White Paper

EXERTHERM by EATON

Improve Data Center Uptime with Continuous Thermal Monitoring (CTM)

24x7 thermal monitoring improves personnel safety, predicts potential equipment failures and optimizes productivity in modern mission-critical environments

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Introduction

Data centers face increasing power demands as workloads and rack densities increase due to artificial intelligence (AI) and edge computing. The shift toward remote work and compute-intensive operations further accelerates this trend, leading to higher power consumption, increased rack density and elevated heat levels. As a result, there is a greater potential for critical power system issues to result in costly downtime and equipment damage. To mitigate these risks, data center operators must adopt proactive monitoring tools and strategies to detect and address potential issues before they escalate.

Avoiding outages has always remained a top priority for data center operators, yet many current strategies fall short of adequately protecting power infrastructure. Although information technology (IT) monitoring solutions and data center infrastructure management (DCIM) systems have improved visibility across software and networks, electrical systems still require more advanced solutions.

Unplanned outages pose significant financial and operational risks. According to the Uptime Institute's 2024 data center survey, more than half (54%) of respondents reported that their most recent significant outage exceeded $100,000 in costs, while 16% experienced losses surpassing $1 million. Power issues remain the leading cause of severe data center outages, with most respondents stating their most recent serious outage could have been prevented through better management, processes and configuration. These findings underscore the critical need for robust power infrastructure protection to minimize downtime.

Continuous thermal monitoring (CTM) provides real-time power system health data to support early fault detection and timely intervention. With these 24x7 insights into the performance of critical electrical infrastructure, data centers can proactively and cost-effectively avoid some of the most common causes of downtime.

CTM technology offers more than just fault detection – it generates operational data that strengthens data center management. These solutions provide the baseline data that is essential to train AI and machine learning models for trend analysis and proactive maintenance, helping to detect faults before they escalate. By preventing downtime, enhancing safety and reducing risk, condition monitoring is quickly becoming the most cost-effective maintenance approach. Unlike manual inspections, which occur at scheduled intervals and may miss developing issues, condition-based monitoring relies on real-time data to track asset health and predict failures.

In this paper, we will explore the advantages of CTM to illustrate why an increasing number of data centers are implementing condition monitoring to improve operational efficiency and reliability. Additionally, we'll explore how to implement this proactive approach to minimize maintenance labor and costs, while extending the lifespan of critical electrical system assets.

The importance of condition monitoring for critical electrical systems

Power system faults can result in catastrophic power losses to critical systems, leading to expensive unplanned downtime, lost productivity and costly repairs or replacements. Faulty connections and increasing temperatures are one of the primary symptoms of the underlying problems that cause these faults. The regular practice of thermal monitoring enables organizations to detect these temperature changes early, allowing for timely intervention to prevent electrical outages and more severe consequences.

Recognizing these risks, regulatory bodies and industry organizations mandate regular electrical assessments to ensure safety and operational reliability. Various international standards, including those from the International Electrotechnical Commission (IEC) and the American National Standards Institute (ANSI), require ongoing equipment evaluations. In the United States, the National Fire Protection Association (NFPA) 70B standard mandates the development and implementation of an Electrical Maintenance Program (EMP). Similarly, in Europe, ISO/IEC 22237 and EN 50600 set guidelines for preventive maintenance in data centers, while the European Data Centre Association (EUDCA) establishes best practices for operational reliability.

To support compliance with these mandates, many continuous monitoring solutions can be installed within critical electrical equipment, including switchgear, transformers, bus ducts, busway, and cable connections commonly found in data center applications. These devices provide real-time, predictive monitoring capabilities, enabling operators to make more informed safety and maintenance decisions while reducing the risk of unexpected failures.

This technology can also help reduce the labor associated with routine maintenance. The NFPA 70B standard in the United States includes language that permits the use of continuous monitoring and predictive techniques to extend maintenance intervals beyond the traditional prescribed schedules.

For example, NFPA 70B Table 9.3.2 outlines the mandatory maintenance intervals for equipment condition assessments – stating infrared thermography must be performed for all electrical equipment every 6 or 12 months, depending on the equipment condition assessment. The 2023 edition 7.2.1.2 also allows the use of permanently mounted sensors to monitor the quality of bolted connections, cable connections and bus bars.

Table 9.3.2 Maintenance Intervals

Equipment Condition Assessment				
Product	**Scope of W ork**	**Condition 1**	**Condition 2**	**Condition 3**
All equipment	Infrared	12 months	12 months	6 months

Additionally, there is a proposed update to 2026 NFPA 70B Section 7.4 focused on infrared thermography that would include allow permanently installed continuous temperature measurement devices to satisfy previous requirements found within the section.

These shifts underscore the growing recognition that data-driven condition-based maintenance is an effective alternative to interval-based approaches, offering the added benefits of reduced labor and cost.

Move beyond manual electrical system maintenance

Equipment overheating and electrical distribution system issues can pose significant risks in data centers, but electrical hotspots often serve as early warning signs to prevent these issues. Factors such as overheating connections, insulation degradation and loose electrical joints contribute to power disruptions, which, if left unchecked, can lead to downtime, lost productivity and reputational damage.

