DETECT FAILURES IN COMPLEX TECHNICAL SYSTEMS

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ABSTRACT

The paper analyses possibilities of failures detection in specific technical systems. On the basis of preliminary analysis a suitable type of combined analysis is determined which detects failures with an emphasis on non-destructive approach. This method can be used for diagnostics and failure detection in systems of central power supplies used in transportation, especially in researching phase of the product life cycle. The paper presents the use of modern thermo visual technology which is documented by direct material and marking the measured temperatures on the locations of particular failures.

1 GENERAL INSTRUCTIONS

Recently, a strong emphasis has been put on ensuring safety of machines and systems that might, under certain conditions, endanger public safety. However, the issue of safety and dependability relates to the issue of failure occurrence and timely identification. Such failures may cause the system fail or stop functioning. In order to stop such failures to occur, diagnostic methods and tools are both appropriate and reliable. Technical diagnostics is instrumental in detecting primary failures, whereas even the most critical failures can be detected through non-destructive approach. Presently, detection of failures in technical systems does not only include meeting legal requirements, but also the overall safety and dependability of the system in question. It is required not only to identify and analyse failures, but also minimize their possible causes in the phase of researching, developing and designing new products. At this stage of the life cycle of the product or equipment is therefore necessary to establish a number of logical steps that can draw attention to failures which may endanger public safety in a systematic way.

The aim of the paper is to describe the methodology of failure detection process in complex technical systems. This method is very sensitive to preparation of individual steps of solution and requires the knowledge of functionality of a monitored object. The monitored object is a central power unit, which is presently used in railway transportation. Central power units are used as a substitution of rotary electrical generators (dynamos) for supplying electric equipment in passenger railway wagons. Central unit is multisystem equipment which supplies a wagon at all required AC&DC voltages which can occur in a main line of railway systems across the Europe.

2 PRELIMINARY ANALYSIS AND DEFINING BASIS FOR DETECTING POSSIBLE FAILURES

The first step in an initial phase of project is the analyzing and then specification which subsystem is the most critical from failure occurrence point of view and its impact on the whole system functionality, i.e. potential failure of which subsystem could be the main reason of a total shut down of the system. At present, the requirements for production growth and its quality are closely connected to requirements for dependability of technical system. An early diagnostics and checking of technical condition in many cases allow detecting potential failure, which could cause serious damage of the system in operation. The most effective way of failure detection in machinery is the process which does not require machine disassembly. After preliminary analysis of a suitable method selection we chose the method of thermovisual diagnostics followed by heat stability tests. Thermovisual diagnostics has several advantages, such as a non-invasive character, and it can detect an area with abnormal heat generation during operation of central power unit. Heat stability tests can be split into two parts: dry heat tests and cold tests.

2.1 Thermovisual measuring analysis

Thermovisual measuring enables in full operation detection of overheating in a non-desctructive way and provides a possibility to measure contactlessly surface temperature of the objects using an infrared thermo sensor. The results of temperature measuring are digitally displayed with the recognition of temperature levels which significantly helps during failure detection and analyzing. A thermocamera works on a basis of an infrared radiation, which is emitted by examined objects. This radiation is concentrated by opto-mechanical system of an infracamera to a semiconductor detector, which converts the radiation into electrical signal. Made images are possible to work into a final image called a thermogram, which displays a heating curve (temperature changes) of the examined surface area. It is suitable to use this technique in the initial phases of research because it can detect abnormally hot electrical contacts or components; thus proceed in risk analysis of the central energy source as a whole.

At the beginning of measuring by a thermovision camera we were focused on a whole central power unit. Gradually, the parts with no heat dependence were selected; thus it could be concluded that these parts of the central unit would not be responsible for system failure followed by equipment failure. Real temperatures were simulated at which the research institute provides the operation of equipment. These temperatures meet technical conditions and specified ranges of the equipment. Temperature range is from -25°C to + 55 °C.

The main reason of these failures are electric current connections which were preliminary recognized as the root cause of thermal hazard and subsequently cause the malfunction of central power unit or some of its subsystems. Heat failure criterion is a fact, that in steady thermal conditions an electrical current connection and its input have the same temperature. At the beginning of measurement it was necessary to set threshold temperatures to avoid incorrect colour interpretation. To measure accurately it is important to set a minimal range; thus to ensure the finest step between temperature levels. Through mutual comparison of equipment surface temperatures (between phases, between fields, etc.) it is possible to localize the places with higher temperatures which indicates a possible failure. An initial idea is that during scanning by a thermovision camera an infrared radiation, emitted by the area of a defective connection of two conductors leading an electric current, is detected.

