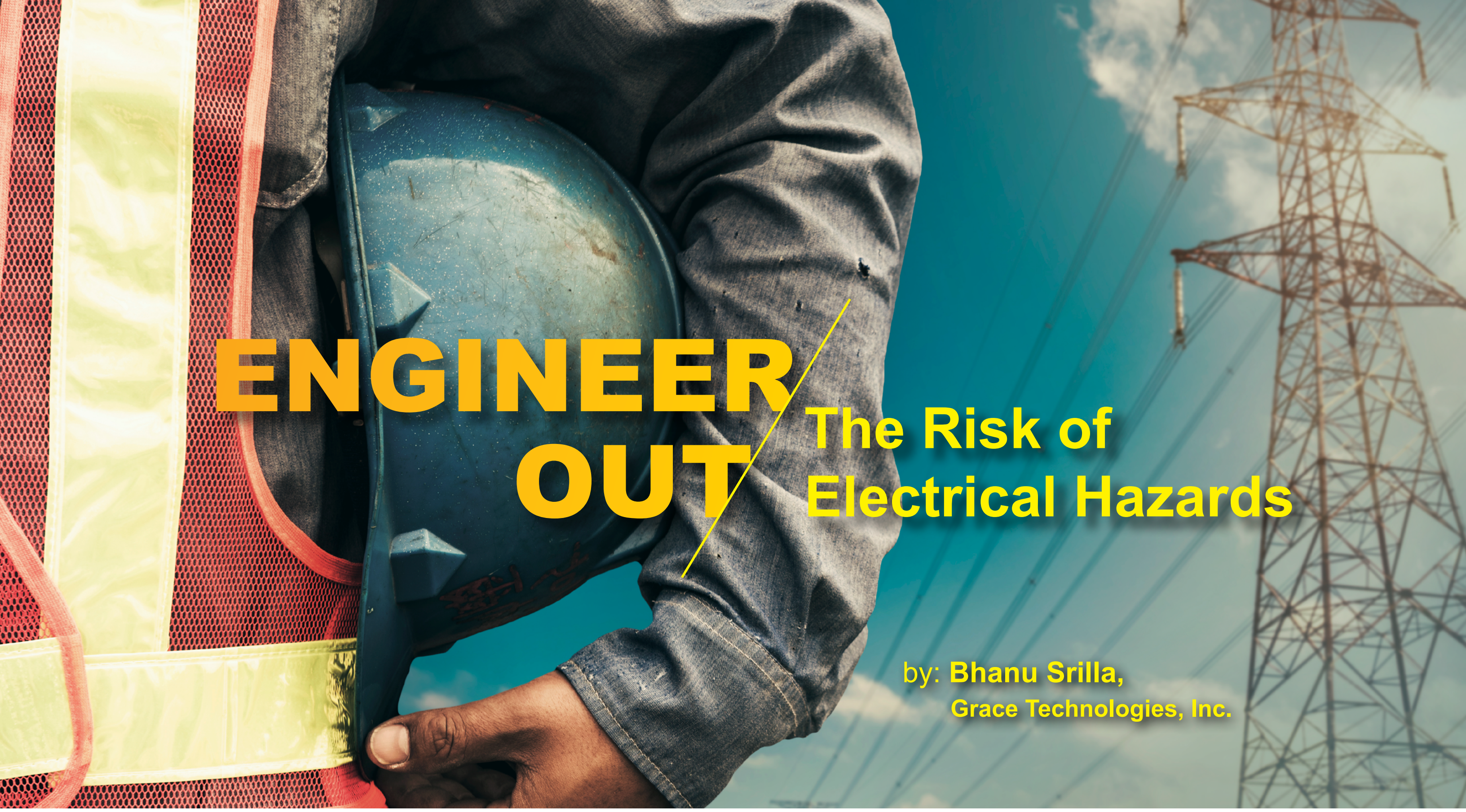

ENGINEER OUT The Risk of Electrical Hazards

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Continuous Remote Temperature Monitoring of Electrical Systems Offer Safety Benefits Beyond Costly Open-Door IR Inspections

Unplanned shutdowns often result in major economic loss for businesses, and often can be directly attributed both to improper equipment maintenance and to safety hazards that arise while performing maintenance tasks. Though many organizations mitigate these risks by several means using PPE, policies, and procedures, the workers' exposure to the hazards still exists.

