THERMOGRAPHIC INSPECTION OF RELAYS FOR RAILWAY SAFETY EQUIPMENT

Anna Vladova Andonova[1], Emil Ivanov[2], Andrew Stanchev Andreev[3]

[1]Technical University of Sofia, Dept. Microelectronics, 8 Kl. Ohridski str, 1797 Sofia, Bulgaria
Phone: +359 2 9653263, e-mail: ava@ecad.tu-sofia.bg
[2]Higher School of Transport, Dept. Communication Technologies, 158 Geo Milev str., 1574 Sofia, Bulgaria, Phone: (+359 2) 9709426, e-mail: eivanov@vtu.bg
[3]Centre of Biomedical Engineering "Prof. Ivan Daskalov", Bulgarian Academy of Sciences, Acad.G.Bonchev str. Bl.105, 1113, Sofia, Bulgaria, Phone: +359 88 7526408,
e-m@il: andrew.andreev@binnetix.com

The following article presents results of the implementation of thermo-monitoring methods followed up by processing of IR images. Field purpose is diagnostics of contacts wearing-out in the relays for railway safety equipment. Acceleration testing has been performed for contacts wearing-out in the relays under alternating current (AC). In real environment a commutation thermographics has been recorded in sequences mode with IR camera model FLIR P640. Specially developed software is used for digital processing of the images. Serving the Railway automation, criteria for early diagnostics of "bad" contacts in relays have been developed.

Keywords: Thermographic inspection, Railway safety equipment, Reliability.

1. INTRODUCTION

Despite of impressive development of the power electronics, electromechanical commutation preserves certain field of application in the present-day technical systems. Electromechanical commutation presents some possibilities, which can not be realized by the semi-conductor elements:

– simultaneous commutation of many separate circuits;

– resistance equivalent to zero and infinity in the two statuses of the commuting element;

– extremely high resistance between the control and execution part of the commuting element.

There are fields, where these qualities are of significant importance – for example at problems solving of electromagnetic compatibility.

Still actual problem of the day is the mechanical wearing-out of the contacts, which defines its low reliability.

At present the Railway automation still uses utterly relay systems for train traffic management. There have been used relays with specific construction, defined as elements with asymmetrical failure. Within these elements the probability for failure type $0 \rightarrow 1$ (instead of logical 0 in case of failure in the exit to appear logical 1) is slightly small, compared to probability for transition $1 \rightarrow 0$. Based on that, the securing systems are synthesized in way that when system failure occurs to avoid dangerous development of the transport process. This leads only to motion suspension of the machine, but not to crash. In a system like this, for middle sized train stations are used over hundred relays. A problem of significant importance for the train traffic is the contacts wearing-out and performing optimal regime for replacement.

2. CONCEPTION FOR THERMOGRAPHIC RELAY RESEARCH

Despite of impressive development of the power electronics, electromechanical commutation preserves certain field of application in the present-day technical systems. Electromechanical commutation presents some possibilities, which can not be realized by the semi-conductor elements:

Two exploitation principles are applied in the electromechanical commutation systems. Under the first principle after failure occurring fallows replacement of the element. Under the second principle all of the elements are being replaced in stated period of time, on the base of their average lifetime of failure. Both principles have its disadvantages.

The wearing-out of the contacts is accompanied by thermal processes. Those processes can be analyzed by thermo-monitoring methods [2]. On one hand optimal working regimes for contacts wearing-out can be selected, one the other hand the degree of wearing-out can be controlled, as well as the time for replacement.

There are four working regimes of the contacts. The difference is result of the electrical conditions, physical processes and the wearing-out. Two of these principles are in our scope of interest:

2.1. Closed contact

Closed contact main parameter is the transience resistance R0.

Common ground point of the contacts is not extended over the whole covered surface. No matter how good the contacts are polished, there are some protruding spots in which exactly the contact has been made. Currents/electricity lines are gathering at the contact areas. This defines the density resistance R_c. It depends of the material of the contacts, the total shared surface and the contacts pressure. By increasing the contact pressure, the numbers of contact points are also increased. The contact resistance depends also from the resistance of thin layers formed on the surface of the contacts. For example on silver contacts a layer of silver oxide (Ag_2O) is formed with thickness of 10^{-8}cm and resistance of 0,5 to 1,5Ω. Layers are formed on the surfaces due to different polluters, for example dust. Transience resistance is increasing in the working process with the contacts wearing out.

When powerful electricity flows for prolonged time, the temperature of the contact may exceed the material melting point, which ultimately leads to contact welding. That is why for some type of contacts it is given maximum electricity load to prevent from welding I_{max}.

