APPLICATION NOTE

Monitoring transformers with infrared cameras

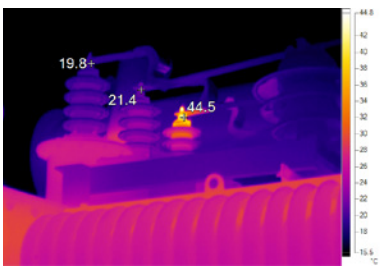
Most transformers are cooled by either oil or air while operating at temperatures much higher than ambient. In fact, operating temperatures of 65 °C for oil-filled units and 150 °C for air-cooled transformers are common. Nevertheless, problems with transformers often manifest themselves in overheating or hot spots, making thermal imaging a good tool for finding problems.

Power and distribution transformers change electric current from one voltage to another. They accomplish this process when electricity flowing through a coil at one voltage induces current in a second coil. The amount of change is a function of the number of windings on the coils.

The following discussion focuses on monitoring external and internal conditions of oil-filled transformers. Dry transformers also can exhibit both external or internal connection problems, and external connection problems can be detected as with oil-filled units. Beyond that, dry transformers have coil temperatures so much higher than ambient, it is difficult to detect internal problems before irreparable damage occurs. Other diagnostic technologies, including built-in temperature and pressure gauges, may be more reliable for assessing the internal conditions in dry transformers.

The procedures described here should be conducted in conjunction with the recommendations of international, and where available, local guidelines on infrared thermal imaging inspections. Of the standards listed below the US NFPA is the most developed and is often referred to by other local standards:

- US NFPA Standard 70B, Recommended Practice for Electrical Equipment Maintenance. Inspection of transformers is described in, Chapter 9: “Power and Distribution Transformers.”
- VATh – Richtlinie: Elektrothermografie and DIN 54191 – Zerstörungsfreie Prüfung – Thermografische Prüfung elektrischer Anlagen for Germany
- ÖNORM M 3043 Zerstörungsfreie Prüfung – Thermografische Prüfung elektrischer Anlagen for Austria



There are also approved international standards, describing general use of infrared thermography for diagnostics:

- ISO 18434-1 Condition monitoring and diagnostics of machines—Thermography—Part 1: General procedures
- EN 16714-1 Non-destructive testing. Thermographic testing.—General principles

Other international norms are still under development:

- ISO/AWI 10881 Non-destructive testing—Infrared thermography—Guidelines for examination of electrical installations
- ISO/NP 18434-2 Condition monitoring and diagnostics of machines—Thermography—Part 2: Image interpretation and diagnostics

What to check?

At a minimum, use your thermal imager to look at external connections, cooling tubes and cooling fans and pumps as well as the surfaces of critical transformers.

What to look for?

In oil-filled transformers, monitor the following external components:

- **High- and low-voltage bushing connections**
  Overheating in a connection indicates high resistance and that the connection is loose or dirty. Also, compare phases, looking for unbalance and overloading.
- **Cooling tubes**
  On oil-cooled transformers, cooling tubes will normally appear warm. If one or more tubes are comparatively cool, oil flow is being restricted and the root cause of the problem needs to be determined.
- **Cooling fans/pumps**
  Inspect fans and pumps while they are running. A normally operating fan or pump will be warm. A fan or pump with failing bearings will be hot. A fan or pump that is not functioning at all will be cold.

Problems with surge protection and lightning arrestors leaking to ground and current tracking over insulators can also be detected using thermography. However, finding such problems requires the capture of subtle temperature differences often under difficult-to-monitor conditions. Ultrasound or some other technology might be a more reliable monitoring technique for these problems.

For thermography to be effective in pinpointing an internal transformer problem, the malfunction must generate enough heat to be detectable on the outside. Oil-filled transformers may experience internal problems with the following:

- **Internal bushing connections**
  Note: connections will be much hotter than surface temperatures read by an imager indicate.
- **Tap changers**
  Tap changers are devices for regulating transformer output voltage to required levels. An external tap changer compartment should be no warmer than the body of the transformer. Since not all taps will be connected at the time of an inspection, IR inspection results may not be conclusive.

A good approach is to create regular inspection routes that include the transformers on all essential electrical circuits. Save thermal images of each one on the computer and track temperature measurements over time, using the software that comes with the IR camera. That way, you'll have baseline images with which to compare later images that will also help you determine if temperature levels are unusual and, following corrective action, determine if maintenance was successful.

Fluke Connect® and cloud share

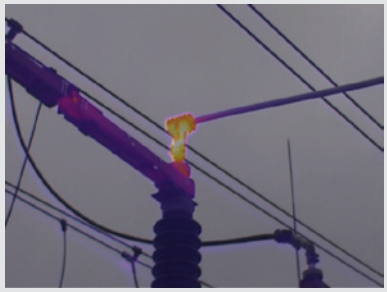
Modern technologies provide the opportunity to improve the saving and sharing of inspection results. Use the Fluke Connect app to save data to Fluke Cloud and assign measurements to specific equipment immediately while working in the field. When you find something that requires immediate attention, use the app for quick analysis, then create reports in the field, and collect all necessary data to share results with your colleagues, who need to respond on findings, requiring emergency response, via Fluke Cloud™.

Fluke Connect Assets will help to keep records of your equipment health, follow trends of changes on equipment and reveal hidden correlations and regularities in equipment performance by combining the histories of different type of measurements.

