IMPROVING RELIABILITY AND DECREASING LOSSES OF ELECTRICAL SYSTEM WITH INFRARED THERMOGRAPHY

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ABSTRACT
Temperature and the resulting thermal behavior of electric power generation and distribution equipment and industrial electrical systems and processes are the most critical factors in the reliability of any operation or facility. Temperature is by far the most measured quantity in any industrial environment. For these reasons, monitoring the thermal operating condition of electrical and electromechanical equipment is considered to be key to increasing operational reliability and decreasing electrical losses.

Keywords: *infrared thermography, thermal anomaly, wavelength, condition monitoring, predictive maintenance, overheating*

1. INTRODUCTION

Infrared thermography (IR/T) as a condition monitoring technique is used to remotely gather thermal information for monitoring the condition of virtually all of the electrical components on an entire system and from generation to end user. Once the baseline is established, IR/T will reveal the thermal variances deviating from the norm. This localized thermal deviation can either be caused by an overheated condition or absence of heat. The information is reviewed and decisions are made for repair, or to plot the temperature change over time and repair the component at a more opportune time. The information can be stored and fully analyzed at a later date providing complete computer-aided predictive maintenance capabilities and trending.

2. HISTORY OF THERMOGRAPHY

In 1800, astronomer Sir William Herschel discovered infrared, and thus began the exploration of the science of thermography. Sir William designed and created his own telescopes - becoming very familiar with lenses, mirrors and light refraction. His thermography research began with the knowledge that sunlight was made up of all the colors of the spectrum, and that it was also a source of heat, so he set out to determine which color(s) were responsible for heating objects. The first thermography experiment utilized a prism, paperboard, and thermometers with blackened bulbs where the temperatures of the different colors were measured. As sunlight passed through the prism, Sir William observed an increase in temperature as he moved the thermometer from violet to red in the rainbow created by the light. Herschel noted that the hottest temperature was actually beyond red light, and that the radiation causing this heating was invisible. He called this invisible radiation "calorific rays." Today, we refer to the light/energy as infrared, and the measuring of the heat emitted as thermography [5].

3. SIMPLY PICTURE OF HEAT

Infrared Thermography is simply a picture of heat. All the bodies emit energy from their surface as electromagnetic waves, which magnitude is directly related to their temperature. The hotter the object is, the more energy it tends to radiate. Such temperature settles the wavelength of the emitted energy; the colder the object is, the higher its wavelength will be, whereas the hotter it is, the lower its wavelength will be. This last case, is the one of the infrared energy, non visible to the human eye, but visible by means of an infrared camera [3].

The radiation measured by the infrared camera depends not only on the temperature of the object but also on its emissivity. The radiation coming from the surrounding area and reflected on the object also influences the measuring. Therefore, to measure the temperature accurately, besides the effects of different sources of radiation that interact with the object, other variables such as emissivity, distance between the camera and the object scanned, environment temperature and humidity, must also be considered. In addition, due to the characteristics of the infrared radiation, to detect any overheating by IR scans, the heat generated must be “directly” in sight of the thermographer.

4. INFRARED CONDITION MONITORING

Universally, the electric industry understands that temperature is an excellent indicator to the operating condition and hence the reliability and longevity of an electrical component. Associations like IEEE, ANSI, IEC and manufacturers all publish standards and temperature ratings for electrical components. It is well understood that the life of electrical components and materials is drastically reduced as temperatures are increased.

Infrared condition monitoring is the technique capable of revealing the presence of an anomaly by virtue of the thermal distribution profile which the defect produces on the surface of the component. The defect will normally alter the thermal signature of the surface due to the change in the amount of heat generated and the heat transfer properties of the component. To determine an adverse operating temperature of a component it is necessary to first determine a baseline. For electrical systems the baseline is established when the system is operating under normal load and operating conditions [1].

Once a clear understanding is obtained on what the normal thermal signature is for the many electrical apparatuses and components, the thermography technician will be able to quickly identify a thermal anomaly. On larger more critical components such as transformers, circuit breakers, capacitors etc., the baseline images and data will be stored and compared to new data collected from each inspection interval [2].

For the classification of thermal abnormalities, three critical levels and their corresponding recommended maintenance actions were defined [6]:

I -Overheating ≥ 130°C (Serious): immediate outage of the equipment affected for the repairing of the anomaly.

II - Overheating between 100°C and 130ºC (Priority): repairing of the anomaly as soon as possible.

III - Overheating between 75°C and 100º C (Programmed): repairing of the anomaly when possible

Correction factors considering the effects of variables such as emissivity, environment temperature and relative humidity, wind influence and distance to the object were established to be considered in the measuring. Maximum admitted loadability for the whole facilities to be scanned were set and tabulated (for instance identifying the equipment with the lowest load capability of the bay). Therefore, the overheating measured at any level of load could be referred to such maximum admitted loading level, so as to consider the most unfavorable conditions that could be present during their operation [4].

