DIAGNOSTICS OF THERMOVISION BROADCASTERS

M. ŠIMKO, M. CHUPÁČ, M. GUTTEN, M. ŠEBÖK, D. KORENČIAK
Faculty of Electrical Engineering, University of Žilina,
Univerzitná 1, 01026 Žilina, Slovakia, Email: gutten@fel.uniza.sk

Abstract: *This paper describes the problem analysis of thermal sensors; it examines the functional principles and application of non-contact temperature measurement. The knowledge in infrared radiation measurement enables us to use the methods of thermovision diagnostic more effectively and to localize deviations in quality of electrical distribution network and connections.*

Key words: sensor, thermovision, measurement, diagnostics

1. Introduction

Temperature can be measured by means of electromagnetic radiation analysis of an object surface. In this way, it is possible to define a distribution of a temperature field on a surface of measured objects without contact, with the accuracy of 0,1 degrees of Kelvins (altern. ˚C).

Infrared radiation is only a part of a large spectrum of electromagnetic radiation having the same physical attributes as visible light. It includes transverse electromagnetic waves, which expand through vacuum, gas, liquids and solid substances.

Sensors are devices that sense physical parameters and transform it to another one suitable for further processing and evaluation. The main advantage of non-destructive diagnostics of electric systems based on infrared diagnostic techniques is the ability to record and process infrared radiation (thermal) as a real thermal image of a scanned object (thermogram). Moreover, it is able to detect mistakes (errors) by means of overheating in certain areas. Temperature increase in distribution lines as well as electric machines gives us an early alert on progressive deterioration of transition resistance in power connections.

2. Theoretical Analysis

Sensors absorb infra-radiation on their sensing surfaces, which leads to heating up and finally to a signal to be sent to sensor's active part. Timewise, temperature change in the sensitive part of the sensor is a relatively slow process. Fig.1 represents a model of a thermal sensor.

If the sensing element is characterised by thermal capacitance C, absorbance α at the ambient temperature T_A with thermal conductivity G, then for the radiance flow $\Phi(t)$ which changes over time following equations apply:

$$\text{for } \Phi(t) = 0 \text{ then } T_D = T_A, \quad \text{for } \Phi(t) > 0 \text{ then } T_D > T_A. \tag{1}$$

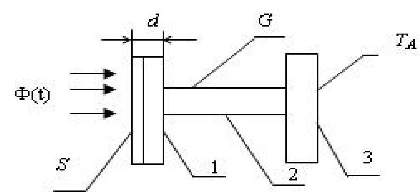

Fig. 1. A model. Simplified construction of thermal sensor: 1 - sensitive part of a sensor with temperature T_D, sensor's active area S and thickness d, 2 - thermal bridge with thermal conductivity G, 3 - base with temperature T_A.

If we consider ideal state, i.e. absorbed energy equals to conducted energy via a thermal bridge, then for such a thermal balance the following formula can be applied:

$$\alpha\Phi(t) = C\frac{d}{dt}[\Delta T(t)] + G\Delta T(t), \tag{2}$$

where $\Delta T = T_D - T_A$ is temperature increase of sensitive part of a sensor, as it is heated up by absorbed input radiance current $\alpha\Phi(t)$.

Assume that the radiance input current change in time is as follows

$$\Phi(t) = \Phi_0 + \Phi_m \cdot e^{j\omega t} \tag{3}$$

and the resulting temperature increase is:

$$\Delta T(t) = T_0 + \Delta T_m \cdot e^{j(\omega t - \varphi)}. \tag{4}$$

In this equation the first symbol represents the d.c. part and the second symbol is the harmonic part. On the basis of formulas (3), (4) we can design electrical (substitute) structure of thermal sensor (Fig. 2).

Temperature increase ΔT is delayed when compared with the input radiance current $\Phi(t)$. For amplitude ΔT_m and a phase shift φ we conclude:

$$\Delta T_m = \frac{\alpha\Phi_m}{\sqrt{G^2 + (\omega C^2)}} \quad \text{and} \quad \varphi = \text{arctg}\left(\frac{\omega C}{G}\right) \tag{5}$$

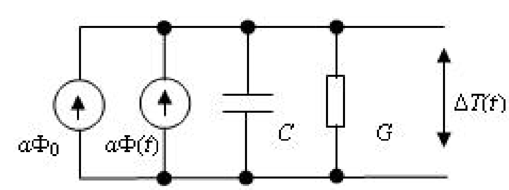

Fig. 2. A model. Construction of a thermal sensor.

