations—in lost efficiency, higher costs, unnecessary power usage, and unplanned downtime.

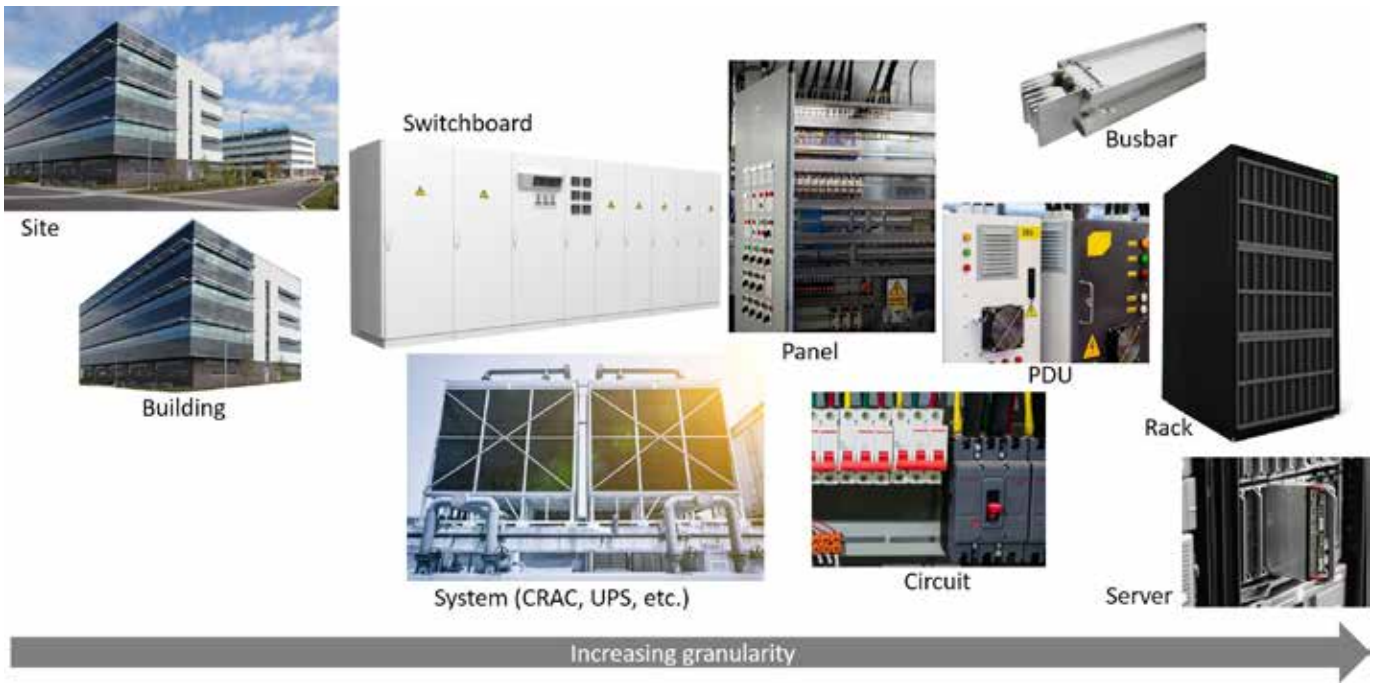

Figure 1. *Levels of monitoring range from site level (measuring the feed from municipal utility services) down to individual rack and server level. Having access to more granular data increases the efficiency and control that can be achieved. An optimal metering set-up results from integrating both downstream and upstream data.*

The Technology Gap – Hardware

Most of the large metering product OEMs have been selling essentially the same solution for a decade or more; there has been little innovation in the market. For example, to implement sub-breaker metering for a six-breaker circuit typically requires a DC facility to purchase, install, monitor, and maintain six individual meters, one per breaker. It is clear how this benefits the OEMs: they get to sell six units, with little incentive to develop better products that would enable customers to integrate metering.

The pressures for maintaining "status quo" in metering technology include a strictly cost-based focus on the part of large electrical component manufacturers. For them, it's more profitable in the short- and medium-term to sell customers the standardized products they already have and can manufacture at mass scale, rather than invest in R&D. In many cases, metering products represent only a fraction of a manufacturer's product portfolio, thus they have little incentive to listen to end-users and software integrators for ideas on how to improve metering products.

The result of this stagnation is that, as legacy data center systems age, there are no effective hardware solutions available to upgrade older equipment. Operators have been forced to turn to various software solutions to try and meet evolving metering objectives. The capabilities of these solutions, however, are still limited.

The Technology Gap – Software

There are many software-based approaches to data center monitoring and control, incorporating not only electrical usage but tracking a full range of system metrics. These software solutions include Data Center Infrastructure Management (DCIM) applications and Building Management Systems (BMS).

