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Preventive diagnostics of Instrumentation and Automation by thermographic measurements

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Abstract

In the paper some results and application of infrared thermography method for diagnostics of the electrical equipment at a sector “Instrumentation and Automation” of a thermo-electric power-station are presented. A methodology for periodicity choice of thermography survey is offered. On the ground those certain instructions for evaluation the thermal condition of the surveyed equipment are developed.

1. Introduction

The infrared thermograph (IRT) is well-known and usable technique especially in defects detection of industrial objects with different functions on the base of overheating [1, 2]. Except for the non-destructive diagnostics the IRT is used very often for preventive monitoring [3]. The thermograph has got valid advantage in comparison with the traditional techniques – thermometers, thermocouples, thermo sensors etc., because of its instantly temperature reading and traceability of the tendency toward variation [4]. An infrared camera captures not only single frames but also series of images and can give the dependence of the effects from the time [5]. Nowadays the base task of thermograph survey is to discover local overheating areas dependent on potential defects. After the defect is localized the task is considered as performed. The IRT can be converted into a full value approach of technical diagnostics on the basis of mathematical methods and computational technologies for survey results.

The engineering diagnostic is intended to solve two tasks. The first one is to be established a technical diagnosis. The second one is connected with the technical condition prognostication. During establishing diagnose the engineer look for the areas in disappear, the cause for faults are defined and their technical condition is kept under control. The decision of the second task gives an assessment of the object’s resource (the rest of object’s life) with a definite probability. In most cases the complexity of the equipment failure mode defining is closely connected with the development of diagnostic models. Such models should describe the physical processes of the equipment. The second task of the diagnostic does not any decision yet.

Non-contact thermographic survey gives an essential priority over preventive diagnostics of electrical objects and equipment [6]. The study objects are some more substantial systems of “Instrumentation & Automation” sector that are responsible for equipment no defective and safety condition of working. Thermography survey on electrical terminals, circuit-breakers, cable canals, safety fuses, transformers, electrical loads (electro motors), invertors, cabinets with protection systems etc. is accomplished. The final goal of the used thermographic survey was to reduce the volume, time and cost of the repair works in sector A&I at “Bobov dol” thermo-electric power-station.

2. Data processing and analysis

The assessment of the real technical status of the objects at A&I sector is important for their affective exploitation. The resource planning takes into consideration the wearing out of the objects and waste time in looking for failures. So it is getting the better new methods for accomplish an effective and distance diagnostics without turned off load. Thermovision diagnostics allows discovering developing defects in electrical equipment and effective evaluation of the object technical state.

Anomalous thermal conditions of the electrical equipment under different load can be discovered by the thermovission diagnostics. It is needed to collect data from some concrete conditions of the tests under higher current load (for example 50% or 100%).

In the technical documentation is used the next equation for thermovision date evaluation under increased loading:

$$\Delta T_n/\Delta T_r = (I_n/I_r)^2 \tag{1}$$

where ΔT_n - prognosis surface temperature of an object at nominal current I_n; ΔT_r – overheating surface temperature under observation under a concrete current I_r.

However the experiments and results show greatly heightened temperature values after using the eq.(1). The heightened prognosis data leads to an incorrect expert evaluation and incorrect recommendation respectively.

The collected thermovision test data can not be analyzed and compared with others data (for example from another thermo-electric power-station) because of numerous tests peculiarity (carried out in different time, power, current, voltage, temperature, ambient condition etc.),

The object cooling by reason of radiating, the electrical resistance temperature, the object size influence size of the convection etc. are some of numerous factors with different degree of influence on the thermovision diagnostics conclusions. Disregarding those factors influence plays a negative role on the thermography control results and the final expert decision respectively.

To avoid this kind of disadvantages a system for thermography data processing is developed. The system permit statistical data processing of many ears collected from the thermovision control of the current equipment. The aim is to evaluate reliability characteristics and resource of the surveyed equipment.

The database includes results of the thermography survey as well as the needed technical information for the object of diagnostics:

- life and working condition;
- capacity and kind of the repair activities;
- results from prevention tests and measurements.

It is possible an effective evaluation of the object technical condition by using the whole complex of factors built into the system. The basic structure of the analysis process is shown on figure 1. The general block diagram of the proposed system is shown in Fig. 2.

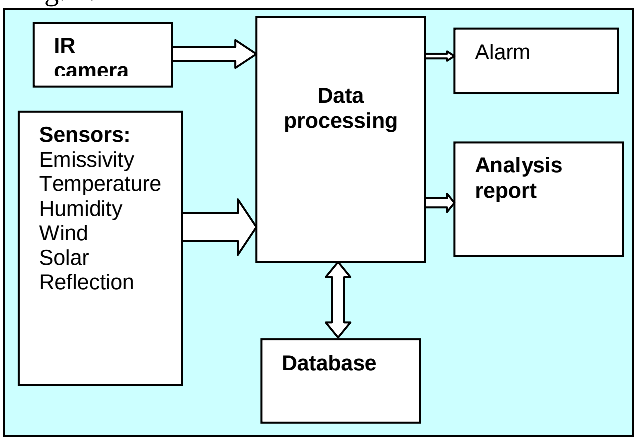

Fig.1. *General block diagram*

Разработената програма отчита топлоотделянето от нагретите обекти, конвекционалните потоци и излъчването от повърхността. Отчитането на влиянието на околните условия, позволява не само да се оцени тимпиратурата на прегряване от отделните дефекти, например контактни съединения при различни токове и температури, но и да се приведат експерименталните данникъм нормирани (приведени) стойности), например при 20°C и 100 % (или 50 %) натоварване, независимо от условията на изпитване. Например при изчисленията по ур. (1) дават превишаване на експерименталните стойности до 3 пъти, в сравнение с преизчисленията в програмата.