3. Experimental Measurements

We carried out measurements over the period of three year seasons (spring, summer, autumn) by thermovision camera ThermaCAM SC 640 including its accessories, while temperatures were monitored by pyrometer, too. There is the course of heating characteristic of the junction feeder line-spacing collar, capacitor frame at the transmitter power of 60% (connection not being in good conditions).

Fig. 3 represents the temperature dependency of junction (feeder line-spacing collar, capacitor frame) and feeder line on the transmitter power, in this case junction being in order (drawn up and clear).

Generally speaking, if the junction feeder line-capacitor frame, spacing collar and the like, is in order (good stage, drawn up and clean), it must not be warmer than the feeder line to which it is connected.

The heating characteristics of the junctions depending on the transmitted power are shown in Fig. 4. The values of junctions heating against the feeder line ($\Delta t = T_{sp} - T_l$) which are plotted in the graph were obtained as follows: junctions temperatures (T_{sp}) are the temperatures measured, and the feeder lines temperatures (T_l) are data acquired from dependency measurements shown in Fig. 3.

In the case that the junction is slacked or polluted the temperature increase in relationship with transmitting wave power has a parabolic characteristic.

In Fig. 5, there is an example of a thermogram realized on the KW transmitter working at f=11990 kHz, transmitter power being 250 kW.

Measurement has been performed during a summer period, when temperature of feeder line (Fig. 6, ARO 4) is T_l = 20,3 °C. Temperature of junction (ARO 1, ARO 2) feeder line-spacing collar is in the first case T_{sp}=20,5 °C and in the second case T_{sp}=20,4 °C. Temperature of junction (ARO 3) feeder line-capacitor frame is T_{sp}=20,2 °C. As it results from the previous analysis and from Fig. 4, the temperature rise of junction (defined as $\Delta t = T_{sp} - T_l$) is Δt=0,2°C in the case of ARO 1, Δt=0,1°C in the case of ARO 2 and Δt=-0,1°C in the case of ARO 3.

It is possible to conclude that the temperature rise is of a very small value and the junction is in good condition. In the case of ARO 3 it attains a lower value than in the case of a feeder line, as it was assumed by the theoretical analysis. The temperature growth of a junction is lower than the temperature growth of a feeder line. Due to its bigger surface the junction has bigger ventilating losses and therefore it is better cooled down by air circulation than the feeder line.

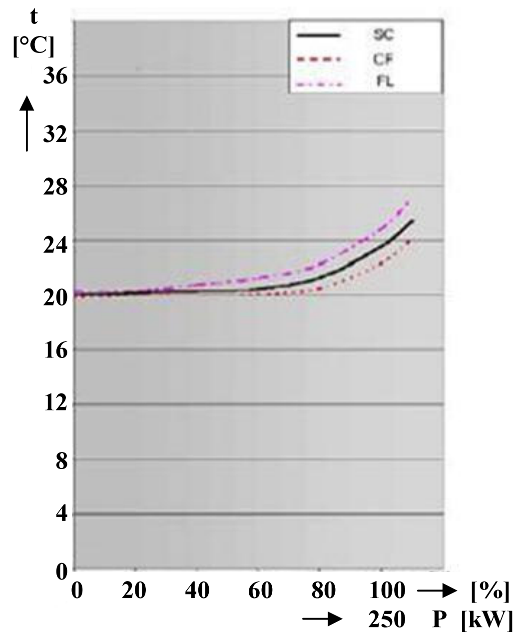

Fig. 3. Relationship between temperature of connection (feeder-line, capacitor frame) spacing collar and power. Connection I drawn up and clean. SC-spacing collar, CF-capacitor frame, FL-feeder line.