DCIM approaches can vary widely and may incorporate many or all of the functions of BMS, such as monitoring and maintaining HVAC and power generation systems, plus IT Service Management (ITSM) functions such as asset tracking and customer service tickets. DCIM also often adds on rack and server management and monitoring data center metrics like utilization/availability, network connections, and more.

DC organizations can choose to purchase commercial off-the-shelf packaged DCIM applications, deploy a patchwork of systems covering different sets of functions, or build homegrown solutions to perform key functions and/or to link legacy systems together. Whatever solution a data center chooses for DCIM or BMS, it's important to be aware of both the capabilities and the limitations of any given solution.

For example, off-the-shelf BCM packages from electrical power OEM vendors often offer a limited set of metrics—those that can be generated easily within the capabilities of their existing equipment product lines. There has not been an effort made to understand the full set of possible metrics that customers might find most useful and then explore ways to provide those metrics by developing new products, features, and reporting capabilities.

MCMS SUCCESS STORY:

A quick and inexpensive solution to track kVA

One large telecommunication DC planned to purchase a large number of meters (one per circuit) from a well-known electrical component OEM to install into their facility. The primary metric they wanted to monitoring across the facility was kVA (kilo-volt-ampere). The meter manufacturer proposed to charge millions of dollars for software licensing and a six-month custom software development and integration service project to accomplish this goal.

The company turned to an MCMS supplier for help. Within two weeks the supplier's product engineering team added a register to its existing MCMS device that could provide a simple calculation: mass × Volts = kVA. The telecom was able to install these custom multi-circuit meters to obtain data they wanted, much more quickly, and with the purchase of a much smaller number of devices, saving both CAPEX and installation costs.

While some of the DCIM and BMS software packages are well-designed in concept, their application, particularly when used to retrofit existing DC facilities, is hardly straightforward. Problems can arise when attempting to integrate with legacy equipment and electrical systems due to several challenges:

- Integrating with different protocols, from BACnet to MODBUS to SNMP;
- Coordinating and rationalizing varied equipment standards and capabilities;
- Configuring the software to function across multiple environments.

The result is that DCIM/BSM implementation costs can add up very quickly, but with no guarantee that the software ultimately will be able to provide the accurate, actionable data needed by DC operators.

The Solution: What's needed in the industry now is smarter metering hardware that can integrate with any legacy systems (whether MODBUS, TCP/IP, Ethernet, etc.), with easy-to-use software. Instead of relying on the same cadre of big electrical OEMs, look for solutions designed and built by companies that specialize in metering systems and have developed innovative products to meet the need of today's users. The solution can be found in MCMS.

Bridging the Gaps: Multi-Circuit Monitoring Systems (MCMS)

As technology has evolved, the data center industry has evolved and grown alongside it, adopting or even pioneering new systems and equipment to improve performance and efficiency. But metering components have not kept pace with this evolution; until recently, the only available products still offered the same basic capabilities year after year. Even when organizations upgrade or replace old equipment, they have only had the option to purchase identical or equivalent components to the old meters they are replacing.

Finally, there is a new, better option in the market. Multi-circuit metering systems take advantage of the last decade of technology advancements—such as smaller processors and chip sets— to create sophisticated metering products that integrate monitoring and analysis capabilities. They can help DC operators not only track electrical activity but increase efficiency and prevent adverse events.

Essentially, an MCMS replaces multiple single-point meters with one sophisticated metering component. An MCMS comes with its own firmware that's capable of connecting with a full range of DC systems and protocols, making it an affordable, "universal" meter that can be installed virtually anywhere—monitoring a UPS, PDU, switchgear, racks in the white space, etc. This adaptability enables an MCMS to capture power quality metrics at a granular level, while linking with other MCM components and legacy meters facility-wide for integrated tracking and analysis.

