TIA

WHITE PAPER

POWERING THE EDGE

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INTRODUCTION

Edge data centers (EDCs) are typically smaller than a traditional data center. While they may be deployed in traditional data centers, increasingly, they are deployed stand-alone in small configurations ranging from one to a few racks. EDCs can also be prefabricated modules that are built offsite with the necessary infrastructure, such as containerized purpose-built edge data center placed at a site (i.e., 5G cell tower, industrial site, transportation hub, etc.).

While EDCs often need to adapt to varying conditions based on the location, considerations for the design and construction of the facility and the availability of resources remain the same. An EDC therefore still requires an infrastructure that delivers critical power capacity essential for operations. While edge computing addresses the challenges of latency and transport cost associated with traditional data centers, electrical power in the EDC must also be planned to support required rack densities while ensuring effective power distribution, availability, efficiency, and protection.

SUPPORTING RACK DENSITY

Rack power density in all data centers is on the rise as new high-performance applications and powerful hardware that packs more power into each piece of equipment become commonplace. Data center owners and operators are therefore striving to save space by consolidating workloads. The same rack density and efficiency trends seen in larger data centers are also seen in edge computing. The infrastructure required for supporting a smaller EDC footprint therefore results in increased power density per rack.

Planning for the right rack density and installing the supporting electrical infrastructure will ensure the usefulness of the site for many years. For future proofing, a key recommendation is to design the infrastructure for future capacity expectations, even if less power is initially required. In addition, when options are available for different voltages at the EDC site, higher voltage should be chosen as it allows higher power density to be provided with lower amounts of current, which translates directly to lower losses.

Table 1 below can be used to determine the appropriate power circuits that could be brought to the rack to support the required density. If utilizing AC Power, bringing 3-phase power to the cabinet should be considered as it can support much higher power densities with similar amount of current. As shown in the table, a 3-phase 30A/208V circuit can provide 8.6kW of power, which is significantly higher than a 5kW capacity supported by a single-phase 30A circuit. Bringing 3-phase power to the cabinet level also helps with load balancing and minimizing upstream harmonic currents.

NORTH AMERICA

Typical Circuit	Typical Plug Type	Equipment Voltages Supported	Max. Capacity (kW)
1-ph 15A, 120V	L5-15 / 5-15	120V	1.4
1-ph 20A, 120V	L5-20 / 5-20	120V	1.9
1-ph 30A, 120V	L5-30	120V	2.8
1-ph 20A, 208V	L6-20	208V	3.3
1-ph 30A, 208V	L6-30	208V	5
1-ph 20A, 120/208V	L14-20	120V, 208V	3.3
1-ph 30A, 120/208V	L14-30	120V, 208V	5
3-ph 20A, 208V	L15-20	208V	5.7
3-ph 30A, 208V	L15-30	208V	8.6
3-ph 20A, 120/208V	L21-20	120V, 208V	5.7
3-ph 30A, 120/208V	L21-30	120V, 208V	8.6
3-ph 50A, 208V	CS8365	208V	14.4
3-ph 60A, 208V	460P9/460P9W	208V	17.3
3-ph 60A, 120/208V	560P9/560P9W	120V, 208V	17.3
3-ph 20A, 240/415V	L22-20/520P6/520P6W	240V	11.5
3-ph 30A, 240/415V	L22-30/530P7/530P7W	240V	17.2
3-ph 40A, 240/415V	532P6/532P6W	240V	18.4
3-ph 60A, 240/415V	560P6/560P6W	240V	34.5

INTERNATIONAL

1-ph 10A, 220/230/240V	Country Specific	220V,230V,240V	2.2/2.3/2.4
1-ph 16A, 220/230/240V	Country Specific / 316P6/316P6W	220V,230V,240V	3.5/3.7/3.8
1-ph 32A, 220/230/240V	332P6/332P6W	220V,230V,240V	7/7.4/7.7
3-ph 16A, 220-240/380-415V	516P6/516P6W	220V,230V,240V	10.5/11.1/11.5
3-ph 32A, 220-240/380-415V	532P6/532P6W	220V,230V,240V	21/22.1/23
3-ph 63A, 220-240/380-415V	563P6/563P6W	220V,230V,240V	41.4/43.6/45.2

Table 1: Typical circuits vs. equipment power requirements

DISTRIBUTING POWER

When it comes to distributing power in an EDC, it's important to first know what is considered critical or non-critical power loads. Critical load includes servers, storage, switches, and other devices required for operation, as well as security systems such as fire detection and suppression, video surveillance, and access control. In an EDC, the monitoring and management system is also now considered a critical load component due often remote location and lack of human presence. Critical load systems for any EDC deployment should ensure clean, high-performance power and 100% availability compared to non-critical loads, which include systems and equipment that do not impact functionality, operations, or security of the EDC. (i.e., lighting, printers, etc.)