On the figure 2 some inspected objects in A&I sector at “Bobov dol” thermo-electric power-station are shown.

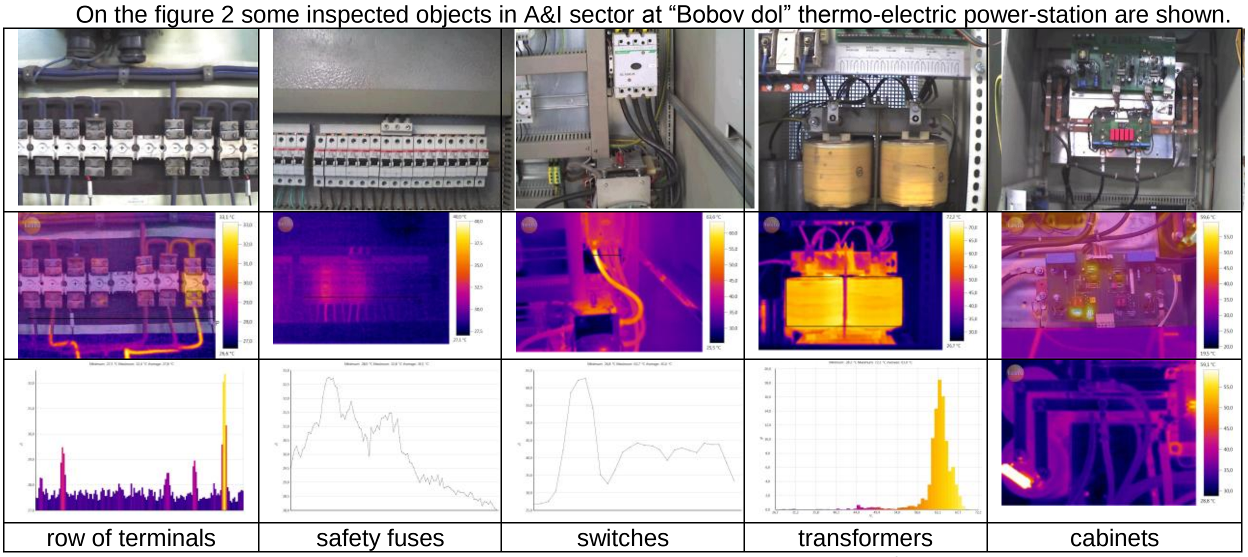

Fig.2. *Thermograms of some of monitoring objects in КиП&A sector*

Thermal status evaluation of the electrical equipment and current supported parts according to the construction and working circumstances is realized:

1) on the standardized temperatures of heating (temperature of overheating);
2) on the temperature excess;
3) on the coefficient of defaults;
4) on the base of temperature variation dynamic analysis at time;
5) by measured temperature values compared in a phase ore between phases knowing the good working parts.

At the time of thermovision survey the next indicators are used:

-ΔT – temperature excess, defined as a difference between the measured temperature on the heating and the surrounding air temperature;

-δT – overheating temperature, defined as exceeded measured temperature on the inspected element over the analogue others elements at the same conditions.

Different areas according to degree of faulty are distinguished on δT and load current $0{,}5I_n$ during for example of contacts conditions evaluation. In table 1 some criterion for contact joist are illustrated by using two indicators.

Table1. *Indicators and degree of failures*

Indicator for contact's working condition evaluation		Degree of failures
K_d	δT	
K_d <= 1.2	δT = 5…10ºC	**initial stage of fault** – should be checked and some measure should be taken to remove it during planned repair
K_d=1.2…1.5	δT =10…30ºC	**drifting fault** – requiring a measure to remove it in the nearest future stopping of the equipment
K_d > 1.5	δT> 30ºC	**emergency fault** – requiring immediately removal

Different experiments for analyzing the emissivity factor influence on the error of thermografic control results are taken. The values of the emissivity factor have been selected to be received an acceptable measuring error. On the figure 3a, b is shown a thermogram and the optical picture, on figure 4a, b - dependences on the emissivity and reflective temperature, respectively. On the figure 3b it can be seen that in these kind of inspection there are elements with quite different emissivity.

a)