The main criterion to decide whether it is an inconvenient connection is not only an absolute temperature of connection, but especially temperature difference to other connections, possibly its temperature gradient. By measuring, observing and comparing to archived data we set possible decisions on quality of an examined connection. Found heat failure is judged according to its importance in regard to a measured rise of temperature, relevant current load and expected current load. In this way we can get a track of a found failure and its importance in a place. The next phase of an analysis is to elaborate a complex report including general information on colour thermogram supplemented with colour photography and marking a site of a failure on the graph. In the next figure there are outputs of a thermovision camera on an anticipated failure place which were made in an area of a high voltage convertor. Repeated measuring showed a heat failure, so it confirmed a hypothesis on a site of failure.

This fact significantly conduced to a decision which direction to take when deducing hazard formation and its solution. It is evident, that this kind of analysis can reveal only possible hazards, which are caused by a physical quantity heat. All discordant locations phases were found in the sites of the high voltage converter, but in different areas. The high voltage converter was scanned in operation in specified time intervals. The aim is to observe temperature and heat focuses distribution and especially changes of these temperatures which can indicate possible sources of hazard.

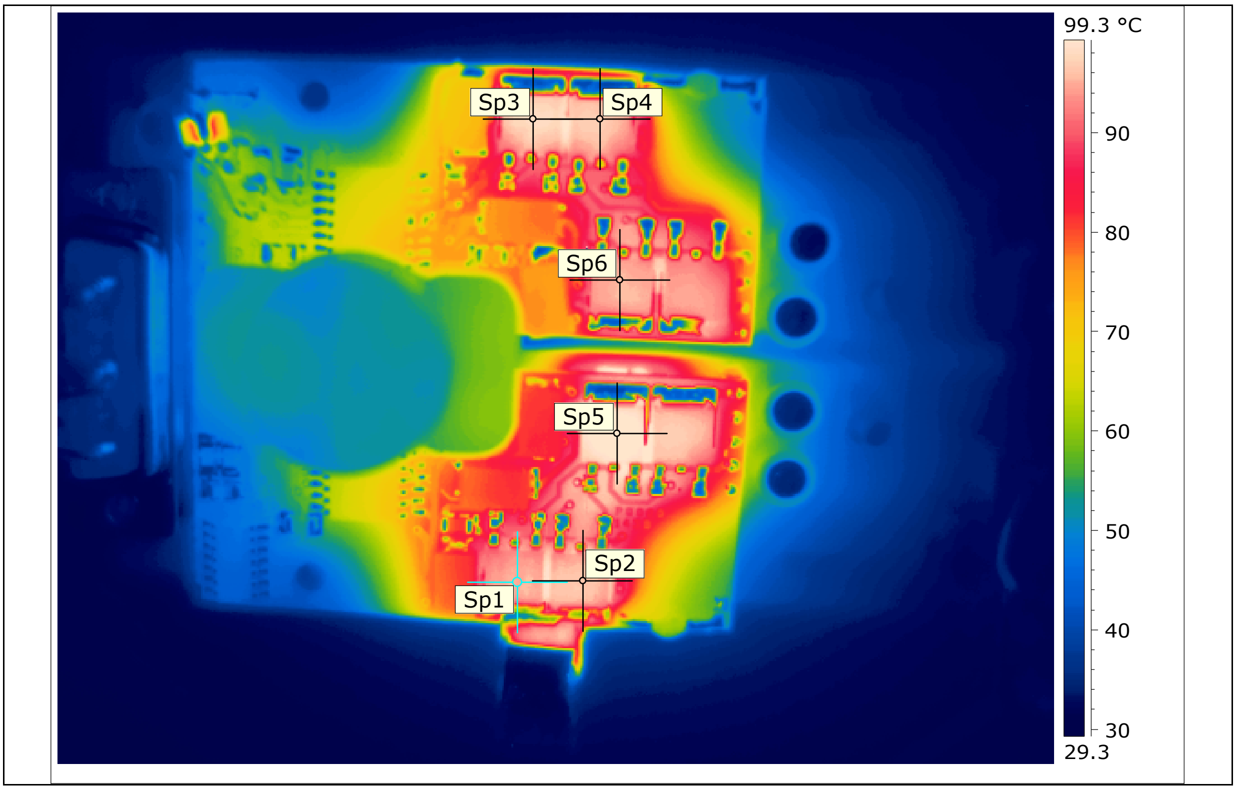

Figure 1 Thermovisual image, convertor

As can be seen from a thermograph in **Figure 1**, in some measurements the temperatures go over up to 45°C, which is unaccepted. The findings suggest that the central power unit does not work in a defined working temperature range, because thermal junctions between the components appear.