PRIMARY AC AND DC POWER SOURCE

EDC operators should choose primary power distribution based on available source, the needs of the equipment, availability and serviceability requirements, capex and opex, and energy efficiency opportunities. When considering AC or DC primary power, key decision factors include capacity of the system, utilization percentage, and efficiency based on load, equipment power type uniformity, battery type/quantities, and allied infrastructure capex and opex.

For a primary AC power source, high-voltage (HV) or medium-voltage (MV) power must be stepped down to low-voltage (LV) based on the power supply requirements. Deployment of step-down infrastructure should be carefully sized for availability, losses, and the capex and opex required for setup, operation, and maintenance. While traditional equipment runs via AC power, some data center equipment has shifted to more efficient DC power that limits losses. While it is ideal to simplify the power distribution method to reduce inefficiency from power conversions, implementing only DC power is often not an option due to a mix of power input requirements from various devices. Implementing a DC-only power source may also be complicated due to limitation of the available site power source.

Telecommunications systems have long been powered via DC power, which has the advantage of safety and the ability to be stored via batteries versus other forms of backup power such as diesel generators that require frequent periodic maintenance and refueling, which can be challenging at remote EDC locations. While a majority of DC systems operate on -48V per the traditional standard, other commonly used DC voltages for equipment include +24VDC and -60VDC. These voltages provide the ability to work on live conductors with minimal risk of personal injury. While there are other DC voltages used throughout the world, ranging from 20VDC to 110VDC at the equipment end, and up to 600VDC for battery backup systems, this paper focuses solely on DC power distribution from the source (i.e., battery, UPS, etc.) to end equipment such as a switches, routers, multiplexers, and servers.

When distributing DC voltage, voltage drop over the length of circuit, especially at the battery end-point voltage (EPV), is a key factor. Managing voltage drop is significantly easier in smaller-size EDCs versus traditional data centers and equipment rooms. However, it is still necessary to carefully calculate voltage drop according to distance from the DC power source and other loads on the same circuit to ensure that cables are appropriately sized to match the final loads. While performing voltage drop calculations, worst-case scenario should be utilized, which includes the maximum loads at the maximum distance(s) at a total battery discharge condition. A possible strategy to reduce the required cable cross sections and number of runs is to consider the use of busways to distribute DC power that enable a lower voltage drop per meter. This may prove to be especially beneficial for EDCs where space can be limited.

UNINTERRUPTIBLE POWER SUPPLY (UPS)

UPS are the lifeline for any critical infrastructure, ensuring continuous and uninterrupted operation in the case of outages, while delivering clean power to sensitive networking equipment. There are three common types of UPS systems:

- Online—Generally known as double conversion UPS, online UPS systems convert the incoming AC power to DC and then back from DC power to AC for output. Due to this double conversion, the AC output is clean pure sine wave power that is more efficient and less damaging to critical equipment. Online UPS are widely used for protection of equipment requiring an AC power supply.

- Line Interactive—Providing both power conditioning and battery backup, line interactive UPS always has the battery-to-AC power converter always connected to its output. When the input power fails, the transfer switch opens and power flows from the battery. Line interactive USP offer less protection against variations in electrical frequency and harmonics than online UPS.

- Standby—Also known as offline UPS, standby UPS is a simple, inexpensive way of distributing power to equipment directly from the mains input with limited filtration and integrated surge protection. This UPS with its simplest design and technology is better suited for small offices, personal home computers, and other less-critical applications, and is therefore not recommended for EDCs.

Power quality issues can occur at any location, and online UPS should be used for protection of all EDC critical loads that require uninterrupted operation, as well as considered for non-critical loads.

RACK-LEVEL POWER DISTRIBUTION UNITS (PDU)

Rack PDUs are the last leg within the power chain where the facility power and the IT infrastructure intersect and cannot be overlooked. Modern day intelligent PDUs can also provide integrated environmental monitoring and access control, making them the foundation of an effective rack-level management strategy. Rack PDU's are generally available in six different functionality levels as shown below in Table 2.