Thermographic Reports, provide information that identify with certainty the item on which a thermal abnormality has been detected, together with a picture and a thermographic image of the abnormality detected, to facilitate the repairing tasks for the maintenance personnel. Besides, they add additional information, such as over-temperature registered and temperatures of reference, load level at the time of the scan and maximum admitted load, overheating above the environment temperature referred to the maximum admitted load and thermal classification of the abnormality.

Next figures present infrared Thermography of thermal anomaly detected on fuses [5].

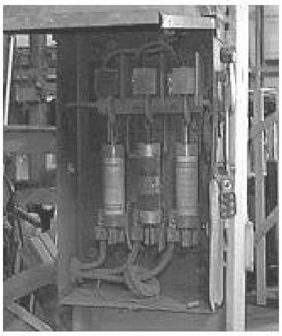

Fig. 1 Visual: What you see

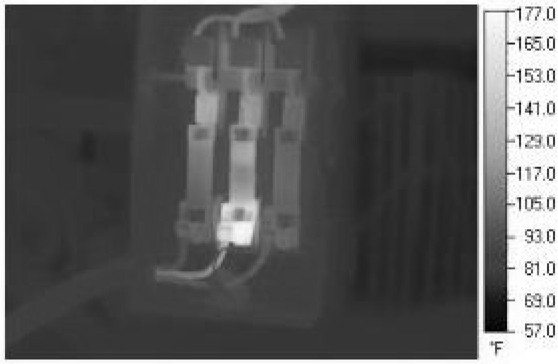

Fig. 2 Infrared Thermogram: Before

Fig. 3 After cleaning center fuse contact showing decrease of 70 deg. in temperature

From the results of IR scans performed during the period 1999-2005 (Fig. 4), arose that most of problems were found in conductor connection accessories and bolted connections (48%), mainly derived from deficiency of adjustment and/or materials (anomalies in bimetallic surfaces joints, rust, non adequate use of inhibitory grease).

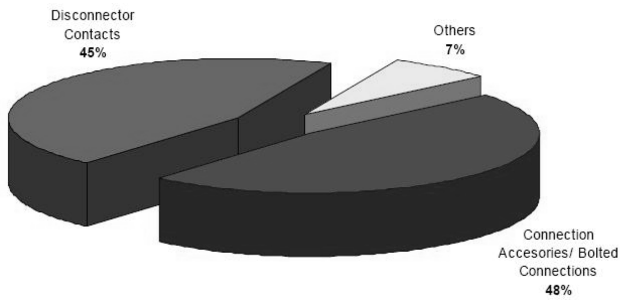

Fig. 4 Distribution of thermal abnormalities by component Period 1999-2005 [6].

Besides, an important number of thermal anomalies appears in disconnectors contacts (45%), from mainly of defected contacts by deformations, deficient pressure of contact, incorrect alignment of arms and dirtiness (Fig. 5).

Anyway, a significant number (7%) grouped in Others validates the efforts of scanning all the equipment identified.

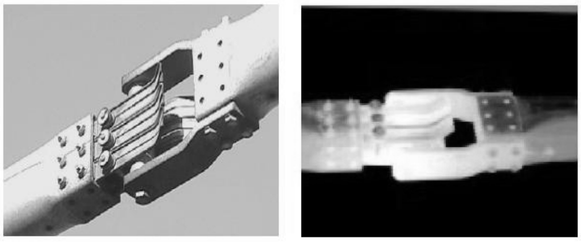

Fig. 5 Disconnector contact and Infrared Thermography of thermal anomaly detected on this item.

These determinations allowed to focus the tasks developed during the scheduled PM, introducing improvements in the maintenance practices carried out. Besides that, an increased awareness by the maintenance working teams in the actions executed to solve the abnormalities detected was achieved, resulting this in an important contribution for the decrease of the critical "hot spots" found.

By analyzing the evolution of the abnormalities detected during the period 1999-2005, we see that in the period as a whole, a growing tendency to the reduction of thermal abnormalities related with the total number of item scanned for all critical levels is presented [6] (Fig. 6).

The decrease of thermal abnormalities with higher critical level is attributed to its early detection and their addressing by means of programmed outages, taking corrective actions to prevent the abnormality could evolve to a worse critical level. On the other hand, the decrease of thermal abnormalities with a lower critical level can be attributed to an improvement in the practices of the maintenance working teams since the experience acquired.