The influence of random factors over the transience resistance defines the significant difference between same types of contacts. So it is necessary vastly over supplying when we define I_{max} in order to achieve satisfactory liability.

The thermo-monitoring methods [2] are giving the opportunity of revealing technological reserves and achieving reliable high voltage commutation using the same constructive decisions and materials. A thermographic can display the gathering of the lines, respectively the count and the total contact surface. In this manner back at producing stage the bad contacts can be removed, in order the reliable relay work to be guarantied at high voltage commutation. In the exploitation process the thermographic can provide information of contacts wearing-out degree and to determine which contacts are subject of replacement.

2.2. Contact opening

Under contact opening the resistance is changing from R_0 to ∞. Under uniform motion the below formula applies

$$R = \frac{R_0}{\left(1 - \frac{t}{T}\right)}, \tag{1}$$

where:

T – Time for full contact opening;

t – Current co-ordinate of the time, beginning at the moment of the contact opening.

When opening contacts a tension between them occurs. In the beginning the distance between the contacts is small and it is possible occurrences of discharge phenomena. Those phenomena are connected to destroying or carrying out material from one contact towards another. If demolition does not occur, then occurs high increasing of the roughness, respectively to the transience resistance of the closed contact. This stands behind the conception “contacts wearing-out”.

At circuit commutation with inductive characteristics when contacts has been open, a jump in the voltage is been observed. This increasing is due to the saved within inductivity magnetic energy. The size of the occurring tension is directly proportional to inductivity, of the speed of the decreasing voltage and it is inversely proportional to the active resistance of the circuit. The inductive characteristics subserve the arising of discharge phenomena and the wearing-out of the contacts. Total avoidance of those phenomena is not possible. The question is conditions to be created for quick suspension of these undesired events.

On the thermographic image the areas of increased resistance and destroyed contacts can be monitored [2]. In this manner under periodical observation bad contacts relays can be indicated, removed or replaced.

3. Experimental Stage and Results

First-rate relays used in railway safety equipment type normal small-size contact-pin/plug are investigated. On Fig. 1 are displayed image and schematics with the position of terminals relay type НМПШ-03/90. Those types of relays are specially developed for commutations of powerful electricity circuits in Railway automation.

For the thermographical researches it is used IR camera type FLIR P640 [1]. Thermographics are based on relays real-time process of working. The image has been taken as sequences with different frequency of reiteration and for different voltages of commutation. Relays with different work off exploitation operating resourcee has been researched.

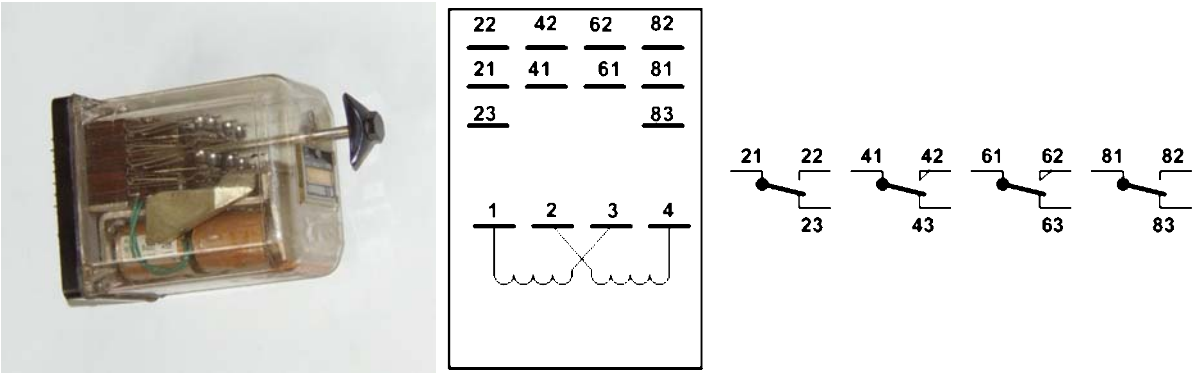
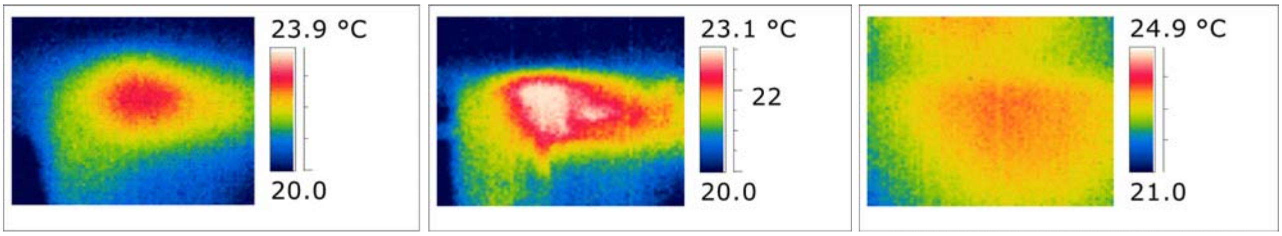


Fig. 1. Relay type НМПШ03-90.

