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THE TELEMETRIC, MULTICHANNEL DATA ACQUISITION SYSTEM AS A BLACK BOX OF ELECTRICAL MACHINE – ROTOR BARS FAILURE DETECTION EXAMPLE

Abstract

Damage to the rotor constitute approximately 10% of all damage of the electrical machines. Diagnosis should be focused on those failures, that occur most frequent or are the most destructive or expensive. The article describes an interesting case of electrical motors damages. These electrical motors were used for propulsion of railway vehicles and measurements were taken during normal operation of the train. In this article the sample results of the measurements are presented. Measurements and registrations held remotely using telemetry devices, which concept was developed by authors of this article.

INTRODUCTION

Electrical machines, like any other electrical or mechanical device failures as well. The reasons of failure are improper operation, as well as so-called aging. Excluding the first cause and analyzing the causes of electrical machines other failures, it can be concluded that they are a consequence of the progressive aging and wear of materials used to production of the machine [1]-[4].

According to the authors, the accuracy of the technical evaluations of electrical machines is unsatisfactory, despite the extensive literature on the topic. An example would be an evaluation of the technical condition of the rotor's cage of induction machine. Induction machine with a damaged cage can work seemingly normal, it can even do the consecutive starts. However, even a minor fracture of one of the bars is the beginning of the destruction of the cage. In general, the degradation of the rotor's cage is progressive and leads to serious machine failure even to catastrophic failure and destruction of the entire drive [8], [12]-[14].

The authors during nearly 20 years of expertise and research realization met with three types of working devices supervision:

1. Individual diagnostic tests of electrical machine. Provide information about the current condition of the electrical machine. Maintenance service shall decide of tests and measurements performance only if worrying symptoms such as the appearance of smoke, perceptible rise of temperature, a subjective increase of noise, etc. has been noticed.
2. Periodic off-line diagnostic tests of electrical machine. This form of diagnostic tests carried out in a long period of time, determine the trend of some parameters changes which identify the technical condition of the machine.
3. Continuous monitoring. On-line diagnostic tests realized together with measurements of other parameters (like electrical and mechanical parameters) allows to specify the technical condition of electrical machine. The alarms are able to be set by adopting the right criteria.

Many years of experience of the authors in the field of research, diagnostic and monitoring of electrical machines made it possible to develop a device that is used during the research work carried out in the laboratory as well as the measurements carried out in industrial environments. This device is a standalone, telemetry, multi-channel data acquisition system for monitoring in a long-term operation of electrical machines and other devices. The telemetry, multi-channel data acquisition system (Figure 1) designed by the authors is resistant to environmental conditions: noise, dust, temperature, humidity etc.

Fig. 1. *The data acquisition system in the implementation of a three-channel.*

Presented telemetry, multi-channel data acquisition system has functions that allows the measurement, record, save the results and send information about the current situation on the observed object. The software implemented to the telemetry device allows the registration of instantaneous values, mean and RMS value of measured signals, define thresholds that trigger the registration. Threshold can be set independently for each channel.

The appropriately formatted SMS or e-mail message can be sent to the telemetry device to receive a report of completed registration and status of the telemetry device. All of these features give the user the ability to remotely control the measuring device and measuring process.

1. CONSTRUCTION OF THE TELEMETRY DATA ACQUISITION SYSTEM

The standalone, telemetry, multi-channel data acquisition system is characterized by:

- simple installation,
- dual power supply,
- real time clock,
- input channels with the ability to change the measuring range,
- standard voltage input (+/- 10 V),

– the ability to calculate the FFT of the measured signal,
– sampling frequency 12,8 kHz,
– write to nonvolatile memory,
– the ability to define the type of registration (instantaneous values, RMS and mean value),
– function of the "black box" - write to memory after crossing the threshold from a user-defined time before and after the event,
– communication with pc by GSM or ethernet,
– communication with user by GSM,
– communication with user by internet.