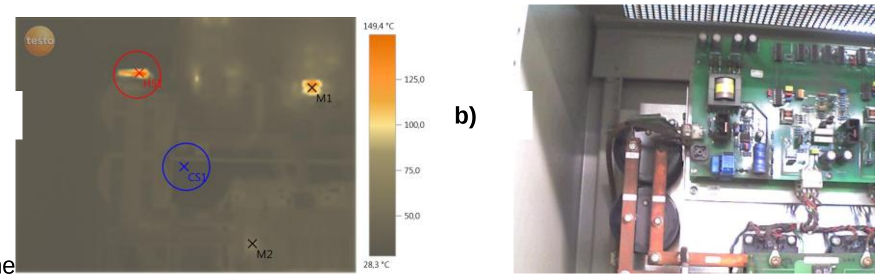

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Fig. 3. *Thermogram a) and a photo of one object of diagnostic in A&I – b)*

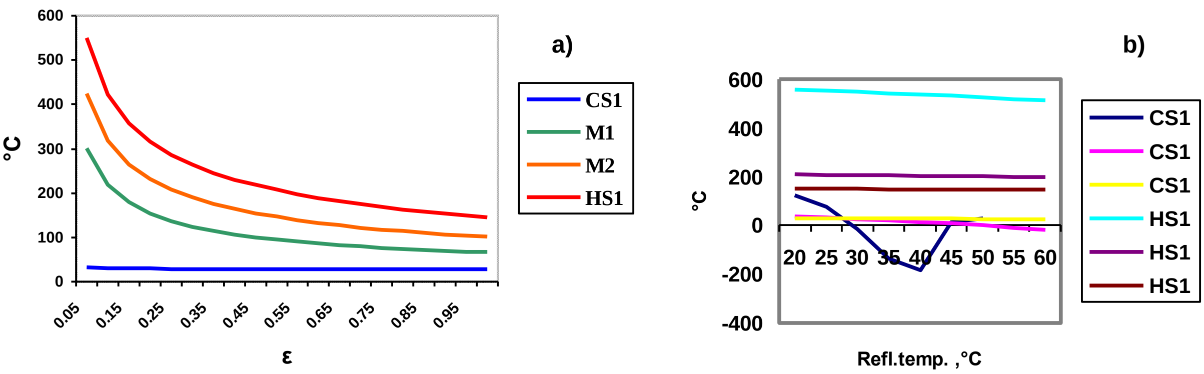

Fig. 4. *Temperature dependence of the emissivity – a); Dependence of the Reflected Apparent Temperature (RAT) – b)*

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3. Thermovision survey regularity selection

The results from the thermography survey are used for reliability indices assessment. This imposes another plan of survey taking into consideration the need of increasing the prognoses evaluation accuracy for faulty free equipment exploitations. The need is dictated by the fact that the equipment heat field anomaly get ahead of failures in electric processes.The failure probability is increased with increasing the equipment time of working. Therefore the time between thermovision surveys of the equipment is varied and planned according to a priori data of equipment wear (defined resource and degree of wearing out). So the average wearing out rate and reliability evaluation formula of the equipment should be corrected. On the other hand the correct using of experimental data from the thermovision survey is also required.

For example the reliability of a surveyed item *P* can be written:

$$P = f\left\{\frac{(T_{\max} - mt)}{\sqrt{A_1 t - A_2 t^2}}\right\} - f\left\{\frac{(T_{\max} - T_n)}{\sqrt{A_1 t - A_2 t^2}}\right\} \tag{2}$$

$$m = \sum_{j=1}^{N}\left(\frac{\sum_{i}^{k}\left(T_i^j - T_{i-1}^j\right)}{\Delta k}\right) \Bigg/ N \tag{3}$$

$$A_1 = \left\{\sum_{j=1}^{N}\left[\sum_{i}^{k-1}\left(z_i^j\right)\right]\right\} \Big/ N(k-1) \tag{4}$$

$$A_2 = \left(\frac{\Delta T}{dN}\right)^2 \tag{5}$$

$$z_i^j = \left[\frac{\left(T_i^j - T_{i-1}^j\right) - \sum_{i}^{k}\left(T_i^j - T_{i-1}^j\right)}{k}\right]^2 \tag{6}$$

where *f(x)* – Laplace integral; Δ – interval between the measuring (thermo vision inspections); *t* – time of product exploitation; T_{max} – maximum warrantable temperature value according to the specification of the product; T_n – nominal temperature value of the surveyed product; T_i^j – measured average value of the *j* -product from *N* – total number of the analogous products; Δ*T* – difference between the maximum and minimum temperatures of the surveyed product during a series of *κ*; *k* – number of temperature measurements during *j* - product monitoring.

To evaluate the prognosticated reliability parameters of the electrical equipment in A&I sector the values of Δ and time *t* from the exploitation beginning of the equipment are used.

4. Conclusions

The infrared thermovision diagnostic is reliable and allows finding the failures in A&I operatively. The results of this diagnostic are used in conducting of plan-warning activities.

Thermography survey results from equipment failure as well as from a normal condition of working are used for reliability prognoses of electrical equipment and its components.

Results from a thermography survey are also utilized as initial data in a priori estimation of A&I equipment reliability.

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