Functionality	Basic	Locally Metered	Branch Metered	Outlet Metered	Switched	Switched & Outlet Metered
Basic Distribution	✓	✓	✓	✓	✓	✓
Remote Management			✓	✓	✓	✓
Input Metering		✓	✓	✓	✓	✓
Branch Circuit Metering			✓	✓	✓	✓
Outlet Level Metering				✓		✓
Outlet Level Switching					✓	✓

Table 2: Types of PDUs and their functionality

For EDCs, it is highly recommended that rack PDUs with remote management capabilities are chosen. Outlet switching enabled by relays at each individual outlet of the PDU is also highly recommended as it allows power to individual IT equipment to be turned on or off or recycled remotely. This capability can save EDC operators and network managers from making a trip to the site just to reboot hung-up IT equipment, as well as allow site administrators to properly provision IT equipment. As a best practice, all the outlets should be kept in the off position until a request has been received and approved by the administrators. In addition, it is highly recommended that the relays of an outlet switching PDU be "bistable / latching" type as they draw power only in the event that they change state. Preventing unnecessary power draw during normal operation can ensure longevity of the relays, as well as help improve overall efficiency.

PDUs with outlet level metering capability are also ideal for improving efficiency, as it provides visibility into equipment draw of individual IT equipment. This information allows identification of ghost servers that are no longer in use but still consuming energy, providing justification for new energy-efficient IT equipment. The information can also serve as the basis for setting appropriate power budgets for each piece of equipment, either within the equipment software or via a data center infrastructure management (DCIM) solution.

Additional considerations when selecting rack PDUs for EDCs include:

- Compatibility with the electrical circuit being brought to the rack.
- Physical compatibility with the rack.
- Appropriate number and type of outlets to support all equipment that will be installed within rack.
- Ability to handle ambient temperature of at least 60 °C. Note that if a vertically-mounted PDU is chosen, they may be mounted in the back of a cabinet behind the server exhaust where temperatures are higher.
- Ability to network and consolidate multiple PDUs via IP addresses. It is also desirable that a redundant communication path is available in the event of a network connectivity loss within the array.
- Simple integration within DCIM platforms through the support of integration methods such as SNMP (Simple network management protocol), API (Automated Programmable Interface) or CLI (Command-Line interface).
- Ability to perform bulk configurations and firmware upgrades for rack PDUs remotely.

POWER DISTRIBUTION CONFIGURATIONS

In designing the power distribution systems from incoming power sources to UPS to rack-level PDUs, there are multiple power distribution scheme options as shown in Figures 1, 2, and 3 below.

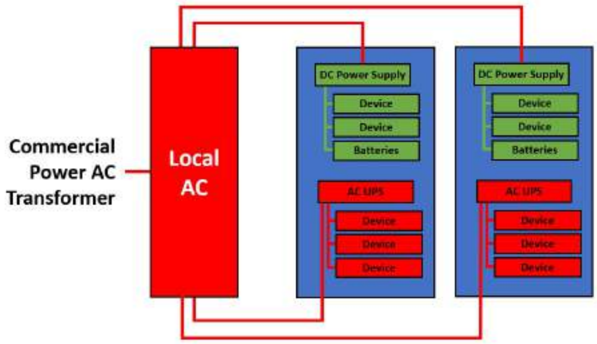

Figure 1: Commercial power to individual racks/cabinets

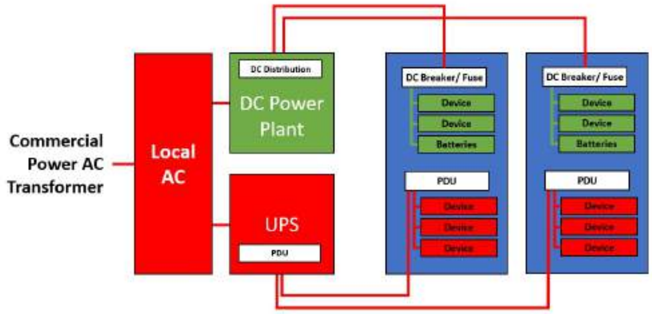

Figure 2: Commercial power to DC power plant / UPS

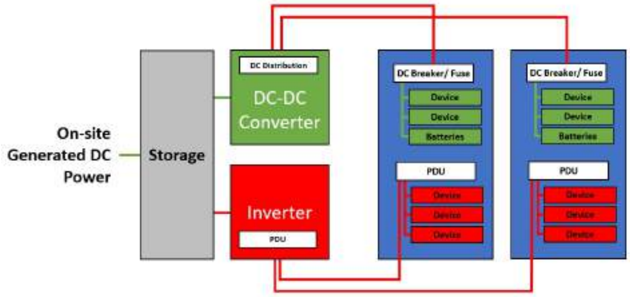

Figure 3: On-site generated power (i.e., generator, fuel cell, renewable) to individuals racks/cabinets