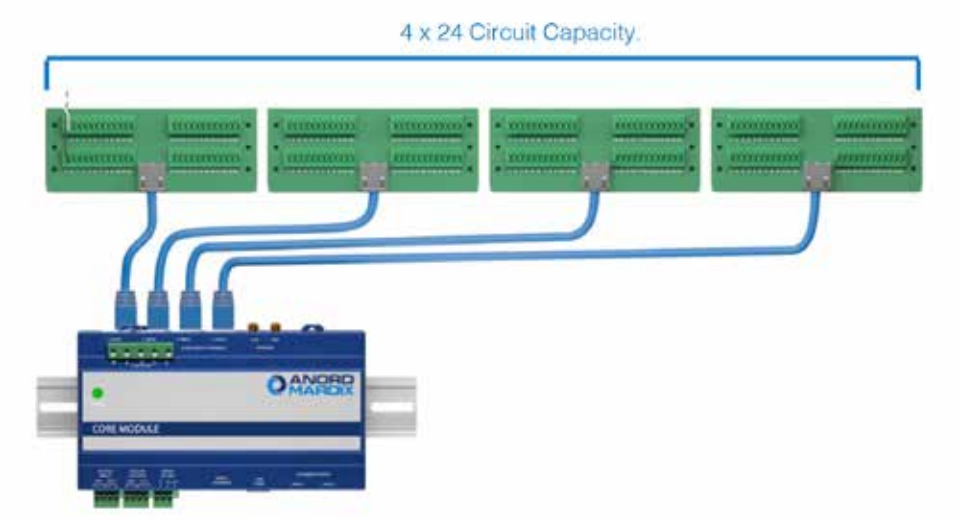

Figure 2. *Example of a basic MCMS installation (for legacy retrofit or new build), using Anord Mardix MCM to provide an economical solution for monitoring switchgear, PUDs, or any electrical equipment. Each CT Interface Card supports 24 circuits. The set-up shown can monitor up to 96 circuits (32 x 3 phase).*

In developing MCMS, engineers set out to create a "calculation engine" that goes beyond off-the-shelf, pre-programmed chips. This innovation has allowed MCMS systems to become much more cost effective than their predecessors, while offering a richer set of features and capabilities. By leveraging technology advancements, an MCMS offers high-end performance at an affordable price. Among their many advantages:

- MCMS systems are a "smart" solution, capable of simultaneously supporting various protocols (e.g. BACnet, SNMP, MODBUS, TCP/IP, etc.), which enables easier integration into software systems without excessive costs of EGX / conversion devices.
- MCMS systems provide more functionality that traditional meters, which typically offer data on just Volts, Amps, and Watts. Now, a single MCMS meter can provide that data plus metrics that previously had only been available by installing multiple high-cost, single-point meters. The MCMS standard adds harmonics, waveform capture, and even measures the presence of voltage at the circuit level.
- A user-friendly interface (built in HTML) for easy set up and and customization. Installing MCMS doesn't require a service technician or vendor software support to configure the system for the specifics needs of any facility. The user interface makes it quick and easy to get the metering installed and the system up and running, for fast start-up and commissioning. It is also easy to make changes when required (e.g., to swap out breakers).
- No overhead software or middleware is required, MCMS uses native Ethernet and all protocols. The system can connect easily with any component that uses standard protocols.
- MCMS hardware is "future-proof"—it was designed with future operating requirements in mind. The systems are modular and scalable to easily accommodate evolving industry standards. For example, the MCMS uses a single IP address, which can be used for more than just metering. Data from IO modules, breakers, temperature and humidity sensors can be consolidated. No separate software system is required to monitor key metrics for PQM, BCM, temp/humidity, and other auxiliary contacts.
- An MCMS has higher polling rates and larger data storage capacity, which enables key data to be captured for later analysis.
- The MCMS is wireless-capable. While many DC facilities run metering connection directly off the main switch; in some high-rise or other facilities it would take extra cost and effort to wire panels for every floor. For these building environments, wireless metering may be a better option, especially as high-bandwidth 5G networks become more widely available.

MCMS SUCCESS STORY

Cost-effective CBEMA-ITIC Metering Solution

Today, MCMS can offer a standards-compliant metering solution that is more cost effective than traditional power meter products. For example, a U.S.-based large enterprise data center needed to purchase Remote Power Panels (RPPs) that could meet the Computer and Business Equipment Manufacturers Association (CBEMA) and Information Technology Industry Council (ITIC) power quality standards. They wanted to be able to establish a CBEMA/ITIC curve to optimize their power.

One option would have been to purchase an RPP and meter from a major electrical OEM. With additional installation and set up costs, the required metering would basically have doubled the cost of the RPP itself.

Instead, the customer purchased an RPP from Anord Mardix for less—which already has MCMS capability build into its firmware—for a complete solution and no additional installation costs.

