

Infrared Inspections and Applications

by Don A. Genutis

THIS IS THE THIRD IN A SERIES OF ARTICLES that focuses on electrical inspection methods and technologies performed while the electrical system remains energized. Although no-outage inspections can be very valuable tools, always remember to comply with proper safety guidelines when conducting the energized “on-line” inspections.

Instrumentation

Infrared equipment used for electrical inspections range anywhere from handheld spot thermometers to sophisticated imaging devices with high-resolution thermal and visual color displays. The popularity of infrared technology is apparent today by the wide price range and variety of instruments available. For the successful service provider, instrument cost is secondary to having equipment that provides high-resolution images and allows for accurate and efficient report writing. Features such as user-friendly software can automate the process of collecting, reporting, and archiving infrared images and thermal data. Sophisticated features such as Blue Tooth voice comment recording, built-in auxiliary laser target-pointing devices, and visual (conventional camera-type) imaging can add to the instrument cost but can greatly assist report accuracy and efficiency. When choosing an infrared instrument, one must consider these features along with their associated costs.

Personnel Qualifications

The following statement obtained directly from the NETA Maintenance Testing Specifications summarizes the need to have Infrared Technicians possess a broad range of both electrical and thermography experience. *“It is a necessary and valid requirement that the person performing the electrical inspection be thoroughly trained and experienced concerning the apparatus and systems being evaluated as well as knowledgeable of thermographic methodology.”* Without extensive experience and training in both disciplines, improper diagnostics may result in unnecessary repairs, or leaving the customer with misinformation that results in reduced electrical reliability.

Typical Applications

For electrical systems, infrared instruments are generally used to identify current-carrying conductor anomalies. Over time, connections become loose from cycling temperature variations due to loading fluctuations and vibration associated with electrical equipment operation along with many other factors. Higher resistances occur across these problem connections, and heat is created based on the associated I^2R losses. Heat is indirectly measured by the objects emissivity using the infrared instrument. Left unattended, these problem connections worsen over time and eventually lead to complete failure. Infrared technology is capable of identifying these problems and should be incorporated into annual maintenance plans. Other conductor problems that generate heat and can be detected by infrared instruments include overloaded circuits and circuits with substantial harmonic content. Dirty, corroded, and damaged connections or faulty contacts can also be detected.

Benefits

A major insurance carrier estimates that approximately 25 percent of all electrical failures are attributed to faulty electrical connections. Therefore, many insurance firms are the driving force behind requiring facilities to conduct annual infrared

surveys. Infrared technology has evolved into one of the best overall technologies for preventing failures and has the added benefit of not requiring an outage to perform, as it can be done on line. Several additional benefits of infrared technology are listed below:

- The testing is **nondestructive**.
- Infrared technology allows you to **“see” the thermal image**.
- The results can be **trended and compared** to previous results.
- Pictures taken of the problems can provide **a record of the problem**.
- The results may be **used for prioritizing** repairs.
- The infrared survey **is relatively economical**.
- The technology **helps increase reliability**.
- The technology is predictive in that it identifies problems before complete failure or damage occurs, thus allowing for a proactive maintenance approach or program!

When Is It a Problem?

It is not necessarily easy to properly detect and diagnose an electrical problem with infrared technology. This is why having a technician with the right combination of electrical and thermography experience is so important. Technical knowledge and field experience in electrical testing are mandatory prerequisites for nonroutine problem identification and for recommending corrective actions. However, the following guideline taken from NETA Maintenance Testing Specifications provides a good general reference in regards to temperature differences and their associated severity level.

TABLE 100.18
Thermographic Survey
Suggested Actions Based on Temperature Rise

Temperature difference (ΔT) based on comparisons between similar components under similar loading.	Temperature difference (ΔT) based upon comparisons between component and ambient air temperatures.	Recommended Action
1°C - 3°C	1°C - 10°C	Possible deficiency; warrants investigation
4°C - 15°C	11°C - 20°C	Indicates probable deficiency; repair as time permits
-----	21°C - 40°C	Monitor until corrective measures can be accomplished
>15°C	>40°C	Major discrepancy; repair immediately

Temperature specifications vary depending on the exact type of equipment. Even in the same class of equipment (i.e., cables) there are various temperature ratings. Heating is generally related to the square of the cur-

rent; therefore, the load current will have a major impact on ΔT . In the absence of consensus standards for ΔT , the values in this table will provide reasonable guidelines.

