# Application of thermal imaging in electrical equipment examination

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***Abstract-* The paper states about applying thermal imaging measurement methods to electrical equipment diagnostics. Modern infrared mapping techniques allow to take fast and non-exhausting measurements of devices that are not easy accessible or where measurements are dangerous to humans. Thermography has found it's principal use in power engineering in diagnostics of electrical apparatus and equipment, mainly transformers and insulators.**

## I. BASIC IDEA OF THERMAL IMAGING

Thermography, also called thermal imaging, is a type of infrared imaging. Infrared radiation is electromagnetic radiation of a wavelength longer than visible light wavelenght, but shorter than that microwaves. It's name means "below red", because of red being the color of visible light with the longest wavelength. Infrared radiation has wavelengths between about 750 nm and 1 mm, spanning five orders of magnitude. Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14.000 nanometers or 0.9–14 µm) and produce images of that radiation [2]. Wien's displacement law is a law of physics that states that there is an inverse relationship between the wavelength of the peak of the emission of a black body and its temperature (Figure 1). Since infrared radiation is emitted by all objects based on their temperatures, according to the black body radiation law, thermography makes it possible to see environment with or without visible illumination.

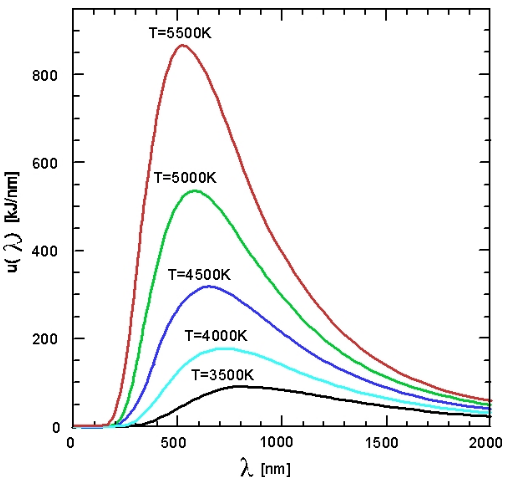


Figure 1. The wavelength corresponding to the peak emission in various black body spectra as a function of temperature

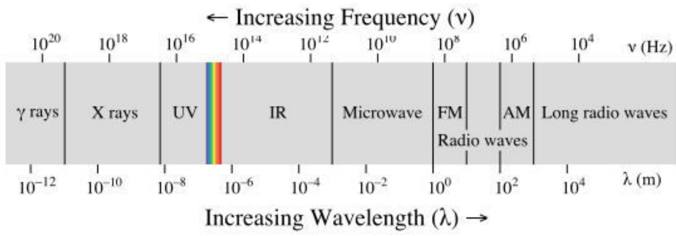


Figure 2. Electromagnetic spectrum

The amount of radiation emitted by an object increases with temperature, therefore thermography allows one to see variations in temperature. When viewed by thermographic camera, warm objects stand out well against cooler backgrounds; humans and other warm blooded animals become easily visible against the environment, day or night.

## II. THERMOGRAPHIC CAMERAS

A thermographic camera, sometimes called a FLIR (Forward Looking InfraRed), or an infrared camera less specifically, is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 450–750 nanometer range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm) (Figure 2). Cameras create a thermal image of observed target, generally in scale from black (coolest) thru red to white (hottest), and also provide on the image a reference scale. Thermographic cameras can be broadly divided into two types: those with cooled infrared image detectors and those with uncooled detectors [3].

Cooled detectors are typically contained in a vacuum-sealed case and cryogenically cooled. This greatly increases their sensitivity since their own temperatures are much lower than that of the objects from which they are meant to detect radiation. Typical cooling temperatures range from 4 K to 110 K, 80 K being the most common. Without cooling, these sensors (which detect and convert light in much the same way as common digital cameras) would be 'blinded' or flooded by their own radiation. The drawbacks of cooled infrared cameras are that they are expensive both to produce and to run. Cooling and evacuating are power- and time-consuming. The camera may need several minutes to cool down before it can begin working. Although the components that lower temperature and pressure are generally bulky and expensive, cooled infrared cameras provide superior image quality compared to uncooled ones.

In principle, superconducting tunneling junction devices could be used as well as infrared sensors because of their very narrow gap. Their wide range use is difficult because their high sensitivity requires careful shielding from the background radiation.