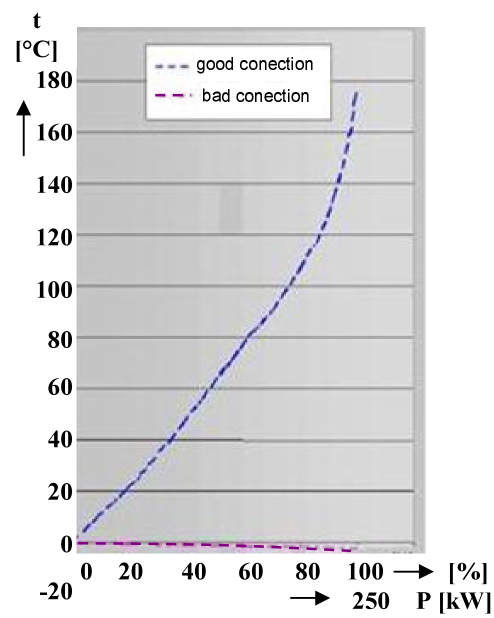

Fig. 4. Relationship between temperature rise amount of connection and feeder line upon power $\Delta t = T_{sp} - T_l$

In Fig. 6, the area of defect is localized in feeding distribution of antenna, i.e. feeder line-spacing collar, where difference in temperatures $\Delta t = T_{sp} - T_l$=101°C is recorded. However, during the inspection, it is necessary to pay particular attention to antenna itself and to other parts of antenna transmitters. The recorded or calculated temperature values (temperature increase) are assigned to particular class of classification scales in relation to their size. In relation to that, there are different measures recommended for different classes so as to eliminate found defects. During the measurement, it is necessary to take the influence of wind speed into account, for and further recommendations which have to be part processed measurement methodology.

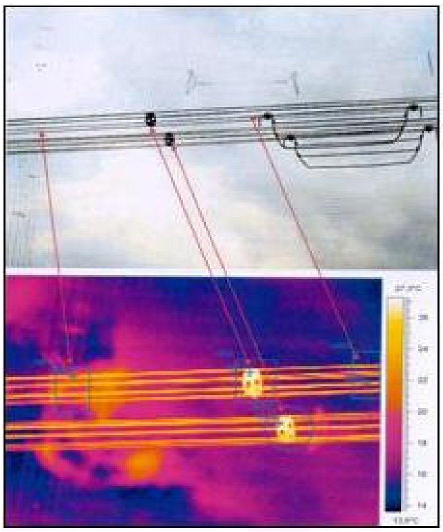

Fig. 5. Thermogram of the junction feeder line-spacing collar, capacitor frame

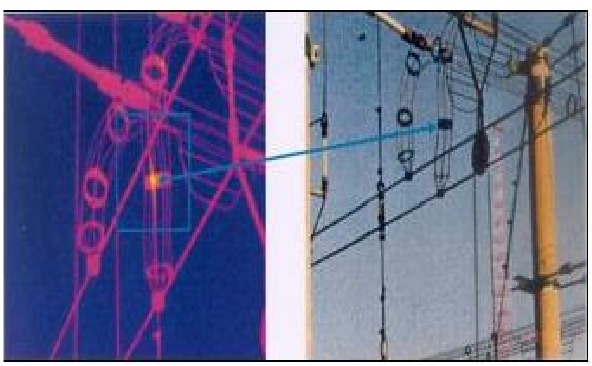

Fig. 6. Thermogram of the junction feeder line-spacing collar

4. Discussion to the measured data

Measurements where the percentage current load is not possible to obtain (circuit is loaded less than 50% current load). If we use the equation for temperature calculation, increase to 100% current load. To evaluate the quality we obtain significantly larger figures of the calculated temperature increase than of the real measured temperature increase.

The result is incorrect evaluation for the operation to be cut off because of the error, useless waste of material for the replacement of the false parts and of course, a negative economic effect.[4]

Measured data can not be used as a limits factors (perturbing influence of the environment, currentweigh, voltage fluctuation, effect of the objects´ emission nearby the measured object).

If we do not consider these elements in course of calculation, there the negative influence of the results of the thermovision diagnostics will be possible.

5. Conclusions

Thermovision diagnostics (thermodiagnostics) is a relatively young technical discipline classified to the branch of technical diagnostics. Its benefits have been many times verified and in series of cases this diagnostics is irreplaceable or with very big limitations replaceable by other diagnostic methods. By the routine diagnostics and by early detection of defects in their initial stage, it is possible to prevent vast repairs. The effectiveness and speed of measurements strongly simplify the process and result in extensive economical effect (savings). Referring to significant contribution to problem diagnostics of radio transmitters and aerial systems, we emphasize the potential of thermovision technique application, which becomes at a fast rate a part of various branches in Slovak Republic as well as in other countries.

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