An alternative method of evaluation is the standards-based temperature rating system as discussed in Section 8.9.2, Conducting an IR Thermographic Inspection, Electrical Power Systems Maintenance and Testing by Paul Gill, PE, 1998.

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It should be noted that many times the problem might be the absence of heat or less heat than other similar conductors or items. One example is parallel conductors where one (or more) of a group is not conducting their proportional share of the total current. Another example is poorly balanced single-phase loads on a three-phase transformer or distribution system.

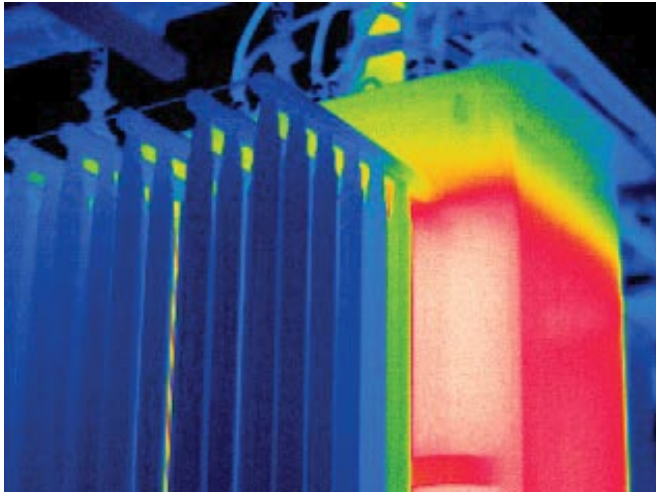
Additional Infrared Applications

In addition to typical conductor problems that are commonly detected by infrared equipment, there is an ever-growing number of additional applications that can be useful provided that the technician’s imagination and experience is utilized when analyzing electrical systems. Some examples of these less-common applications are described below.

Transformers

The liquid level of fluid-filled transformers is critical for the performance and longevity of the transformer. Liquid level gauges can become damaged or illegible over time causing unreliable indication. Infrared imaging of the transformer can often detect fluid levels and radiator convection cooling

problems. The thermal image below shows a very warm transformer main tank and very cool radiators indicating a low transformer fluid level, which is preventing the radiators from functioning. This problem can lead to transformer overheating which creates abnormal thermal stress on the paper winding insulation and results in reduced transformer life.



Another infrared application for fluid-filled transformers is to compare the temperature of the load tap-changer (LTC), if so equipped, to that of the main tank. Generally, the main tank temperature should be warmer than the isolated LTC tank. Similar temperatures can indicate dangerous leaks between the two tanks or severe “coking” or arc debris buildup on the LTC contacts.

Overheating of dry type transformer core assemblies can provide indication of serious core delamination problems which can allow eddy currents that are responsible for inefficiencies resulting in increased thermal and electrical losses. This abnormal heating also causes winding insulation deterioration and reduces the life of the transformer. Associated follow-up electrical tests should include checking for proper operating voltages, individual phase loading and balance, and an analysis of harmonic content of the load.

Switchgear

A great deal of investment is presently being made in the installation of thermal viewing ports for switchgear. These ports allow infrared inspections to be performed without removing switchgear covers, thus significantly reducing or eliminating worker arc-flash exposure. The installation of permanent infrared sensors and continuous infrared monitors are also viable methods for recognizing potential thermal failures of critical equipment.

The integrity of outdoor switchgear assemblies is often compromised by defective strip heaters. The strip heaters increase the switchgear temperature slightly above ambient in order to prevent condensation during daily or seasonal temperature changes. The functionality of these strip heaters and their effectiveness to perform this duty can be deter-

mined by performing thermal imaging of the switchgear enclosures. In other words, and once again, the absence of heating identifies a potential problem.

