A White Paper from the Experts
in Business-Critical Continuity™

Proper Application of 415V Systems in North American Data Centers

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Network Power

Introduction

Increasing pressure to reduce operating expenses and be more accountable for energy usage has pushed many data center owners to take steps to maximize efficiency while maintaining the availability required for their business-critical data centers. One option that has attracted their attention is increasing the voltage of power distributed to IT equipment to reduce transformer losses while increasing the efficiency of the server power supplies.

However, while these efficiency gains are real, they may not be quite as high as some data center owners perceive them to be. Furthermore, adopting this strategy may lead to additional application concerns that, if not properly addressed, may pose a risk to the safety of data center and maintenance personnel.

Fortunately, Emerson Network Power's unique end-to-end capabilities provide a safe and effective means of distributing high-power concentrations efficiently, without compromising availability or personnel safety.

Traditional Distribution Configurations

In North America, the standard voltages commonly found in a data center are:

- 575V 3 Phase
- 480V 3 Phase
- 208V 3 Phase
- 208V 1 Phase
- 120V 1 Phase

These voltage standards have been in place for decades and are a direct representation of how power is distributed based on specific phase and line conditions.

For example, today's most common distribution voltage, 480V, is a three-phase power feed. However, this voltage must be transformed to a lower voltage in order to be compatible with data center IT loads.

In most North American data centers, voltage step-down is handled by the Power Distribution Unit (PDU), which converts the load from 480VAC on the primary side to 208/120VAC. The conditioned power is then distributed to the IT equipment, which typically has single-phase power supplies with inputs that can automatically accommodate a range of voltages – typically from 100V to 240V. To utilize 120 VAC power, the line-to-neutral (L-N) voltage derived from a 208V three-phase power feed must be used. However, in most data centers, servers are powered by a 208V single phase line-to-line (L-L) connection.

Advantages of 415/240VAC Distribution

There are a variety of factors driving the adoption of 415/240VAC distribution. First, distributing at these increased voltages enables overall efficiency to be enhanced by eliminating the need for a voltage transformation along the power path. For example, in a 415V system, the L-N voltage is 240V, which is compatible with most all IT loads. By shifting the UPS output distribution voltage to 415/240 V three-phase (L-L/L-N), most of the existing servers today can be powered with 240V single-phase (L-N) without any intermediate transformation. Removing the need for a transformer streamlines the power path and can increase efficiency approximately 1.5 percent.

The adoption of a 415/240VAC distribution model also can yield additional savings at the device-level in the form of increased efficiency for server power supplies. As previously mentioned, today's power supplies can handle a wide range of incoming voltages. Based on the actual voltage being fed into the power supply, efficiencies can range from as low as 80 percent (at 100V nominal) to as much as 94 percent (at 240V nominal) across all manufacturers.

Furthermore, while the typical efficiency differential between 240V and 208V gained at the server power supply today is a relatively minimal, only 0.3 percent across most of the load range, the efficiency differential between 240V and 120V servers can be as much as 2 percent for a given power supply. It is this value that often gets overstated by some manufacturers when comparing 415V distribution to "traditional methods," as there are relatively few servers or peripherals installed today that are operating at 120V.

Addressing the Downsides of 415/240VAC Distribution

As is the case with most attempts to maximize efficiency, there are issues that can complicate the potential savings. In the case of 415/240VAC distribution, complications can include increased costs (associated with running neutral conductors), an increased potential for fault currents and decreased availability if downstream equipment is not configured to accommodate the higher voltages and concurrently higher available fault currents found in these systems.

In a typical data center with 480/208 VAC distribution, the 480V power feed is connected to a primary transformer, so it does not require installing a neutral wire. But, in a 415/240VAC distribution model, the 240V is derived from a L-N configuration —making it absolutely necessary to provide a full neutral conductor within the system and to all of the distribution points. In most cases, this requirement increases the costs of electrical labor and materials required to construct the facility by approximately 20 percent. This increase is due in large part to the additional copper wires required to distribute and manage the neutral currents for the 240V distribution feeds.