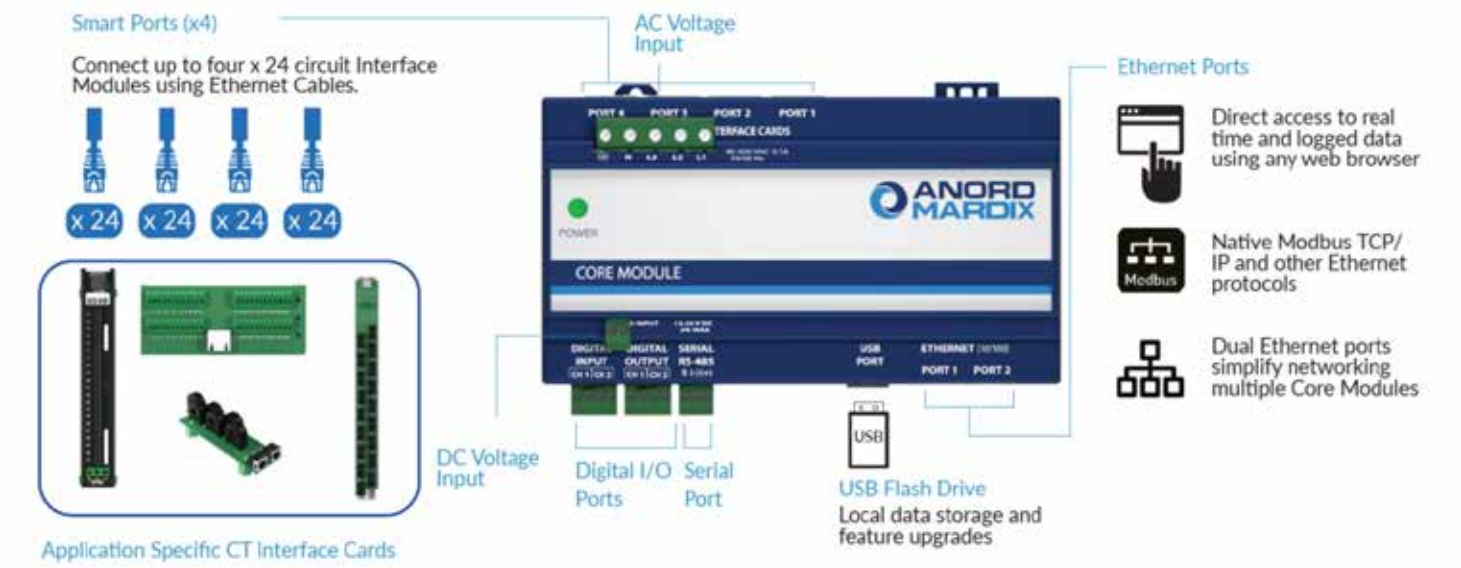

Figure 3. *As a "smart" solution for DC power monitoring, the Anord Mardix MCMS is built around the Core Module 96 circuit power monitor, measuring all circuits in switchgear, PDUs, RPPs, or panelboards to provide critical, logged and real-time data on power consumption. No additional software or integration is necessary, and it can be integrated into DCIM.*

Benefits of Multi-Circuit Monitoring Systems

The benefits of deploying metering systems in a DC environment are well established. MCMS solutions build on those benefits with enhanced capabilities, more data captured, and more actionable insights into what's really happening at all levels of a data center's power systems. MCMS metering is also easy to install and typically less expensive than comparable metering products, while offering more features.

Table 1. *MCMS makes more data available, integrates high-level and granular data, and incorporates advanced analysis, providing myriad benefits to data center owners and operators across every segment of the industry.*

Enterprise DCs	Colocation DCs	Industrial & Commercial DCs
• Standardization on integration (reduces start-up time and overall cost) • Supports PUE initiatives and ROI calculations • RCA • High density supporting functionality - Bulk upload / programming capability -Field serviceable hardware designs - Do more with fewer components (gateways, VREF cards, etc.)	• Supports meeting and reporting on SLA Requirements • Supports billback capability • Retrofit legacy sites (both white and grey space) • Modular approach (RPP / Bus mains monitoring vs. upstream PDU feeds) • Software support	• Provides accurate data for standards adherence • Agnostic solution that integrates with legacy equipment • Product versatility to suit a range of applications

With MCMS, you can:

- **Do more with less.** For example, a switchgear with multiple sub-feeds could have 30 breakers with 6 critical feeders. A typical metering approach would be to install 6 meters, each with a different IP address to be managed. An MCMS solution for the same facility would be installing a single feed capable of metering the entire panel, for a fraction of the cost.
- **Access data at your fingertips.** With a wealth of data now available from MCMS, operators can answer almost any question about power flow, utilization, peak usage, maintenance trouble spots, and more.
- **Standardized metering for easy scalability.** MCMS makes it easier to scale-up or change configurations while obtaining consistent data over time. For example: a common set up might include a panel, with a PDU upstream from that panel, and an STS upstream from the PDU. Using the same metering system for all levels makes it easy to add more components, which integrate into the system for a complete data picture. If a facility has tens of thousands of circuits, scalability is a must.
- **Extend metering across sites.** An MCMS is also extensible across multiple sites, able to interface with any legacy or new metering installations. Data across the network is being measured consistently, allowing apples-to-apples comparison and benchmarking across an entire DC portfolio.
- **Reduce maintenance downtime.** The Andord Mardix MCMS is designed with uptime in mind, allowing the units to be easily serviceable without shut down. For example, an MCMS meter can be installed external to bus taps, compartmentalized in RPPs and PDUs, etc.
- Simplify maintenance and service. We understand what it means to have to open up a panel board—some facilities mandate the presence of a certified electrician working after hours to minimize risk. With MCMS meters, we recommend installing them outside the PDU for easy servicing. A routine repair such as replacing a motherboard on the meter or uploading firmware shouldn't necessitate a shut down.
- **Combine PQM capability with BCM data.** Advanced MCMS integrates the full power of PQM and BCM to provide harmonics and wavefom capture at the individual circuit level. Integrating PQM and BCM capabilities enables operators to have a holistic view of their power infrastructure and utilization.
- **Choose a "modular" and/or customized approach.** Anord Mardix can configure a solution to meet specific needs, from a single point meter to the entire busway. For colocation providers with changing customer contracts, MCMS makes it easy to meter at the rack level, integrate with existing systems, and reconfigure as needed.
- **Make old infrastructure new.** Even without replacing or upgrading existing equipment, installing MCMS can provide visibility into the performance of older systems. For example, we recently had success installing MCMS meters and software for a facility with old 1992 GE panels, giving the customer access to a complete set of data to understand this critical piece of equipment.

The Next Generation in Metering Technology: Advanced MCMS

One factor that distinguishes MCMS is that it gives DCs the ability to integrate not only upstream and downstream power utilization data, but to also incorporate additional analytics—such as harmonics and waveform analysis—that go beyond traditional metering approaches. An Advanced MCMS approach makes use of the capabilities already built in to MCMS meters and then overlays sophisticated software and analytics on top to provide a robust view of the entire electrical landscape of a data center.

Harmonics and Waveforms. Harmonics are unwanted currents or voltage distortions that are multiples of the fundamental line frequency. For example if the fundamental frequency is 60 hertz (Hz), which is typical in the United States, then 120Hz, 180Hz, 240Hz, and 300Hz are the 2nd-, 3rd-, 4th-, and 5th-order higher level harmonics, respectively. Excessive harmonic currents can overload wiring and transformers, creating heat and, in extreme cases, fire.

When an electrical anomaly occurs—such as a voltage sag or swell—tracking data can be used to identify the incident. For example, data can be plotted on a CBEMA/ITIC curve to assess the impact: voltage "overages of durations above the curve can damage equipment, and voltages and overages under the curve can cause operational issues." However, plotting a curve has typically been a manual process that may only reveal issues long after the fact.

For real-time power quality monitoring, waveform capture offers immediate, actionable information. An Advanced MCMS approach enables a facility to capture the waveform of the voltage and current flowing through a node at the instant the anomaly is detected and sync this information with the network clock.

Standards Compliance Today & Tomorrow

In developing its MCMS approach, Anord Mardix kept at the forefront a goal that any new products would not only ease the burden of adhering to all current standards but be able to meet or surpass anticipated future standards. Forward compatibility was deemed essential for the viability and scalability of metering products in an environment of rapidly evolving technology that relies heavily on capital-intensive equipment and systems. Today's equipment investments need to continue delivering value for many years to come throughout the lifecycle of a data center.

For example, with the advent of 5G networks data centers can anticipate increased network volume—but how much and when? Installing meters in multiple areas—mechanical spaces, whitespace, racks, UPS systems, etc.—volumes can be closely monitored until utilization patterns are established and understood.