Emittance	0.96	Description, Image Title : IR_0886.jpg Measurement Time : 13,18 hod.
Judged	36.0°C	

Temperature	
Surrounding Temperature	22.0°C
Object Distance	0.2 m
Sp1 Temperature	95.0°C
Sp2 Temperature	96.0°C
Sp3 Temperature	98.2°C
Sp4 Temperature	96.7°C
Sp5 Temperature	100.3°C
Sp6 Temperature	95.3 °C

f[kHz]	Ugh1[V]	Ugl1[V]	Ugh2[V]	Ugl2[V]	Uusm.[V]	C[nF]
50	10,83	-5,4	11,39	-4,82	20,25	180

Figure 2 Analysis thermovisual image, convertor

2.2 **Hear tests analysis**

In the following text the list of individual steps of thermal stability tests is presented and they will be the issue of a further research. To solve this task a special software has been used which is used for diagnostics in an environmental chamber Heraeus- VÖTSCH VSKZ 06/210/S. From the previous outputs of thermovision tests it was necessary to concentrate on a high voltage converter, because it looks that this subsystem causes power unit failure. Both thermal stability tests are performed by software, which provides complex information on operating conditions and failure state of a power unit, including detection and failure data processing. The software is also able to localize a failure on a level of replaceable logical unit with the output of diagnostic results for maintenance and service, and a long-term storage of diagnostic results. The third level of diagnostics enables connecting of service equipment (PC) through a suitable interface (RS232 line, CAN interface…), and optionally it can contain an interface for connection to a central diagnostic computer of a railway carriage. This test is carried out according to a norm "STN 50155/C1 Runway application/ Electronic devices of rail vehicles" and consists of two tests: a cold test and a dry heat test. Parameters which are kept in these tests (temperature in a chamber, device load, supply voltage) are determined by an operator of a device in technical conditions.

2.2.2 Specifield cold test outputs

A device which is not under voltage is placed into an environmental chamber. After cooling down the chamber to a minimum temperature, the device stays at this temperature for 2 hours. After this (keeping at -25°C for 2 hours – in terms of a data sheet related to a particular device) the device is powered and its proper function is checked. After the test and warming the device to an ambient temperature the test for its function is performed again. Because the sources of potential failure are determined in the part of a high voltage converter; attention is concentrated on this area. By performing of tests we can get a view of possible failures.

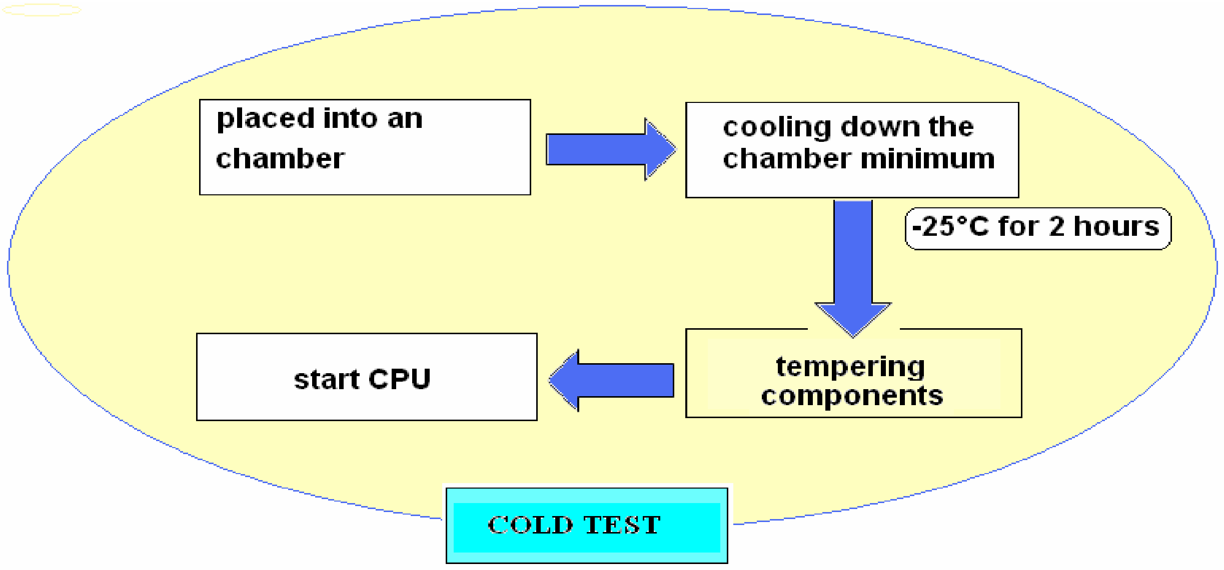

Figure 3 Cold test

A primary failure is identified in a part of converter block, which provides regulation of energizing of driving motors. The root cause of the failure was an error in control circuits of a driver converter.