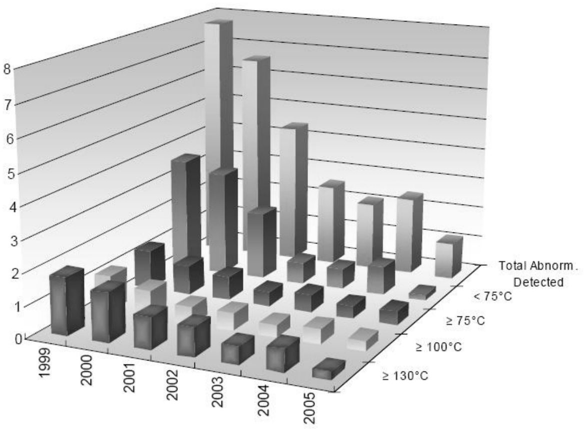

Fig. 6 Evolution of thermal abnormalities by critical levels Period 1999 - 2005 (in per thousand of items scanned).

In all the cases, along the development of the plan as the experience and the knowledge acquired in the application of the technique were used in the improvement of the maintenance practices, thermal abnormalities were decreasing in number and critical level [6].

5. BENEFITS OF INFRARED ELECTRICAL INSPECTIONS

Since most problems on an electrical system are proceeded by a change in its thermal characteristics and temperature, whether hotter or cooler, a properly trained and experienced thermographer is able to identify and analyze these problems prior to costly failure occurring.

Infrared electrical inspections provide many benefits to the recipient. The two key advantages from which the others stem, are:

1. The reduction in disassembling, rebuilding or repairing components which are in good operating condition. This type of repair is meaningless and costly and may lead to a 30 percent reduction of production. Furthermore, it is not guaranteed that the component will be in better condition after the repair, since the location of the problem or cause was not established. With infrared thermography you identify and hence repair only what needs repairing.

2. Problems that truly exist will be identified quickly, giving time to repair the problem before failure. In most cases, the problem is identified well before the problem becomes critical. Depending on the temperature and criticality of the component, the decision can be made to repair immediately, repair at the first opportune time, or monitor on a continual basis until the critical temperature is reached or until the repair can be scheduled. Identifying a true anomaly, scheduling the repair, and eliminating the actual cause of the problem within a proper time frame is the most efficient and cost effective way to maintain the system.

The other advantages of an infrared inspection program are based on the above overall advantages, yet are no less important. They are:

Safety - failure of electrical components could be catastrophic, injuring or even killing employees, maintenance personnel or the public.

Greater system security - locating the problems prior to failure greatly reduces unscheduled outages, associated equipment damage and downtime.

Increased revenue - with more uptime, revenue is maximized. With less maintenance on good components and faster repairs of faulty components, maintenance costs are reduced leading, to a better bottom line.

Reduced outage costs - the cost of an emergency outage is ten times greater than planned maintenance.

More efficient inspections - since all common electrical problems announce themselves as an increase in temperature, they are easily detected in a minimum amount of time. No service interruption is required for infrared inspections.

Improved and less expensive maintenance - a) precise pinpointing of problems minimizes time required for predictive and preventive maintenance,

b) maintenance efforts are directed to corrective measures rather than looking for the problem,

c) repair only what requires repairing, reducing repair time and unnecessary replacement of good components.

Reduce spare parts inventory - with improved inspection techniques giving advanced warning of failure,

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fewer spare parts are required in inventory. What would it mean to the bottom line if your spare parts inventory could be reduced by 10 per cent?

Reduced operational costs - with the system up and running for longer periods of time, the reduction and improvement of inspections, maintenance, spare parts inventory and outages will reduce the overall cost of operations.

6. CONCLUSION

The main application for thermography has always been, and still is, electrical system inspections. Infrared thermography has been used as a condition monitoring tool to predictively maintain electrical systems, even before the terms "condition monitoring" and "predictive maintenance" were used. In nearest future, virtually every electric generation and distribution company, as well as every major manufacturing and process facility, will be using infrared thermography as a condition monitoring technique to increase reliability and decrease electric losses, or downtime.

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BIOGRAPHIES

František Lizák was born on 4.4.1981. In 2004 he graduated (MSc.) at the department of Electric Power Engineering of the Faculty of Electrical Engineering and Informatics at Technical University in Košice. After studying he worked as a electrical designer. But in 2006 he came back to the University as a PhD student. His thesis title is "Research of electrical losses on the power system".

Michal Kolcun was born in 1954. He graduated (MSc.) at the Faculty of Power Engineering at the Moscow Power Engineering Institute in 1979, where he received a PhD in 1989. He became an Associate Professor of Electric Power Engineering at the Faculty of Electrical Engineering and Informatics at the Technical University of Košice. He was promoted as a professor of power and electric engineering in 2000. Since 1979 he has been working at the Faculty of Electrical Engineering and Informatics at the Technical University of Košice.