Further challenges include a scarceness of qualified and skilled personnel and the facility's availability to perform these tasks. Insurance companies estimate that approximately 25 percent of all electrical failures are attributed to faulty or loose electrical connections, resulting in temperature anomalies (i.e., hot spots) that lead to overheating, intermittent open circuits, and electrical arcs.

Specifically, hotspots that arise from current flow are the greatest enemy of electrical systems, and can affect both the equipment performance and useful life if not found in time. While most electrical equipment is designed to operate on the manufacturer's specified temperature range, it is generally accepted that every 10°C rise in temperature shortens the average reliability of electrical components by 50 percent.

NFPA 70B

SECTION 15.2.15.1: "Temperatures over design levels for prolonged periods can reduce the electrical life of organic insulating materials…"

When the equipment or the connections are continuously subjected to excess temperatures over the design levels, these conditions can reduce the electrical life of insulating materials, causing physical deterioration resulting in lowered mechanical strength that could potentially lead to an arc flash.

Most facilities today use a wide variety of equipment maintenance methods including routine physical inspections, acceptance tests, predictive maintenance tools, and more to combat the facility's electrical system maintenance challenges. Some of these maintenance tasks can be performed in a de-energized state; however, most tasks require inspections performed in fully energized and live conditions to get accurate measurements and reliable data.

NFPA 70B

SECTION 17.9: "Loose connections are the most common cause of excessive heat. Periodic maintenance checks should involve checking for loose connections or evidence of overheating…"

The National Electric Code (NEC) recognized serious injuries, fatalities and monetary damages as a result of "lack of maintenance" and introduced NFPA 70B, a consensus standard that defines the recommended practice for electrical equipment maintenance and provides basic maintenance guidelines for all major electrical equipment (including motor control centers, breakers, switchgear, electrical bus bars, bus ducts, motors, transformer, generators, batteries, and inverters). Chapter 11.17 of 70B defines the guidelines of infrared (IR) inspections, a predictive maintenance method currently used in the industry that enables the user to periodically inspect the equipment for temperature hot spots or anomalies at specified intervals.

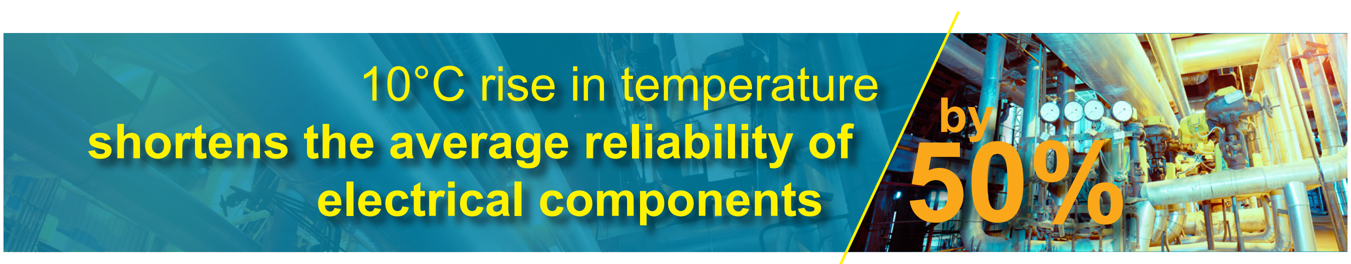
When it comes to identifying potential failure points (PFPs) on which to focus these electrical system inspection efforts, PFPs vary by customer preferences including load conditions, incident energy, environment, and criticality of the equipment. In a typical LV/MV switchgear main bus bar compartment, the PFPs can be prioritized as follows:

1) Load side connections of the breaker, which carry a mix of varying loads (i.e., resistive, inductive, and capacitive)

2) Line side connections of the breaker, which carry high incident energy from the connected sources (i.e., transformers and generators)

3) Field terminations, which can experience mechanical stresses from heavy cables and feeder bus bar connections.