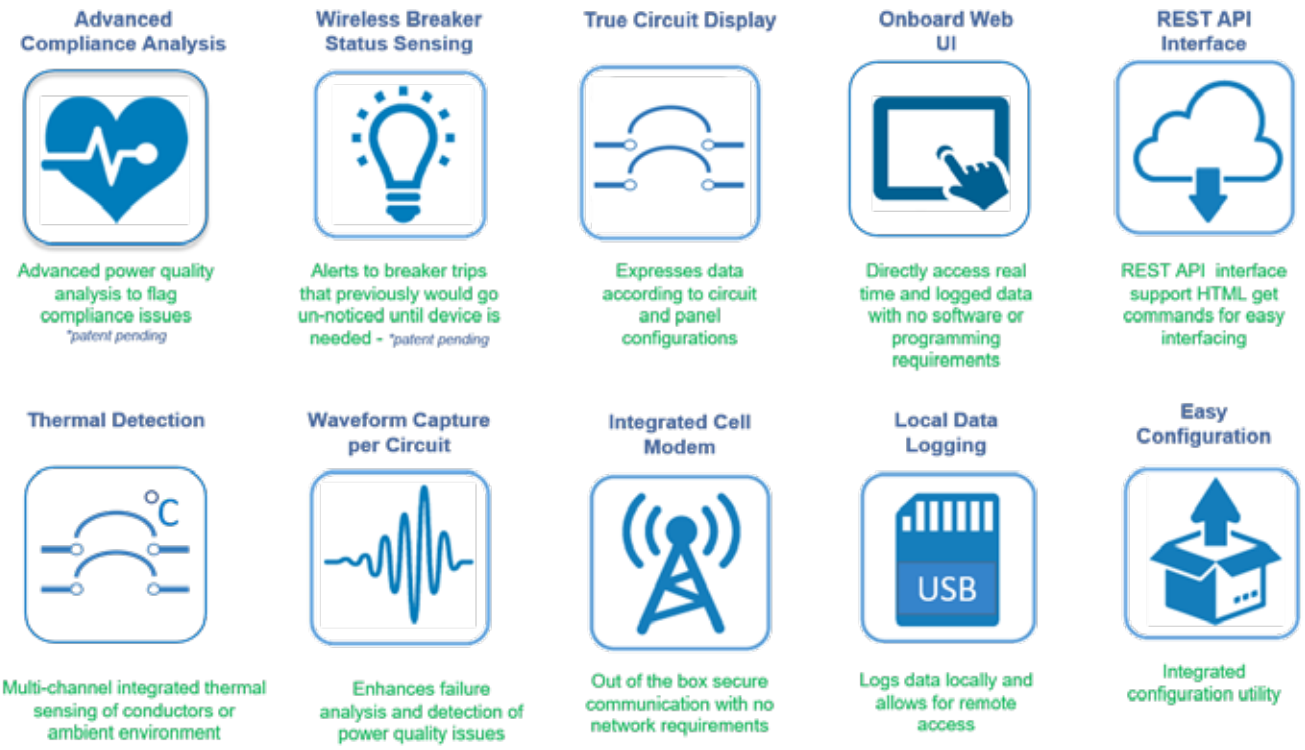

Figure 4. *The full slate of Advanced MCMS features available from Anord Mardix.*

Advanced MCMS: Customer Success Stories. In keeping with the principal "you cannot manage what you do not monitor", incorporating these additional analytics into a facility's monitoring toolkit will greatly expand a DC operators' ability to manage—and prevent problems with—their critical infrastructure. For example, a customer with Advanced MCMS installed at their facility noticed an anomaly in their waveform capture. Refer to Figure 5, below.

They sent the graphs to Anord Mardix support for analysis, and our engineers were quickly able to diagnose that the cause was most likely a breaker going out of phase. The facility maintenance team was able to swap out the breaker to restore system performance. If an overload had occurred on that breaker while its performance was degraded, it would have failed, potentially causing a downtime event.

Similarly, an Advanced MCMS customer was able to use waveform capture to spot a spike on a single circuit. On further investigation, they tracked the spike to a specific rack where a power unit had failed. By catching and replacing the unit quickly, they prevented the single failure from turning into a cascading failure (as other units became overloaded) and taking down the entire rack.