Medium-Voltage Splices and Terminations

Although many problems associated with splice and termination components are related to insulation failure that can be identified by on-line partial discharge surveys, still many problems are associated with conductor integrity. Several utilities require infrared scanning of underground vault splice assemblies before personnel are allowed into these areas. In this capacity, infrared is used as both a safety and a reliability tool. Additional infrared applications include the inspection of pad-mounted transformer premolded elbow assemblies. One utility estimated that approximately 30 percent of its elbows had been found with thermal problems due to connection, probe, or crimp deficiencies.

Low-Voltage Bus Duct

Low-voltage bus duct assemblies are popular for facility applications that require distributing high currents for long distances due to their lower installation cost compared to conduit and cable. Although very reliable, these assemblies are very difficult to test by conventional methods due to limited access caused by their construction. Infrared inspections are one of the few technologies that can help identify bus segment contact problems at joints. Infrared inspections must generally be performed by scanning the outside bus duct enclosure. Although significant air gaps exist between the bus and enclosure, this technique has been successful in detecting connection problems. Without detailed internal bus construction information available, the technician should investigate even slight temperature differences occurring at the enclosure near bus segment connection points or coupling joints.

Additionally, bus-plugs or bus-taps depend on a very limited amount of contact area. These points of contact are further dependant on spring tension and are, therefore, especially vulnerable to overheating conditions. Many times this is caused by conducted heat from failing contacts or terminations within the bus-plug assembly.

Heat run tests, also known as continuous-current, temperature-rise tests, are generally conducted by the manufacturer in order to verify adequate conductor size for the application. However, occasionally applying high currents to bus or circuit breakers in the field can reveal problems that may not be apparent during normal operation. The cost of performing this test generally limits its use to problem troubleshooting when other testing avenues have been exhausted.

Noncurrent-Carrying Items

Many times other problems can be spotted with ancillary items which normally do not carry current and, therefore, (mistakenly) are not part of the normal infrared survey. Thermographers, experienced in the vastness of potential problems, will many times glance around in their field of

view and spot other items radiating heat (or not radiating heat), which will raise their curiosity level to the point of a closer look. Many times a metallic structural support, cableway, or cable tray assembly, none of which should be carrying current, will indicate heating that is apparently from electrical current flowing. Field measurements of hundreds of amperes have been seen numerous times and are most commonly the result of excessive eddy currents caused by inductive heating. This heating effect can cause the surface temperature to rise well beyond the boiling point of water, potentially presenting a burn hazard to personnel or the deterioration of other substances in close proximity.

Grounding connections normally do not carry continuous current; therefore, a ground connection showing any increase in temperature can indicate a possible problem. Further investigations of these types of problems have uncovered a variety of issues, such as ground loops, broken or disconnected grounds, and high impedance faults.

Conclusion

The infrared survey is a great initial screening or detection tool for potential problems, but additional electrical tests should be performed in order to confirm initial conclusions. It is extremely easy to have a false positive thermal image; therefore, other measurements such as millivolt drop tests, current readings, harmonic analysis, power factor, and others should be performed on suspect observations. These additional tests are mandatory as certifiable test results may be necessary or required for investigative or litigation purposes.

Deluxe or premium camera systems can fix many field errors after the image has been stored, but basic fundamental errors such as focus, range, or distance cannot be corrected after the survey. Additional common mistakes are incorrect emissivity settings or assumptions and reflected or indirect contributions.

Lastly, the infrared survey remains one of the best overall tools for detecting potential electrical problems. The popularity of the technology and the low cost of equipment have allowed nonexperts to implement infrared survey programs. However, the additional cost associated with upper-end equipment and experienced technicians with certified training may very well be worth every penny when important decisions are made based upon infrared survey results.

Mr. Genutis received his BSEE from Carnegie Mellon University, has been a NETA Certified Technician for 15 years, and is a Certified Corona Technician. Don has nearly twenty-five years of practical field and laboratory electrical testing experience. He is presently serving as Vice President of the Group CBS Eastern U.S. Operations and acts as Technical Manager for their subsidiary, Circuit Breaker Sales & Service located in Central Florida.

Other Acknowledgements:

The author would like to thank Harold Orum of Halco Service in Los Angeles, CA for his valuable assistance with this article. Harold is a NETA Affiliate and has accumulated more decades of electrical experience than he will admit to.