2.2.2 Specifield dry heat test outputs

During a dry heat test the attention was focused especially on a converter block. The test for function of the device was done through a dry heat test at a temperature + 55 °C. The chamber was heated up to the temperature 70 °C. After reaching this temperature, the test for function of the device was performed.

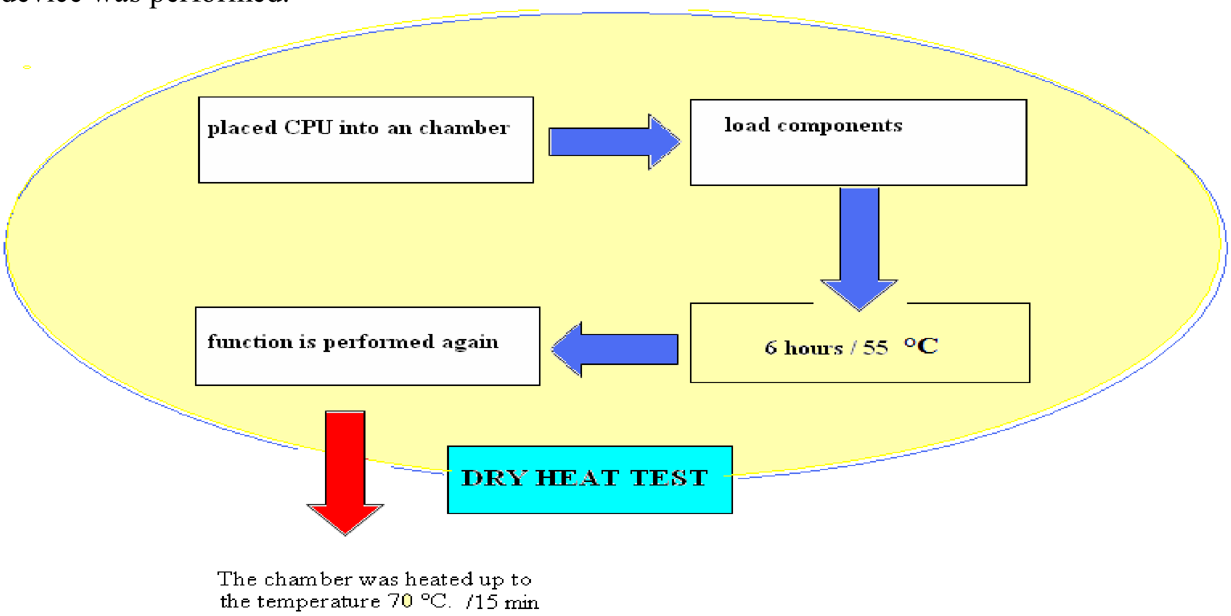

Figure 4 Dry heat test

After connecting a notebook to a diagnostic interface of environmental chamber diagnostic software evaluated that the failure is on the converter. This failure was in the place of diodes assembly. An error was made during a design of this protection block. After component data sheet checking, it was recognized, that improper type of a diode was selected. This type cannot meet the requirements specified for this device. At low current it is not necessary to install a cooler on a diode body. However; rising temperature of a chip causes a higher cut-off current of the diode and this caused a device collapse. It means that at a temperature 70°C and particular thermal resistance, the diode body should not exceed a standard temperature 70°C on a chip. The output of test results was a corrective action and recently an appropriate cooler has been designed.

3 CONCLUSION

One of the practical tasks that the paper solves is to define a suitable method which will be used in failure analysis. We determined a combination of methods of analysis because of complexity, which was necessary to follow. The essence of combined (mixed) methods is coincident use of some procedures of failure detection. Thermovisual diagnostics helped to detect provisional places of hazard and it was deduced to a subsystem of a central power unit, in a place where a failure occurred, the system becomes malfunctioned. This part of a central power unit is in a place of a driver converter and a failure was caused by a wrong design and selection of components on a board. In this case the faulty components were diodes; they are already replaced by a more powerful one with higher thermal load level. Another very serious failure occurred in a driver converter block, it was in control circuits of a sub-driver.

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