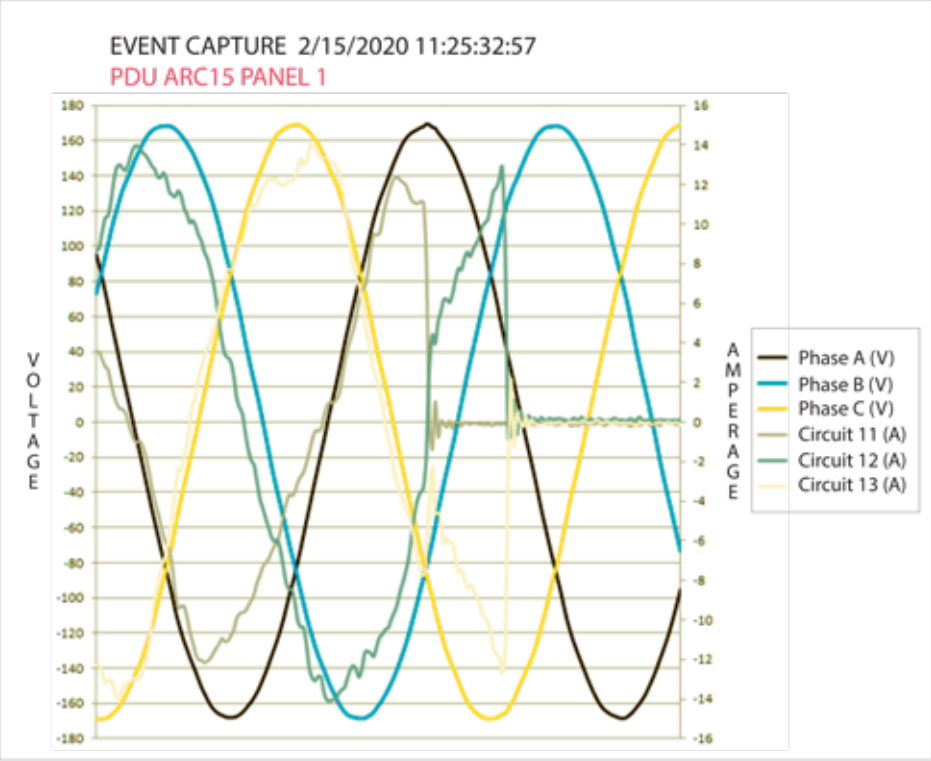

Figure 5. *Waveform capture graph generated from the Advanced MCMS at a customer facility (top) indicates that a breaker was experiencing some current anomalies likely due to faulty loads. The waveform capture provides evidence that this issue was load based specific to this circuit and was not a result of poor power quality from the source.*

Applications of Advanced MCMS

The above cases are just two examples of how Advanced MCMS has enabled customers to troubleshoot issues that occur at a granular level and use high-grade analytics to prevent large-scale adverse events. There are many additional use cases where Advanced MCMS delivers value, from identifying a single tripped breaker to monitoring a high-density mission-critical network of facilities. Refer to the additional use cases outlined in **Table 2**, below.

The ROI of Advanced Multi-Circuit Monitoring

The monetary return on investment for any advanced MCMS installation depends on a range of different factors that can vary widely across different facilities, infrastructures, and business models. It is challenging to define a universal ROI customers can expect; nevertheless, the benefits of advanced MCMS are broadly applicable in most data center environments. Those facilities who have deployed MCMS report positive—often significant—ROI. An organization can examine the impacts outlined below to quantify how they might apply to its operations, and thus estimate an anticipated ROI. MCMS can have a direct and long-term impact on data center costs in the following areas:

- **Measure peak demand capability:** Accurate, detailed measurement enables colocation data centers to identify utilization trends, apply peak-demand pricing, and provide more accurate and detailed billing statements to their customers. This information helps customers better understand their service patterns and costs, leading to increased customer satisfaction and retention.
- **Mitigate overtime costs:** Deploying metering has the immediate effect of reducing the overtime costs often associated with taking manual readings of every panelboard circuit. Automating circuit data capture might include using local displays, placing meters on separate networks, etc. To calculate the ROI, determine ongoing labor costs, then compare those figures to the one-time cost of MCMS purchase and installation. After a break-even point is reached, additional cost savings are pure ROI.
- **Reduce stranded capacity.** Facilities without metering typically must incorporate a generous amount of "buffer" in operating thresholds to ensure adequate margin of error for the integrity of the facility. This can result in a significant amount of stranded capacity and underutilization. Deploying MCMS enables operators to identify and understand their stranded capacity. It provides the data needed to balance loads throughout the facility to avoid overloading circuits and mitigate the risk of potentially dropping a load.
- **Customer Billback.** MCMS enables colocation providers to employ real-time revenue grade monitoring, providing the option of billing customers on actual usage, and potentially saving lost revenue. The customer marketplace has already started to shift towards this billing model. Installing MCMS capability today will enable operators to immediately change over in response to existing or new customer requests, thus keeping a competitive edge in the market.
- **Facility Management I (at the Macro level):** An MCMS enables DCs to calculate the amount power going to cooling vs. the amount of power going to servers—and understand the gap. The larger the gap, the more potential areas there are for facility improvements.
- **Facility Management II (at the Micro level):** By identifying racks that are consuming the most power consumption, a data center can identify those that will require the most cooling (e.g. racks that will need to be located on a raised floor with vented tile positioning). Thus MCMS data supports the most accurate space planning.
- **Increasing Safety:** With MCMS branch metering, a facility can limit the exposure of its workers to high voltage and reduce the risk of arc flash. Having access to granular-level data from outside a panel also reduces the potential of tripping branch circuits. Any time a human has their hands on an electrical panel there is potential risk. With MCMS, cover panels no longer have to be opened for hand clamping, thus mitigating safety concerns.
- **Lifetime TCO:** With detailed, integrated metrics provided by Advanced MCMS, data centers can create detailed modeling of the costs associated with all types of systems and equipment. Incorporating initial purchase and installation costs with ongoing power and resource utilization metrics yields a true picture of capital and operating costs. This data lets DCs calculate break even and total cost of ownership over the lifetime of their equipment.

Conclusion

Whether a facility needs better load management, accurate PUE calculations, or just a better method to maintain adherence to customer SLAs, the common goal for any metering deployment is to capture the most valuable data in the most cost-effective way. The good news for data centers is that technology development has allowed forward-looking meter manufacturers to develop innovative new components that offer more features for the same or lower price than traditional meters: MCMS. These new metering systems are also easier to install and service, thus saving additional costs for installation and maintenance.