Despite these risks, the traditional manual thermal inspection process employed by many data center operators has notable shortcomings. These periodic physical assessments may fail to detect intermittent or developing faults that emerge between scheduled survey intervals. Additionally, accessing electrical components for inspection can be challenging, often requiring shutdowns that necessitate downtime. Thermographic surveys also require equipment to have at least a 40% load at the time of inspection, depend on operator expertise and provide only snapshot data that limits its ability to support predictive maintenance strategies.

Complicating traditional hotspot detection are organizational safety policies and concerns. Many reputable data centers prohibit work on energized electrical equipment to prevent the risk of electric shock and arc flash. Although de-energizing circuits prior to performing maintenance is a common industry practice, it is often impractical in today's always-on data center environments. This means many organizations often have no choice but to conduct inspections while equipment remains energized to minimize downtime, exposing personnel to potentially dangerous conditions.

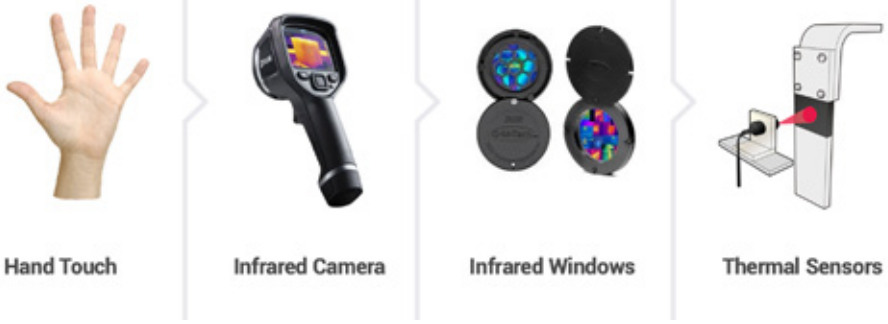
The history of identifying temperature rise in electrical assets

The Technology Evolution…

Infrared (IR) sensors: the next technology step

The most common detection method is to use IR cameras or windows.

New technology enables IR sensors to be installed inside electrical assets, providing condition monitoring for critical joints.



Address electrical problems before they can result in downtime

CTM is a proactive approach to maintaining electrical asset health by providing real-time temperature monitoring to prevent failures and enhance operational efficiency. Unlike traditional thermal inspections conducted periodically, CTM offers 24/7 monitoring of critical electrical infrastructure, ensuring early fault detection and enabling timely intervention before issues escalate. This continuous data collection significantly improves predictive maintenance capabilities, reduces downtime and enhances overall safety in data centers.

One of the primary advantages of CTM over periodic inspections is its ability to provide immediate visibility into electrical asset conditions. By continuously gathering and analyzing temperature data, CTM enables predictive maintenance by identifying gradual temperature trends before they lead to equipment failure. Additionally, CTM reduces the need for human intervention in hazardous environments, improving personnel safety and ensuring compliance with workplace safety regulations.

To maximize its effectiveness, CTM solutions must integrate seamlessly into existing data center management platforms. These solutions should offer scalable and interoperable communication capabilities that allow data to be shared seamlessly with remote monitoring solutions, asset performance management systems, electrical power monitoring tools and power distribution control solutions. The integration of CTM solutions with these centralized management platforms automates data collection and analysis, while offering the baselined data need to train AI-powered models to detect abnormal patterns and predict potential failures. Furthermore, the ability to feed real-time data into cloud-based monitoring solutions provide remote access and centralized management, allowing data center operators to oversee electrical asset health from anywhere.

How CTM improves preventive maintenance

CTM relies on permanently installed thermal sensors that continuously monitor temperature variations in critical electrical assets. These sensors can be strategically placed in essential equipment including switchgear, transformers, circuit breakers, uninterruptible power systems (UPSs), busways, bus ducts, and power distribution units (PDUs) to track key connection points and detect potential overheating risks. The collected data is integrated with existing infrastructure management systems, such as Data Center Infrastructure Management (DCIM), Building Management Systems (BMS), or Supervisory Control and Data Acquisition (SCADA) platforms, ensuring seamless data aggregation and analysis.

Once the temperature data is collected, predictive analytics software continuously analyzes it to detect anomalies. If temperature thresholds are breached or abnormal trends are identified, real-time alerts flag issues for maintenance teams, enabling immediate corrective action before downtime or equipment failure. This proactive approach to thermal monitoring significantly enhances operational efficiency, reduces maintenance costs and mitigates safety risks associated with overheating electrical components.

The advantages of CTM for critical data centers uptime

Traditional thermographic inspections present several challenges that CTM effectively addresses. Periodic thermal checks have limited inspection frequency, often missing intermittent faults that occur between scheduled assessments. Additionally, these inspections require clear access to equipment, which may be obstructed. The reliance on operator expertise introduces the potential for human error, while infrared windows used for manual inspections can degrade over time. Further, some faults only become apparent under high operational loads, which may not align with inspection schedules, increasing the likelihood of undetected issues. Plus, the lifetime costs associated with traditional inspections add up Safety risks for personnel also remain a significant concern, as manual inspections require working near live electrical equipment.