Also, the trend toward data center consolidation and subsequent increases in power density has created sites with unprecedented power capabilities. These higher capacity systems – paired with the proposition of transformerless distribution configurations – require electrical equipment capable of handling potentially higher levels of available fault current (known as “withstand rating” or “interrupting capacity”).

Additionally, there has been increased concern over the safety associated with high-power, high-voltage systems. A major area of concern is the potential for “arc flash” that exists when service and or IT personnel are working around energized equipment. While service personnel are familiar with and should be adequately trained before attempting to work on any energized equipment, IT personnel are not. Therefore, exposure to potentially unsafe situations when working within the IT rack environment puts these personnel at increased risk for accidental injury.

Because most data centers do not tolerate any downtime (planned or unplanned), it is extremely important to understand the available fault current and deploy a power distribution suitable for such applications. Furthermore, it is critical to integrate properly designed protective devices to ensure that it is safe to perform maintenance and install additional IT peripherals without de-energizing the entire system or working with cumbersome and awkward Personal Protective Equipment (PPE).

The following example shows potential differences in available fault current between the traditional 480V and the proposed 415V distribution systems in a typical application. As shown in Figure 1, in a 415V distribution scheme, the removal of isolation transformers significantly increase the potential for fault current from the PDU.

This is extremely important for three reasons:

1. The PDU is one location where electricians may need to make alterations to a live system (e.g., installing additional branch circuits).