Uncooled thermal cameras use a sensor operating at ambient temperature, or a sensor stabilized at a temperature close to ambient using small temperature control elements. Modern uncooled detectors use sensors that work by the change of resistance, voltage or current when heated by infrared radiation. These changes are then measured and compared to the values at the operating temperature of the sensor. Uncooled infrared sensors can be stabilized to an operating temperature to reduce image noise, but they are not cooled to low temperatures and do not require bulky, expensive cryogenic coolers. This makes infrared cameras smaller and less costly. However, their resolution and image quality tend to be lower than cooled detectors. This is due to difference in their production processes, limited by currently available technology.

Specification parameters of an infrared camera system are number of pixels, spectral band, sensor lifetime, MRTD (Minimum Resolvable Temperature Difference), field of view, dynamic range, input power, mass and volume.

## III. THERMAL IMAGING SUMMARY

Advantages:

•You get a visual picture so that you can compare temperatures over a large area

•It is real time capable of catching moving targets

•Able to find deteriorating components prior to failure

•Measurement in areas inaccessible or hazardous for other methods

•It is a non-destructive test method

Disadvantages:

•Cameras are expensive and are easily damaged

•Images can be hard to interpret accurately even with experience

•Accurate temperature measurements are very hard to make because of emissivities

•Most cameras have ±2% or worse accuracy (not as accurate as contact)

•Training and staying proficient in IR scanning is time consuming

•Ability to only measure surface areas

Thermal imaging requires special skills from service staff. Persons directed to use it have to be trained at special courses to get proper knowledge on cameras working conditions, investigated equipment materials and thermal imaging itself. Well trained staff and high quality camera are a must to obtain good pictures.

## IV. APPLICATIONS IN POWER ENGINEERING

One of the common application of thermal imaging in power engineering is examination of power transformers. They can be examined during normal working conditions. Many defects are better visible when transformer isn't switched off, like overheating or cold parts, which would be harder to find with normal inspection methods.

Figure 3. Image of an high voltage transformer

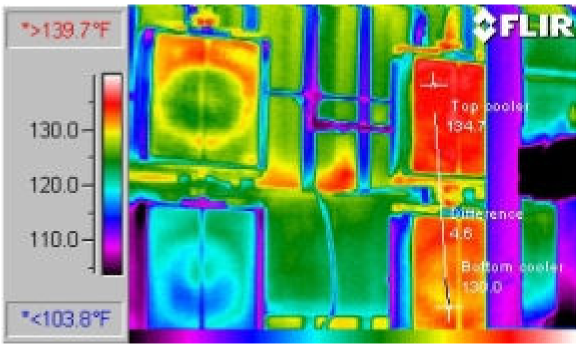


Figure 4. Transformer radiators seen by thermographic camera

This infrared image shows transformer wall with radiators on it (Fig.3). There can be seen a cold radiator on the lower left, possibly due to a bad pump. This could be a serious problem as the capacity of the transformer is reduced and other radiators will work above their nominal working temperature.

Thermal imaging finds it's best application in inspections of insulators and arresters. During normal operation conditions their testing would be dangerous and switching off the line or whole installation very costly [1].

Figure 5. Intermediate station class arrester

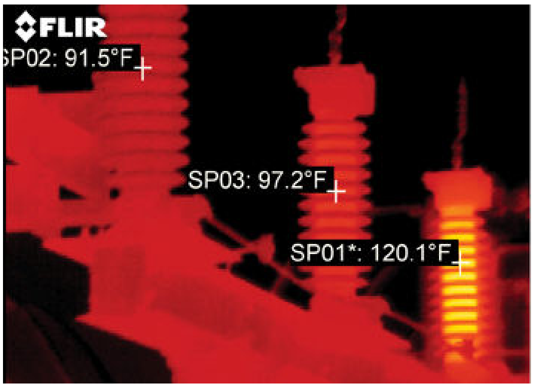


Figure 5. Intermediate station class arrester seen by thermographic camera

Retaining type of medium voltage arrester is used on the distribution side of a substation on three phase feeder lines at the substation to hold the lines (Fig.4). The heating problem with these arresters could have affected the reliability of this three phase feeder line. There can be observed overheating of all three arresters (Fig.5). If this situation would last for too long an fault could occur and the lines held by arresters will be unoperational causing significant costs.

## V. SUMMARY

In order to maintain the reliability of a power transmission lines and distribution system, it is important to be able to identify possible future fault locations. Infrared thermal imaging can make it easier and faster.

## REFERENCES

[1] STRMISKA R., Lightning arresters' effect on power line reliability, Sumterville,2003,6-7.
[2] http://www.infratec.de/en/infratec/submenu/theory/basics.html/,24 March 2008.
[3] http://pl.wikipedia.org/wiki/Termowizor/,24 March 2008.