ENSURING RESILIENCY AND AVAILABILITY

All powered equipment is susceptible to failure or may need to be turned off for maintenance, but the critical nature of ICT equipment cannot afford any unplanned downtime. A resilient, redundant power infrastructure for any facility is key to success for any data center, but EDCs have additional challenges. While traditional data centers largely focus on concurrent maintainability and continuous operation, EDCs also have to consider challenges such as lack of access and availability to resources due to their often remote location. EDCs therefore need development of strategies that work in conjunction with the infrastructure to provide continuous operation.

REDUNDANCY

Redundancy of the capacity components (generators, UPS, HVAC) and distribution paths plays a vital role in ensuring availability. Multiple configurations of redundancy can be implemented via UPS and local alternate power sources (e.g. generators, batteries, etc.) to provide minimal or no interruption of power in case of utility failure.

- **Parallel Redundant (N+1, N+2...N+X)** — A parallel redundant configuration is known as an N+1 redundant UPS capacity configuration. This configuration requires a UPS system to have matching UPS configured in parallel with both outputs connected to a single bus. A parallel redundant configuration can have multiple UPS in parallel configuration, with the maximum number of units defined by the manufacturer. Multiple UPS of same size, manufacturer, and model can also be in parallel with only one unit as a redundant unit. If one UPS fails, the parallel UPS would keep the output continuous with need (N) capacity, sharing the load on all the UPS in the configuration. The outputs of multiple UPS are synchronized using communication cabling between the UPS and common output bus. A parallel redundant configuration is set up in a single electrical distribution path using a single/common power supply.

- **Isolated Redundant** — An isolated redundant configuration works in a single electrical distribution path using a single/common power supply but does not have any UPS in parallel or provide a common output to bus. In an isolated redundant configuration, the redundant UPS does not have to be of the same size, make, or model and can provide system redundancy in case of a UPS failure. Isolated redundant configurations have two UPS in the single distribution path with the first UPS output connected to the second UPS output, and the second UPS output connected to the output bus. In case of failure of the second UPS, or during maintenance, the first UPS will supply power to the output bus with the second UPS output switched to bypass mode.

- **Distributed Redundant (3N/2)** — The distributed redundant configuration known as a three-to-make-two, or 3N/2, provides three or more UPS system/modules with independent input power supplies and output bus. The independent output buses are connected to the load via multiple PDUs and static transfer switches (STS). This is similar to the system+system redundant design described below, but with more probability of output power supply to load with greater redundancy. In case of failure of one UPS, the others will provide continuous power to both individual buses and rack PDUs. Load management is a significant challenge in this type of redundancy configuration.

- **System+System Redundant (2N)** — A system+system compartmentalized redundant configuration is a popular choice in both concurrently maintainable and fault-tolerant rated design. Independent UPS on individual paths provide output to individual dual buses, supplying power to independent rack PDUs. In case of failure of one system, the redundant system will take the complete load and continue to provide uninterrupted power.

STANDBY AND EMERGENCY BACKUP POWER

While EDCs may rely on redundancy of network and mirrored applications for resiliency, many will still require standby and emergency backup power beyond the temporary power of UPS in line with traditional data centers. Popular choice for backup power has always been fossil fuel backup power generators. Alternative standby power technologies may also be implemented, such as hydrogen power cell, direct attached renewable energy, or long-life autonomy battery systems.

When selecting a type of standby power, environmental conditions such as weather, temperature, and altitude should be considered. For example, when deploying generators, many fuel types (i.e., A-type, diesel, kerosene, etc.) may gel at cold temperatures. The availability of fuel and continuous supply, especially in challenging situations like pandemics, is also a key consideration for generators. Operators should have well defined contracts with fuel supply providers, and it is highly recommended to create hubs of fuel storage within the nearest regional data center for emergency situations, natural disasters, or any other situation where a fuel supplier may be unable to fulfill requirements. In general, EDC operators should adopt the best tried and tested method of backup power and continue relying on it.

