Improving Electrical Reliability to Meet AI Power Demand

Industry Challenge: Surge in Power Demand

Artificial intelligence is advancing at an unprecedented pace, driven by large language models and increasingly power-dense GPU architectures. As AI model complexity and training workloads grow, so does the electrical demand required to support the underlying data center infrastructure.

As of 2025, data centers account for approximately four percent of total U.S. electricity consumption, a figure projected to reach nine percent by 2030. This rapid increase places significant strain on regional electrical grids, particularly in areas with high concentrations of hyperscale and AI-focused data centers.

When an electrical grid supports multiple large data center campuses, reliability becomes critical. Even brief outages can result in catastrophic financial losses, service disruptions, and data integrity risks. Utilities in states with dense data center infrastructure, including Virginia, Ohio, Oregon, and Texas, have already warned that accelerating AI loads are beginning to outpace planned generation and transmission capacity. These regions were historically able to absorb steady cloud-computing growth, but the scale and continuity of AI workloads represent a fundamentally different demand profile.

Northern Virginia, the most concentrated data center market in the United States, illustrates this challenge clearly. Utility providers have cautioned that existing substations and high-voltage transmission lines are approaching their design limits, forcing project delays, phased deployments, or major infrastructure reconfigurations. Many legacy grid systems were not designed to support continuous, high-density electrical loads characteristic of modern AI campuses.

What is the Solution?

With an already stressed electrical grid and an increasing need for uninterrupted power, data center operators are turning toward on-site power generation to ensure twenty-four-seven reliability. Among the emerging solutions, wind and solar generation with battery storage, hydrogen fuel cells, and Small Modular Reactors (SMRs) are gaining attention as long-term options to support large-scale, mission-critical facilities. No matter the form of generation, it must be connected to the data center.

Meeting the growing power demands of AI-driven data centers requires more than incremental upgrades. In many regions, electrical grids must be rebuilt, reinforced, and expanded to accommodate sustained, high-density loads operating continuously. Aging transmission infrastructure, undersized substations, and equipment originally designed for variable commercial or residential demand are being pushed beyond their intended limits. Utilities are forced to operate systems closer to their thermal and mechanical limits, narrowing reliability margins and increasing the consequences of failure.

As grid infrastructure is reinforced and expanded, the reliability of individual electrical connections becomes increasingly critical. Substations, switchgear, transformers, and busbar systems rely on bolted joints to maintain both mechanical stability and low-resistance electrical contact. Higher current densities and frequent thermal cycling accelerate preload loss in traditional bolted joints due to differential thermal expansion, vibration, and embedment relaxation.

The Importance of Connection Reliability

One proven method to improve joint reliability in high-current electrical applications is the use of disc spring washers (Belleville washers). By introducing a controlled spring element into bolted joints, Belleville washers maintain consistent clamping force despite thermal fluctuations, vibration, creep, and long-term relaxation. Electrical connections often include dissimilar materials, such as copper, aluminum, or steel, which can exacerbate differential thermal expansion and accelerate preload loss. In high-current connections, even small reductions in bolt preload can increase contact resistance by just a few milliohms, generating localized heating of hundreds of watts and accelerating joint degradation. Belleville washers compensate for a significant portion of this preload loss, often reducing the loss by a factor of five or more, keeping connections within safe operating limits.

In addition to thermal cycling, Belleville washers improve resilience to mechanical shocks, embedment relaxation, and rapid load fluctuations, such as switching events or fault currents, which are increasingly common in grids supplying AI data centers. Their live-load capability reduces maintenance requirements, as joints do not require frequent retorquing, saving labor and minimizing downtime across multiple facilities.

When applied to critical grid equipment, including circuit breakers, switchgear, transformers, busbars, arrestors, and energy storage systems, Belleville washers help maintain stable contact pressure, minimize resistance-related heating, and extend service life. Their use aligns with industry best practices and standards, including IEEE, IEC, and NEMA, for high-current, high-reliability connections, providing measurable improvements in long-term electrical performance and system uptime. Incorporating them is particularly valuable in joints subject to differential thermal expansion and vibration, where conventional flat washers or standard bolting methods would otherwise require frequent maintenance or risk early failure.

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