The challenge facing maintenance teams is that it is not feasible to inspect all PFPs in an electrical system using traditional infrared thermography techniques, due to complexity of the busbar construction and to field-of-view (FOV) limitations. Also, even though thermography solutions provide temperature measurements in accessible locations, the readings are



only intermittent and they can be negatively impacted by the transmissivity and environmental conditions in addition to the skills and expertise of the personnel. The expense of thermography inspections increases when the price of cameras, training, and re-certification of personnel is taken into account.

Following the guidelines of NFPA 70B, insurance carriers of large facilities with power distribution equipment mandate IR surveys on an annual basis at a minimum. NFPA 70B suggests that inspection intervals range anywhere between 6 months to 3 years duration, and the industry's common practice is to have these inspections conducted on a semi/annual basis.

NFPA 70B

SECTION 15.2.15.2: Localized heating (hot spots) can sometimes occur and can be masked because the overall temperature of the surroundings…"

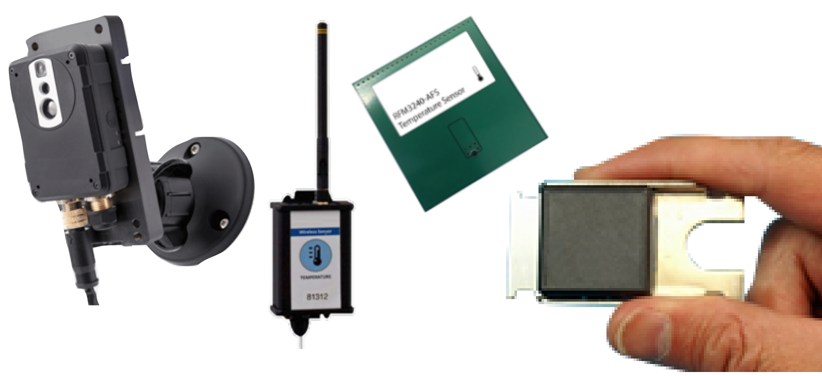
CLASSIFICATIONS OF IR THERMOGRAPHY

Open-door thermography. In open-door thermography inspections, electrical panels must be removed as the thermographers often work within close proximity of energized components during inspections. In this method, thermographers suited in heavy PPE direct the IR cameras at the live conductors to measure the temperature. As thermographers work in the energized conditions, they need to be a “qualified person” as defined by NFPA 70E electrical safety standards. Once the inspections are completed, the equipment needs to be put back in original condition.

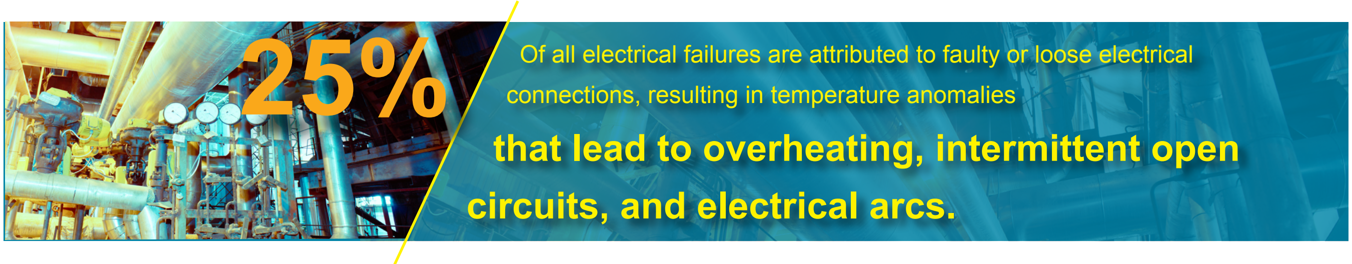
Closed-door thermography. In closed-door thermography, an IR viewing window is mounted on the door of the electrical enclosure. Similar to open-door thermography, an IR camera is directed at the live conductor through the window with which the temperature of the conductors are recorded. Unlike open-door thermography, this method minimizes the risk of exposure to the energized conductors. While the closed-door thermography has many advantages over the open-door, IR windows greatly restrict the visibility to the connections that are crucial with the limited field of view (FOV) based on the location of the window installation and the complexity of the equipment and busbar construction. As most of the standard IR windows are available in 2-inch, 3-inch, or 4-inchsizes, it is often difficult to get the larger FOV without using numerous windows or customizing windows that are specific to the application which could be very cost prohibitive. IR windows installation further poses a great threat to the structural integrity of the electrical panel, and raises warranty concerns.