CTM addresses the limitations of traditional thermographic inspections through 24x7 remote monitoring capabilities, ensuring continuous oversight of electrical assets without requiring periodic manual assessments. By integrating real-time data into predictive maintenance strategies, CTM enables immediate detection of temperature anomalies, allowing for proactive intervention before faults lead to downtime. Continuous monitoring significantly reduces human interaction with electrical assets, minimizing exposure to electrical equipment and improving workplace safety. Additionally, CTM enhances operational uptime by eliminating the downtime required for manual thermal inspections, helping ensure data centers can maintain uptime. With its scalable and customizable nature, CTM can be adapted across various electrical infrastructure, providing a comprehensive and reliable solution for thermal condition monitoring in data centers.

Cybersecurity is also a critical concern in data centers. As organizations adopt continuous thermal monitoring solutions, ensuring the cybersecurity of connected operational technology (OT) networks is a critical priority. Hard-wired CTM sensors provide an added layer of security by eliminating the risks associated with wireless data transmission. Unlike wireless alternatives, physical connections reduce exposure to cyber threats and ensure uninterrupted, interference-free monitoring.

Wired sensors offer several advantages over wireless alternatives. They significantly reduce the risk of hacking attempts that exploit RF-based transmissions. Additionally, unlike wireless sensors that require periodic recalibration or battery replacements, unpowered hard-wired sensors provide reliable and practically maintenance-free performance throughout the entire lifecycle of the electrical infrastructure. This ensures consistent data integrity and long-term operational efficiency while minimizing cybersecurity vulnerabilities.

CTM simplifies thermographic inspection

There are many limitations to traditional manual thermographic inspections, making them less effective for modern data center environments:

- **Limited inspection frequency –** Periodic assessments may miss intermittent faults that develop between inspections.
- **Line of sight issues –** Components must be accessible for infrared scanning, but some areas may be obstructed.
- **Lack of real-time data –** Inspections occur at scheduled in tervals, creating blind spots in asset monitoring.
- **Dependence on thermographer expertise –** Accuracy relies on operator skill, leading to potential inconsistencies.
- **Degradation of infrared windows –** IR windows degrade and must be replaced, reducing measurement accuracy while necessitating downtime and recurring cost.
- **Difficulty detecting faults under low load –** Some issues only appear under high operational loads, which may not align with inspection schedules.
- **High lifetime costs –** Ongoing inspections, shutdowns, labor and the cost of replacing IR windows add significant expenses.
- **Safety risks for operators –** Personnel must work near high-voltage equipment, increasing exposure to electrical hazards.

In comparison, CTM provides a proactive and automated solution that addresses the limitations of manual inspection:

- **24x7 remote monitoring –** Continuously tracks electrical asset health without requiring manual inspections.
- **Real-time data integration and predictive maintenance –** Immediate temperature anomaly detection allows proactive intervention.
- **Reduced human interaction with electrical assets –** Minimizes personnel exposure to energized equipment, enhancing safety.
- **Increased operational uptime –** Eliminates downtime required for scheduled thermal inspections.
- **Fully scalable and customizable –** Adaptable across various electrical infrastructures, ensuring comprehensive monitoring.

Examining successful CTM implementation in a data center

A hyperscale data center faced several operational challenges that threatened reliability and efficiency. The facility needed to maintain a stable electrical infrastructure while adhering to strict non-energized work policies. However, periodic infrared inspections proved insufficient, as many faults developed between scheduled assessments and went undetected. This limitation increased the risk of unplanned power outages due to unforeseen failures, potentially resulting in financial losses and reputational damage.

To address these challenges, the data center deployed a CTM solution, which eliminated the need for manual inspections and significantly improved asset visibility. Real-time data collection allowed maintenance teams to detect temperature anomalies early and take proactive measures before equipment failures occurred. As a result, the facility experienced fewer disruptions, reduced maintenance costs and enhanced overall system reliability. The implementation of CTM is not only helping the data center safeguarded mission-critical operations but also provides substantial cost savings and operational efficiency improvements.

Now is the time to take thermal monitoring seriously

CTM can help data center operators transform preventative maintenance strategies to meet growing demand for data and energy-intensive computing. By providing real-time insights into the health of critical electrical system components, CTM can enhance operational reliability, improve safety and deliver significant cost efficiencies. These sensors enable digitization and future-proof electrical infrastructure, with seamless integration into predictive maintenance programs.

To remain competitive in an increasingly demanding industry, we firmly believe organizations should prioritize the integration of CTM into their electrical maintenance strategies. Investing in thermal monitoring technology not only protects mission-critical assets but also maximizes return on investment (ROI) through improved reliability and operational efficiency. By adopting CTM, data centers can proactively safeguard their electrical infrastructure against the risks of today and tomorrow, ensuring uninterrupted performance in an era where uptime is everything.

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https://www.exertherm.com/industry/data-centers>

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