Using an Advanced MCMS approach, DCs can obtain a robust set of metrics, bringing the insights of PQM to the branch circuit level. Whatever the facility or organizational need, advanced MCMS can help support optimal efficiency and performance in the areas of:

- Operations management
- Facility management
- Providing a standard (and repeatable) approach
- Equipment lifespan
- Customer (end-user) satisfaction
- Adherence to regulations & mandates

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Table 2. *Examples of MCMS use cases, based on real-world customer experiences.*

MCMS Application	Use Case Description	MCMS Value
Facility Management **KEY CONCEPT: reducing the need for human touch reduces the risk of human error**	**Problem:** During routine maintenance windows, any hands-on activity has the potential for human error, such as breakers being tripped by accident, or the wrong RPP being shut down, or similar issues. Using PME with all meters integrated into a single system, inaccuracies result (e.g., showing 0 load when there is load). **Solution:** MCMS branch-level metering with waveform capture increases the accuracy of the subfeed metering, revealing the presence of any load, however small. If breakers are tripped or other interruption, waveform threshold breaches create an alarm notification and capture it as a timestamped event. This data enables customers to identify errors in standard MOPs and provides documentation for internal training. Helps sequence of operations – all metrics are timed off the same clock (e.g., 10 x PM8000 on SWBD will all use a different clock, which may be close but not exactly synchronized). Coordination studies are more valuable and substantial.	• Accurate metering and automatic tracking captures human error at the moment it happens, identifies the source, and allows immediate action to rectify. • Increases efficiency for facility operations procedures
Problem Identification **KEY CONCEPT: Having "eyes" on all parts of the data center**	**Problem**: rack-level outages caused by undetected power supply failures. Leading to breach of SLA agreements and financial penalties, slow response time for resolution, and customer dissatisfaction. **Solution:** A retrofit to install Advanced MCMS with waveform capture at the circuit level enabled rapid identification of a faulty power supply isolated down to the exact rack. Upon investigation, the A-side power supply was found to be inoperable: it was the cause of a current spike and resulting threshold breach).	• Cost savings in reduced manpower spent chasing faults • Cost savings in eliminating SLA penalty payments • Customer satisfaction improvement • Analytics to speed up RCA

MCMS Application	Use Case Description	MCMS Value
Smart Breakers & Strips	**Problem:** Accuracy standards for metered breakers are not as regulated as ANSI and IEC metered parameters. Often, they do not reflect accurately until load reaches 50% of breaker rating. However, Reliance upon inaccurate systems can cause confusion. Additionally, these systems are conjoined with the breaker. If a comms board fails, an entire shutdown is required to swap that single breaker. **Solution:** Use of split core CTs and an MCMS metering system isolated from the breaker creates an environment more conducive for maintenance. MCMS provide more analytics and are regularly more cost effective than metered breakers or "intelligent PDUs".	• More actionable information • Better serviceability • Higher standards of accuracy
Maintenance **KEY CONCEPT: "KISS" (Keep it Simple, Separate)**	**Problem:** Typical OEM metering installations add complexity: meters are installed directly into the power distribution equipment. These systems often use multiple circuit cards (comms, processing, Voltage, etc.) and require each functional board to have a different firmware. When any one of these components go bad, on-site service are needed, requiring coordinated shutdown, which results in excess maintenance labor time and cost. Instead, system designs should simplify maintenance, by incorporating features that allow for easy field-service and replacement when needed. If meters are installed in a compartment outside the panel box, there is no need to open up the panel for routine maintenance checks. Shutting down critical loads should be minimized and done when absolutely necessary. **Solution:** • MCMS designs isolate metering components from the distribution equipment (e.g. panels, busway, internal compartments, etc.) • Simplified meter designs limit the number of circuit cards (and firmware) required • Additional MCMS features to facilitate ease of maintenance include: DIN rail mounting, split-core CTs, Web interface, standard firmware, and more.	• Reduced downtime and eliminating the hassles associated with standard troubleshooting procedures and maintenance activities • Increase safety and reduce risk of accident during routine maintenance
Preventing Equipment Faults **KEY CONCEPT: You can't manage what you don't measure**	**Problem:** Redundant in rack power supplies do not often report status. This means the system can suffer an outage when shifting from A side to B side, if the B-side power supplies are bad and the condition has gone undetected. **Solution:** MCMS can monitor current at the breaker level, detecting spikes that alert end users to investigate specific racks for potential issues, before the power supplies fail during use.	• Value: Reduces troubleshooting times (cost savings) • Mitigates risk of unexpected downtime • For colocation providers, improves customer satisfaction • Provides analytics to speed up RCA, accelerate solution

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