Several new technologies available today provide options for maintenance teams to make the change from intermittent monitoring of critical electrical connections via IR to continuous temperature monitoring via various types of remote monitoring technologies. The benefits of using remote tools include reducing personnel incident energy exposure levels to zero, as no exposure to incident energy means no accidents (see Table 1). Remote monitoring tools further help plant teams avoid electrical hazards by reducing or eliminating the volume of periodic maintenance tasks, and helping plant teams make more data-driven maintenance decisions are made based on real-time equipment condition.

These technologies include wireless sensors, ambient temperature probes, and fixed IR cameras. While wireless sensors are a great fit for remote monitoring, the sensors that are available today require a built-in battery for operation and a wall mounted antenna/ receiver to communicate the temperature tags and signals. The battery condition on these sensors greatly impact the accuracy of the readings and further jeopardize the continuous monitoring capabilities if the batteries are not checked at regular intervals.



Moreover, the signal interferences will affect the readings and the data when numerous sensors are deployed in close proximity. With ambient temperature probes, the user can monitor the overall change in temperature (Δ) inside an enclosure compared to the ambient temperature set points. Though the overall temperature monitoring is achieved with these probes, they will not reveal the actual faulty connections or the condition of the PFPs.



Fixed IR cameras on the other hand, are similar in style with handheld IR cameras with limited FOV that require additional mounting brackets and communication cables. It is practically impossible to mount the brackets, and to run and shield the cables near energized components inside an electrical enclosure. Wireless sensors and fixed IR cameras drive high upfront costs considering per point PFP monitoring and pose installation and integration difficulties while mounting inside the electrical enclosures. Ambient temperature probes are relatively inexpensive but are limited with the capabilities.

A fourth option is monitoring devices that can be securely bolted onto critical connections in electrical equipment to continuously monitor temperatures before

Table 1. Comparison chart of thermographic and remote monitoring solutions for electrical systems.

Description	Open-Door Thermography	Closed-Door Thermography (IR windows)	Continuous Remote Temperature Monitoring
Exposure to incident energy	High	Medium	None
Personal protective equipment (PPE)	Required	Required	None
Device calibration	Required	Required	Not required
Special training, skills and certifications (thermography)	Required	Required	Not required
Data logging and trending capabilities	Manual / No	Manual / No	Auto / Yes
Access to critical connections / complex system geometry	No	No	Yes
Alarm capability	No	No	Yes
Integration with existing SCADA / DCS systems	No	No	Yes
Ambient measurement	No	No	Yes
Installation	N/A	Complex	Simple
Structural degradation	N/A	Yes	No
Inspection frequency	Intermittent	Intermittent	Continuous
Technology	Non- contact	Non- contact	Non-conductive contact

faults occur (see Table 1). These modules incorporate a non-conductive fiber optic technology that securely connects to the PFPs. The head unit is mounted inside the low voltage/control compartment of the enclosure to log and store data that can be accessed and managed remotely via Modbus RTU, TCP/IP, and Ethernet I/P protocols, and deliver accurate hot spot monitoring in inaccessible locations without risk to personnel.

With higher productivity demands and industry's convergence to IoT, it is imperative to safely and continuously monitor critical connections for better maintenance planning of electrical assets with zero risk to personnel. The continuous hot spot monitoring of PFPs, hot spots and similar loose connections enables facility personnel to take a more data-driven maintenance approach rather than relying on routine inspections.

ABOUT THE AUTHOR:

Bhanu Srilla is Director of Product Marketing at Grace Technologies. Bhanu has more than 20 years of progressive experience in power generation and distribution industry, and has led diverse programs in electrical power distribution and control system projects in IEC and ANSI applications for low and medium voltage systems. Bhanu is a Certified Project Management Professional, and holds degrees in electrical engineering, manufacturing systems, and technology management. He can be contacted at: bsrilla@grace-eng.com.