FAULT TOLERANT OPERATIONS

Fault tolerant operations provides maximum redundancy and availability scenarios and necessitates EDC operators having multiple scenarios and management capabilities to keep a site up and running amidst all possible worst-case scenarios. In addition to establishing a core redundancy requirement with system+system redundancy, following are additional key requirements for achieving fault tolerant operations:

- Maintain a minimum of fuel storage based on use cases.
- Establish redundant fuel supply contracts.
- Use a minimum of concurrent maintainability, with a fault tolerant power infrastructure preferred.
- Design 2N compartmentalized capacity components and distribution paths
- Implement continuous and intelligent monitoring and management of cooling, power and fuel supplies for proactive problem resolution.

IMPROVING ENERGY EFFICIENCY

While meeting demand for rack density while ensuring optimal, reduced latency, and lower transport cost is critical, an EDC should not compromise on energy efficiency. In fact, energy efficiency remains a key consideration for all data centers, and every opportunity to save energy should be considered during the initial design phase.

Mechanical infrastructure has always consumed significant power, but due to their smaller size and often remote, unmanned operation, EDCs may provide opportunities for energy-saving practices such as lights-out operation, liquid and free cooling, and other innovative cooling methods. The smaller form factor and dedicated and often self-contained or portable functionality of an EDC also typically requires shorter air supply and return patterns, which may warrant exploring efficient cold-air delivery methods. The wider temperature and humidity range specified by the latest ASHRAE standards also enables operating at temperatures that require less cooling and associated energy.

When selecting equipment for AC power load with energy efficiency in mind, high-efficacy uninterrupted power supplies (UPS) should be adopted. Air conditioning should also have the ability to follow the change curve of load and not waste electricity due to excessive refrigeration. This can be achieved via emerging technologies such as self-learning controls. In addition, today's server equipment with variable fan speeds as opposed to constant speeds allows for sufficient cooling while consuming less energy. Decreasing the air supply temperature allows for lowering the fan power of these servers to achieve higher energy savings as the fans. The impact of increasing air temperature on servers therefore needs to be carefully weighed against the potential energy savings of the cooling system.

The ability to measure power usage is critical to ensuring energy efficiency. Power Usage Effectiveness (PUE) is an energy efficiency metric originated by the Green Grid that is widely used to measure efficiency of a data center at a glance. It is calculated as the ratio of total amount of energy used by a data center to the amount of energy delivered to computing equipment, where a PUE of 1.0 represents 100% of the power being utilized by the IT load. Energy efficiency metrics in an EDC remain a key factor for operations, and optimal PUE ranging from 1.2 to 1.4 can be achieved by using efficient cooling, standalone infrastructure with compact sizing, and minimum requirements for ancillary power loads. EDCs located in remote regions can integrate PUE monitoring capability locally. This capability can also be integrated into a centralized monitoring system to provide operators with valuable information about energy consumption and site efficiency for managing local or regional implementations.

An EDC can be part of any existing enterprise infrastructure or a dedicated new construction. Enterprise facilities that support an edge computing infrastructure need sufficient planning and ongoing analysis to ensure sustainable infrastructure. Opportunities to purchase or generate electricity without carbon emissions varies widely based on location, and considerations for any upgrade or new infrastructure should review energy sources and environmental impact.

Battery storage and alternative energy sources (i.e., solar, wind, geothermal, fuel cell, etc.) that face physical and economic constraints in a traditional data center deployment may be feasible for EDC sites. This may present unique opportunity to improve sustainability while reducing power consumption, optimizing utilization, and supporting new applications compared to traditional data centers. Power usage monitoring and demand response programs through coordination with local utilities may also provide the opportunity to shift energy usage to off peak hours or recover waste heat for other uses, further reducing the impact on the environment while lowering energy cost.

DEPLOYING PROPER POWER PROTECTION

BONDING & GROUNDING

Like any data center, power protection and bonding and grounding should also be a part of an EDC power infrastructure. However, in EDC deployments, bonding and grounding may require the installation of earthing rods specific to the site. As with other data centers, the bonding and grounding system should provide grounding pathways for telecommunications equipment separate from other mechanical and electrical devices, with both being bonded to a common building grounding electrode system.