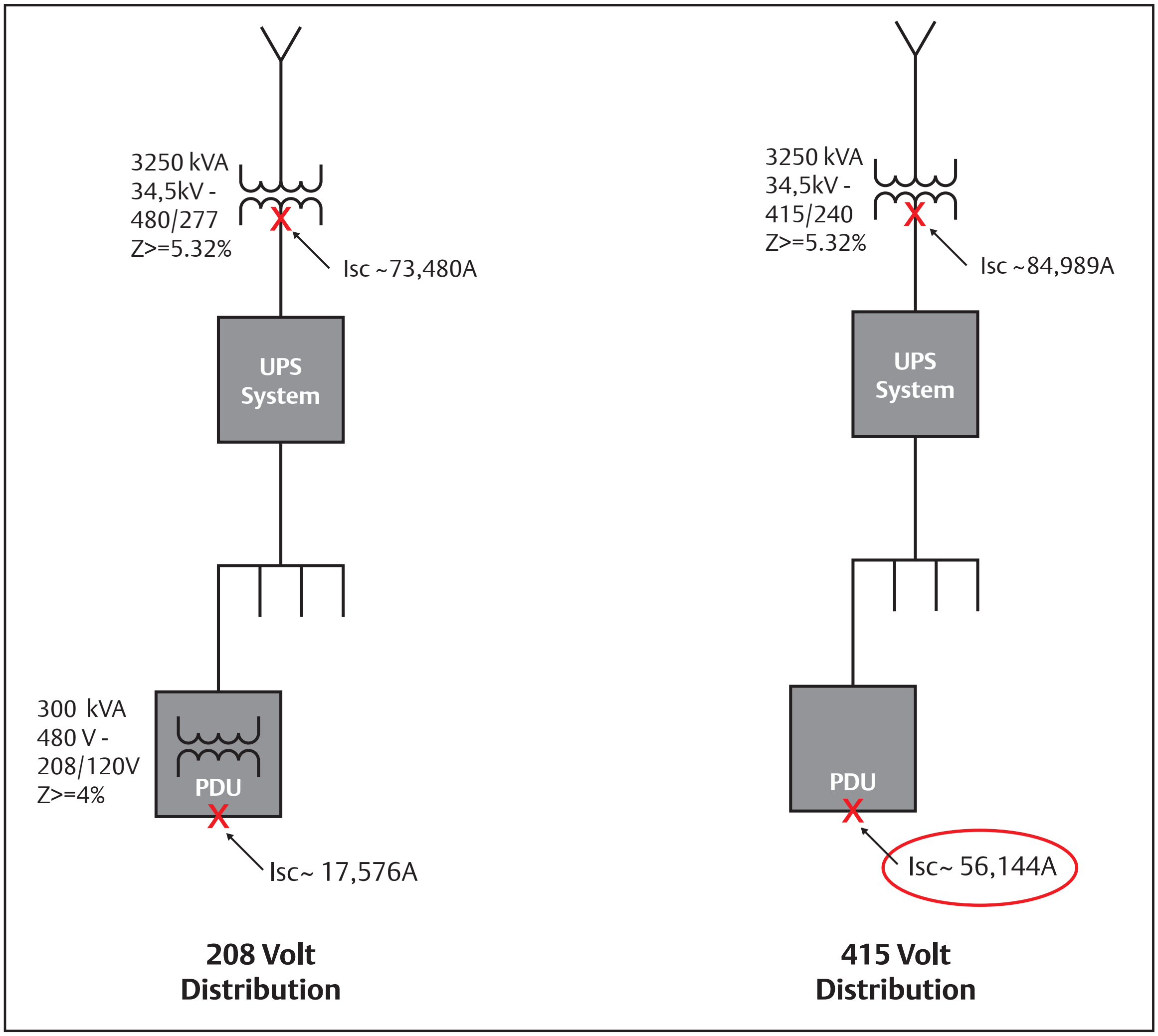

Figure 1. In a 415V distribution scheme, the removal of isolation transformers significantly increases the potential for fault current from the PDU

2. The increased potential for arc flash (which is closely related to the available fault current) contributes to the level of personal protective equipment (PPE) required by personnel to perform work within the data center.

3. Any reduction in current attributed to the power distribution cable establishes the required "withstand rating" of the downstream equipment within the rack (i.e., rack PDUs).

Generally speaking, the higher the potential for arc flash, the higher the PPE level and the more difficult it will be to operate and make changes to equipment in the data center. Based on National Fire Protection Association 70E requirements for electrical safety in the workplace, the level of PPE is dependent upon the theoretical incident of energy level at the point of work. The PPE requirements and energy levels can be seen in the table in Figure 2.

People have asked why 415V distribution already is commonplace in other parts of the world, while 480V distribution remains the most commonly used distribution model in North America. The main reason for this discrepancy is that there are significant differences between the equipment components typically used in the distribution systems.

For example, outside of North America it is more common to utilize fuses, fused switches, and contactors in lieu of circuit breakers. The use of fuses allows for very fast disconnects and provides a high AIC disconnect method, which helps to isolate and manage fault current. However, fuses need to be replaced, rather than reset like circuit breakers.

In North America, electrical distribution products require certification by Underwriters Laboratory (UL), while Europe and the rest of the world use governing standards that require IEC/CE listings. Unfortunately, the panelboards used to distribute higher voltages in the rest of the world are not approved by UL, so a 480V UL listed panelboard is required. These panelboards are larger and more expensive than the standard 240V panelboards used in today's 208V power systems. Their larger footprints may reduce the number of panelboards that can be installed in today's PDUs and remote distribution cabinets; and the branch breakers are different in cost and size than the 240V branch breakers used today.

The next level of protection occurs at the rack PDU, where power is ultimately connected to servers and IT equipment loads. Rack PDUs typically have output circuit breakers which provide over-current protection to the connected equipment. These circuit breakers must be branch rated (per UL489) and capable of withstanding the highest temperatures found within the server racks. While rack PDU circuit breakers are primarily suited to address current overload and fault conditions, traditional rack PDUs themselves are generally not rated to interrupt high-fault currents.