In view of the fact that standardized format for reading IR images does not exists, software for processing and computer analyses of the thermographics was created [2]. The goal is thermographics to be processed meaningless of the type of the used IR camera. An accelerated test of the wearing-out of the relays was carried out. The criterion of wearing-out is the alternation of the resistance, respectively temperature under equal commutation voltage. Under data processing was recognized the fact that the heat is generated buried deep inside a relays structure with loss of thermal insulation between the heat source and the surface the IR camera sees (indirect measurements). After identifying the zones with increased temperature and defining the possible reasons, the tested relays were disassembled for confirmation of the reached conclusions. In this manner a criteria for diagnostics and resource evaluation of the tested relays was formed on the base of the outcome thermal histograms [3].



a) good contact b) bad contacts c) single contact

Fig. 2. Thermographics of tested relays

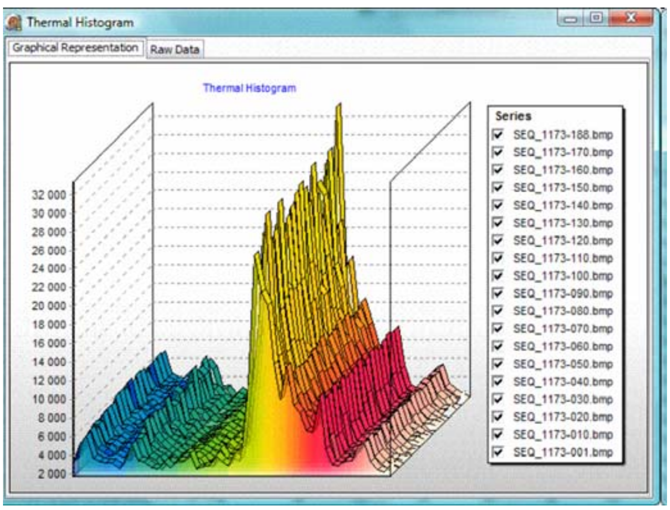


Fig. 3. Batch thermal histograms of a good contact.

On Fig. 2a, b are displayed thermographics of the contact field (including four contacts) of the tested relay. On Fig. 2c – it is displayed thermographics of one contact. The form and the temperature distribution are the first sigh for the status of the contact zones.

On Fig. 3 are displayed 3D layered thermal histograms of sequence of IR images of one contact, made with frame frequency 30 Hz. From the image it is seen the increasing heating of the contact area, as a consequence of continuous commutation in the test.

On Fig. 4 is displayed thermographic and IR profile of the temperature in the area of the contacts. The example is relay with two wearied-out contacts.

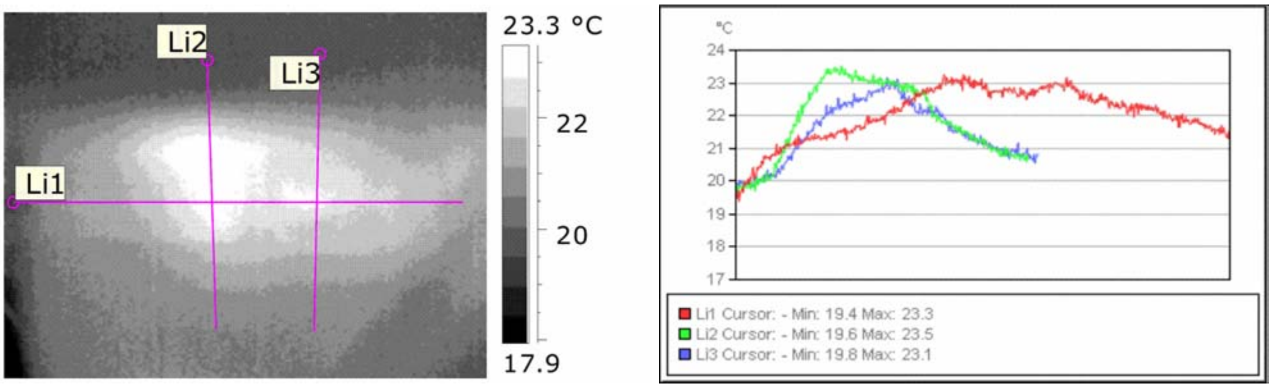
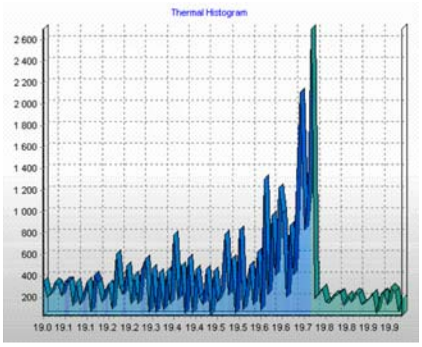
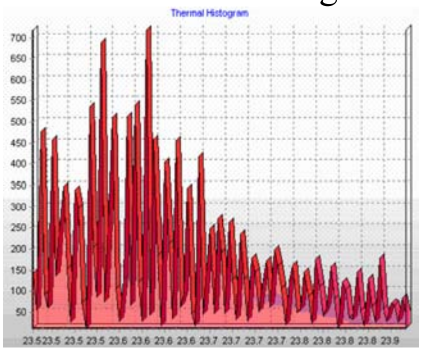