When deploying EDCs in existing buildings, the building's primary bonding busbar will be used. It's also important to still use separate bonding conductors for telecommunications equipment versus other mechanical and electrical systems. Like any data center, keep in mind all the EDC components that require bonding, including racks, cabinets, cabinet doors, mounted IT equipment and components, pathways, etc. The ANSI/TIA-607 Bonding and Grounding (Earthing) for Customer Premises provides detailed recommendations and guidelines for bonding and grounding telecommunications infrastructure. Before implementing, always check and follow national and local codes that may exceed or differ from the requirements of ANSI/TIA-607.

FARADAY CAGES

An inherent advantage of DC power that has been leveraged by telco companies is the use of a Faraday cage formed via continuous covering of conductive material that allows equipment to be shielded against static electric fields. For example, if there is a lightning strike against a nearby structure, massive voltages are generated that can cause induction currents into systems or equipment, resulting in failures. A Faraday cage, which is essentially a hollow conductor, protects the equipment within by causing voltages to flow around the cage's exterior rather than within its interior.

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When using DC power distribution, a Faraday cage can be established around the EDC (i.e., enclosure, rack, container, or other built space) to better safeguard equipment. It is especially a consideration at telecom sites with towers that have a higher risk of lightning impact. Using a Faraday cage around an EDC does however require the AC power to be terminated outside of the Faraday cage. If AC power is required within the EDC, a DC-to-AC inverter would be required.

While the use of an inverter enables the use of a Faraday cage in scenarios that require mixing DC and AC power within an EDC, manufacturers, vendors, and operators/users should be extremely cautious. While ground is ground, DC power uses ground as a reference point for 0 volts DC. AC power does the same at the transformer level, but at the point of use, ground is used to discharge fault currents. When AC and DC power is mixed within an EDC, AC and DC equipment should therefore be segregated either into separate racks, or preferably even separate rows to ensure that AC fault currents with lower resistance and direct path to ground do not mix with the DC ground. Any AC fault currents introduced into the DC system have the potential of damaging DC-powered equipment as AC voltages would far exceed the tolerances of the DC equipment.

FUSE FAIL

Having electrical protective devices integrated into monitoring systems can capture information when any protective devices have tripped. This information can be used to analyze root causes and deploy additional power protection measures to avoid future events.

There are also best practices to ensure protection and minimize risk in the early stage of design that should be followed. For example, arc flash detection and protection of electrical panels is critical for improving improve safety and reducing damage effects of a fault, as well as for measuring fault current and light via arc sensors to minimize arc effects. Arc flash protective systems can also be integrated with other facility and EDC monitoring systems via open communication protocols.

SURGE PROTECTION

A Surge protective Device (SPD) formally known as Transient Voltage Surge Suppressors (TVSS) is a critical device in the pathway of the power and data circuitry. It prevents damage or downtime of active device by diverting or suppressing over current and over voltage during hazardous events such as lightning. An SPD should be placed at the port entry of an EDC facility, container, or enclosure for all power/data metallic ports. In North America, SPDs must meet the NFPA®70, NEC® and/or ANSI/UL® 1449 standard. An SPD is coordinated with its protected circuit and therefore must be selected and sized correctly.

MONITORING AND MANAGING POWER

With edge computing and 5G/6G technology deployments gaining ground globally and becoming more critical than ever, outages could be catastrophic during emergency situations such as natural disasters, pandemics, and acts of war. Operators therefore need to be prepared for the worst possible outage with best possible plan for serviceability. EDCs also have a wide range of operation possibilities with manned to unmanned infrastructure and remote to suburb locality. Monitoring and management systems are critical to ensuring availability and energy efficiency of EDCs.

Monitoring systems like DCIM and building management systems (BMS) can become the onsite eyes and ears for the EDC operator. These systems are critical for monitoring power infrastructure proactively and predictively at remote, unmanned sites. They provide vital information that can be used to ensure ongoing maintenance and to forecast and prevent potential failures. They also provide a unified tool that can provide a broader view of the EDC, beyond just power monitoring. Remote management and control systems are also critical to being able to perform certain tasks without physical presence. Any monitoring and management system selected for an EDC should also be supported via larger operation centers that monitor and manage multiple EDCs with service teams available to engage as needed.

PRIMARY POWER MONITORING

With energy efficiency a key driver, from upstream power to the rack, measuring the incoming AC power provides vital data to determine power consumption and PUE, as well as provide information around critical electrical parameters such as power quality, utility power status, harmonics on the installation, and possible effects from nearby installations.