Fluke thermal imagers include IR-Fusion® technology that fuses a visual, or visible light, image with an infrared image for better identification, analysis, and image management. The dual images are accurately aligned at any distance, heightening details so problems are easier to spot.

IR-Fusion® technology and blending modes:

Full IR view



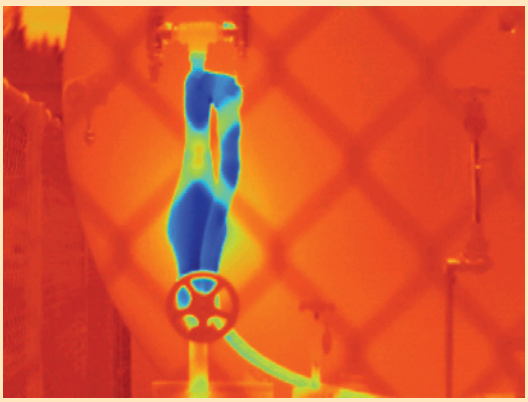
Full IR AutoBlend™ mode

Picture-in-Picture (PIP) view

Picture-in-Picture (PIP) with Autoblend™

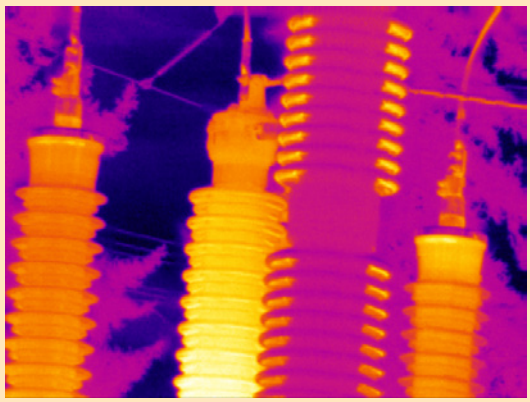
Picture-in-Picture (PIP) with Color Alarm

Advanced focus options to optimize your thermal inspections



LaserSharp® Auto Focus

Capture in-focus images every time with a touch of a button. LaserSharp calculates the distance to your target with a laser distance meter and adjusts the focus automatically.



MultiSharp™ Focus

With MultiSharp focus, images are automatically focused throughout the field of view. The camera takes multiple images and combines them so equipment in both the foreground and background are in focus.

Simply point and shoot.

What represents a "red alert"?

Equipment conditions that pose a safety risk should get the highest priority for repairs. However, the imminent failure of any piece of critical equipment constitutes a red alert. Key operations, maintenance, and safety personnel should play roles in quantifying "warning" and "alarm" levels for the power supplies to critical assets. (Note: alarm levels for specific equipment can be set on Fluke handheld thermal imagers.) Throughout, personnel responsible for monitoring transformers should keep in mind that like an electric motor, a transformer has a minimum operating temperature that represents the maximum allowable rise in temperature above ambient, where the specified ambient is typically 40 °C. It is generally accepted that a 10 °C rise above its maximum rated operating temperature will reduce a transformer's life by 50 percent.

What's the potential cost of failure?

For power delivery companies, transformer failures can be very costly.

Electrical utilities in the Netherlands are considered some of the most reliable in the world. Nevertheless, on March 27th, 2015, a major blackout hit the northern part of the Netherlands, leaving households, hospitals and shops without electricity for over five hours. Road signs and traffic lights went down, people were locked in elevators, trains stopped and there was a major operation disruption at one of Europe's largest and busiest airports, Schiphol in Amsterdam, resulting in all flights being cancelled.

In their annual report TenneT, the utility operator, reported that the blackout was caused by a short circuit at 380 kV substation in Diemen. This blackout affected one million end-users in Amsterdam and the province of North Holland.

Imaging tip

Winds (or air currents inside) in excess of even a few miles per hour will reduce the surface temperatures of transformers and other equipment, causing real problems to seem less significant or even making them undetectable by your thermal imager. Inside plants air currents are often 10 to 15 miles per hour. Buy a high-quality wind meter and use it. When you must inspect in high convection situations, note all problems for a follow-up inspection. Even small temperature increases may become critically hot when airflow is reduced.

For a failed transformer at your facility, you can analyze the cost of: repair or replacement, lost production opportunity and lost labor for affected equipment.

Follow-up actions

Whenever you discover a problem using a thermal imager, use the associated software to document your findings in a report, including a thermal image and a digital photograph of the equipment. That's the best way to communicate problems you find and to suggest repairs.

The Fluke Connect cloud-based system offers solutions for this as well. You can store data from thermal cameras and other measurement diagnostic tools, and plan maintenance or the next inspection accordingly. Storing data in the cloud and sharing it within your team allows everybody to have the necessary data and historical records just when they need them.

Perceived internal problems in oil-cooled transformers can often be verified by a gas-in-oil analysis. The presence of methane in the oil indicates overheating. Acetylene indicates arcing. This test can also be used to help trend the severity of a problem in a transformer that simply cannot be taken down for repairs.

Warning: Never draw liquid samples from an energized transformer except via an external sampling valve. Also, regular gauge and load monitoring and visual inspections for leaks, corrosion, et cetera will help guide further maintenance activities.

[1]http://annualreport.tennet.eu/2015/annualreport/userfiles/pdf/TenneT-AR15.pdf

[1]Background information supplied by John Snell & Associates.

[2]Source: www.aftenposten.no/english

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