Fig. 4. Thermographic and IR profile of a bad relay

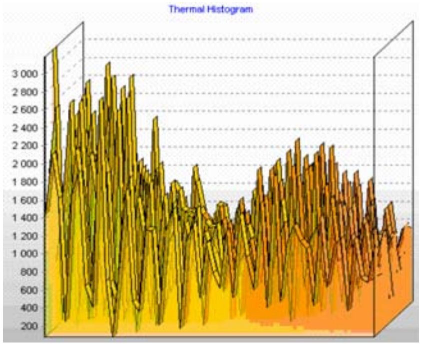
On Fig 5 are displayed different transitional results under proceeding of thermographics for different cases. From the displayed thermal histograms bad contacts can be localized in the commutation process. This leads to forming criteria for diagnostics of bad contacts under different commutation voltage.



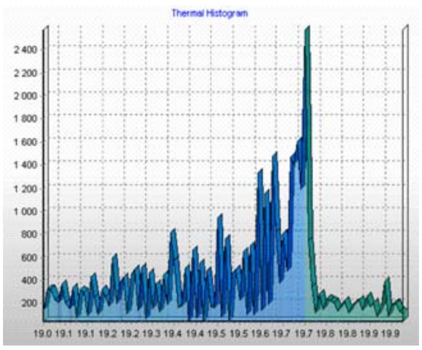
Relay A,
Temperature 19÷200 ^{o}C,
Shot1



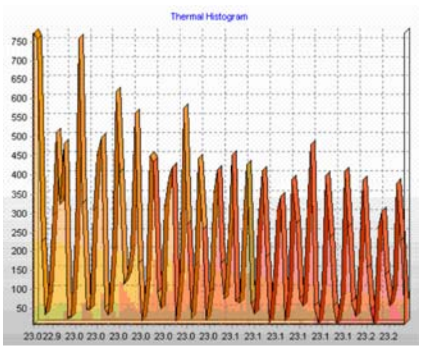
Relay A,
Temperature 22.8-23.4 ^{o}C,
Shot 10



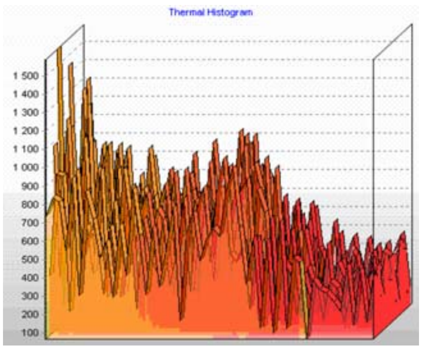
Relay A,
Temperature 22.8÷23.2 ^{o}C,
First 10 shots of one sequences



Relay B,
Temperature 19÷200 ^{0}C,
Shot1



Relay B,
Temperature 22.8-23.4 ^{0}C,
Shot 10



Relay B,
Temperature 22.8÷23.2 ^{0}C,
First 10 shots of one sequences

Fig. 5. Transitional results under proceeding for different cases.

4. CONCLUSION

In this article are presented results from the appliance of thermo-monitoring methods and processing of IR images for diagnostics of relays contacts wearing-out. In great significance for Railway safety equipment stands the solving of the problem with the optimal regime for replacement.

The areas of increased resistance and destroyed contacts can be detected by digital processing of thermographic image. Periodical real time observation with IR camera allows on time to be detected and suspended relays with bad contacts.

Thermo-monitoring methods are revealing technological reserves and ultimately are leading to achieve reliable commutation on high voltage using the same constructive decisions and materials.

In exploitation process the thermographic can supply information of the degree of wearing-out of the contacts and to determine which contacts are subject of replacement.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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