Monitoring of automatic transfer switches (ATS) that transfer load between primary and alternate power sources is essential for viewing ATS status and source position and indicating alarm status. Monitoring of circuit breakers is also a consideration for gathering essential electrical parameters from electronic control units, such as breaker status and voltage. Depending on the solution selected, monitoring systems can provide a high-level of accuracy for information such as harmonics data and recording trip events. Power meters (PMs) and power quality meters (PQMs) are the traditional equipment for monitoring AC feeds. They offer a small footprint and come in a range of options from advanced PQMs and basic multi-function PMs, as well as a high range of capacities to monitor from MV to LV networks.

At the bare minimum, input and branch circuit currents should be monitored for the purposes of ensuring availability. Monitoring Input currents ensures that the upstream breakers do not trip due to overloads. It also allows for chargebacks and load balancing across the multiple phases. Monitoring branch circuit currents ensures that circuit breakers are being optimally used. Warning and critical threshold levels should be set with remote notifications enabled to ensure that breakers do not trip.

Electrical panel temperature sensors also provide interesting and valuable information around electrical panels status and performance, minimizing risks on electrical power distribution downtime by detecting elevated temperatures within operating electrical distribution systems. Electrical panel temperature sensors are also easy to integrate with other monitoring systems, and advancements in wireless sensor technology now allows for wirelessly transmitting information to facility monitoring systems.

UPS MONITORING

UPS should also be monitored for proper power quality, including parameters such as input and output voltages, frequency, and power factor. Warning and critical thresholds should be set based on the acceptable input voltage and frequency ranges of the IT equipment installed.

UPS can have three modes of operation: “online” when the UPS is transforming the input utility power; “on battery” during a power outage; and “bypass” when the UPS is supplying raw utility power due to an internal malfunction. The mode of operation should always be monitored remotely with triggers set whenever the UPS changes state.

In the event of an outage, UPS batteries provide a finite amount of time for providing power to equipment. The runtime available should also be monitored so that appropriate action can be taken prior to battery power running out, such as turning on standby and backup power or initiating a careful shutdown of equipment based on priority to conserve battery power for the most critical equipment. To ensure that the UPS is capable of providing the expected battery life, a runtime calibration should be performed on a scheduled basis. In addition, maintenance information should be easily accessible from any locations, such as last battery replacement date, preventative maintenance dates, etc.

STANDBY AND BACKUP POWER MONITORING

Where standby power systems are in place, monitoring those systems will range from important to critical, depending upon the EDC’s mission. Where generators are in use, power monitoring, including monitoring of the fuel system, must be considered. The use of intelligent systems can effectively monitor the fuel supply and storage regionally. These software-based systems should be able to monitor and alert suppliers in a timely manner for refueling and should invoke an emergency alert if fuel supply is hindered. Detailed monitoring of the generators and its fuel is particularly important where the EDC is to be a dark site (not permanently or regularly staffed). It is recommended that any SPDs deployed in an EDC also have remote monitoring capabilities.

CLOSING THOUGHTS

Edge computing isn't new in concept or practice, but what is new is the way the edge will transform the future of information exchange, management, and control. As cloud-based computing continues to grow, new challenges and opportunities are emerging. And those have manifested in the edge. Considering the power that EDCs will require, innovating how power is supplied to the edge will require a different way of thinking.

Demand for "edge at the curb" (i.e., far edge) will fuel the development and implementation of emerging edge analytic technologies that are limited only by the creativity of humans and will ultimately transform our world by truly enabling smart communities and cities with everything from autonomous cars and delivery systems, to smart resource management, smart traffic systems, crowd control, and entertainment through augmented reality. In the early stages of edge computing, the expectation was that 5G connectivity will be a primary driver. While this still holds true, as edge computing evolves and becomes available at the curb, the appearance, functionality, and power source for curbside edge nodes will need to be carefully thought out. Over the next few decades, renewable energy sources will become more vital to sustaining a growing edge, and as edge components become more ubiquitous and redundant across regions, power resilience will likely become less critical as the loss of any one (or even a group) of edge nodes will go virtually unnoticed by consumers.

TO LEARN MORE ABOUT THE TIA'S WORKING GROUP EFFORTS IN DEVELOPING INFORMATION AND STANDARDS ON EDGE DATA CENTERS (EDC), GO TO THE TIA WEBSITE: HTTPS://WWW.TIAONLINE.ORG

If you have opinions or expertise to lend to this effort, please reach out to **edcinfo@tiaonline.org**.