PPE Level	Typical PPE Example	Energy Level
0	Non Melting flammable materials (e.g., untreated cotton, wool, rayon, etc.)	NA
1	Fire Resistant Shirt & Pants	4 cal/cm2
2	Cotton Underwear plus Fire Resistant Shirt & Pants (possibly requires face shield and hearing protection)	8 cal/cm2
3	Cotton Underwear plus Fire Resistant Shirt & Pants AND a Fire Resistant Coverall – Face Shield & Hearing Protection	25 cal/cm2
4	Cotton Underwear plus Fire Resistant Shirt & Pants AND double layer switching coat and pants – Face Shield & Hearing Protection	40 cal/cm2

Figure 2. The amount of personal protection equipment (PPE) needed by technicians increases as the energy level at the point of work increases

How to Apply 415/240V Properly

Emerson Network Power has the unique ability to deliver 415V across the data center while minimizing all of the potential risks associated with high-voltage power distribution. Below are a series of best practices designed to help data center professionals ensure that their high-voltage power is delivered to the IT load efficiently and safely.

- Use 415/240V distribution for greenfield sites or new, self-contained pods within an existing data center. Limiting to greenfield and self-contained pods reduces the complexity of powering legacy loads and other equipment in the data center (cooling, monitoring, etc.) that may not be capable of being powered via 415/240V. The data center should be designed from the outset to distribute power in this configuration.
- Utilize the inherent efficiency gains of utilizing a 415V In/415V Out Chloride Trinergy UPS and leverage the integrated energy optimization modes to increase the efficiency of the overall system.
- Understand the available fault current and utilize properly selected, high AIC circuit breakers in the UPS distribution panels. Ensuring that the breakers are capable of handling the higher interrupting currents is essential to maintaining a properly designed and safe power distribution system.
- Conduct a full breaker coordination study to ensure that all breakers are designed to properly limit the fault current while eliminating nuisance trips. Selectively coordinate all system devices down to the rack PDU level so that fault conditions are isolated without impacting other IT loads.

	PROS	CONS
480 – 208/120	• Most commonly accepted application • No transformer required in bypass path • Uses standard 240V panelboard & breakers • Transformer lowers fault current	• 1.5-2% transformation energy loss • 208V requires 2 pole breaker • Reduces the number of branch circuits available (2 pole vs 1 pole)
415 – 415/240	• No transformation energy losses • 240V load requires 1 pole breaker • More useable pole spaces • Higher energy efficiency • No transformer costs	• Can't power 120V equipment directly • Requires 480V panelboard & breakers • Higher fault current / arc flash potential • Higher Wiring Costs

Figure 3. The pros and cons of utilizing 480 volt current and 415 volt current in a North American data center

- Utilize Liebert Power Distribution Units with properly sized panelboards that provide distribution breaker options capable of safely delivering high interrupting capacities.

- Utilize Liebert MPX / MPH rack PDU systems equipped with *Optimized Protection Technology™*. Optimized Protection Technology™ utilizes output circuit breakers on the MPX/MPH to provide reliable current overload protection for connected loads. Unlike fuses, circuit breakers do not require the rack PDU to be powered down for reset or to isolate a branch of protected receptacles.

In addition, the Liebert MPX/MPH utilizes hydraulic-magnetic type circuit breakers that deliver full-rated capacity at elevated temperature conditions. Liebert MPX/MPH systems with Optimized Protection Technology™ also include specially selected in-line fuses, enabling the safe deployment of MPX/MPH in applications with high-levels of available fault current. These fuses and output circuit breakers are sized and coordinated to assure the breakers address IT equipment overload or fault conditions and manage high input fault conditions.

Conclusion

A properly implemented 415V power distribution system can reduce operating expenses significantly. Server efficiency will improve by approximately 0.3%, and PDU efficiency will improve 1.5% due to the elimination of the transformer.

In addition, cooling savings will be achieved with less heat being generated by the power system. Lastly, using the energy optimization modes in Chloride Trinergy increases UPS efficiency dramatically over the operating range.

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