The heart of the system is a digital signal processor (DSP). It is a specialized chip for processing digital signals. One structure includes:
– control system,
– arithmetic logic unit,
– ROM and RAM,
– output circuits.

A block diagram of the telemetry data acquisition system realized all the criteria (for the measurement and data processing) mentioned above is shown in Figure 2.

The GSM technology is perfectly suited for monitoring and telemetry measurement system. It has many advantages:
– popularity of GSM communication,
– the possibility of using the existing transmission network structure,
– a large network coverage,
– low cost of construction and operation,
– no need to use special antennas,
– low transfer cost.

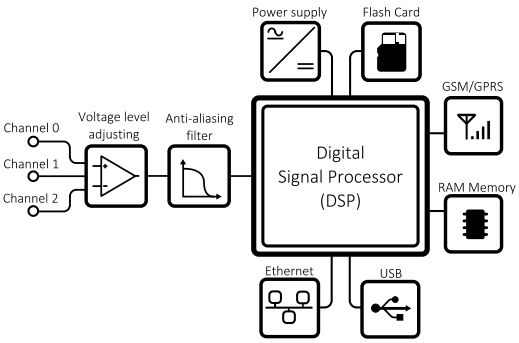

Fig. 2. *Block diagram of the telemetry data acquisition system.*

It is necessary, for telemetry module to work properly, to put in the module suitably configured the SIM card provided by GSM operator that offers services in data transmission.

2. THE USE OF TELEMETRY, MULTI-CHANNEL DATA ACQUISITION SYSTEM FOR DIAGNOSTIC TESTS

The telemetry data acquisition system was use for searching the causes of the rotors cage damages of induction machines used for driving the vehicle of railway traction. Damaged rotors are shown in Figures 3 and 4.

The issue was very complicated. The theoretical causes of repeated failures mutually exclusive [7].

Fig. 3. *Damaged rotor winding of traction machine.*

Fig. 4. *Destroyed rotor.*

It was not possible to form a clear conclusion from the results of tests carried so far. This uncomfortable situation was the direct cause to invite the research team, which includes the authors of this publication.

Tests were carried out according to the following scheme:
1. Evaluation of quantitative and qualitative of occurring damages.
2. Analysis of the structure and method of mounting the machines in the vehicle.
3. Recognition of the basic parameters of the tested machines power supply (voltage converter).
4. Recognition of the tested machines type of duty.
5. Selection of the measuring equipment, including:
   – sensors for reliable cooperation with telemetry data acquisition system,
   – setting the thresholds for measuring and recording,
   – the archivization,
   – communication with telemetry data acquisition system,
6. Mounting the measuring equipment on the real object (on the vehicle traction machines; Figures 5 – 7).
7. Analysis of the results and preparation to laboratory tests.

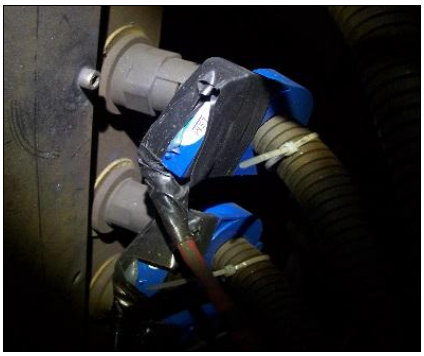

Fig. 5. *Current transducers mounted under the rail vehicle.*

Fig. 6. *Current transducers mounted under the rail vehicle.*

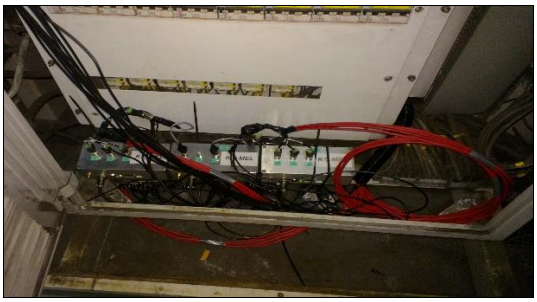

Fig. 7. *Telemetry, multi-channel data acquisition system mounted in the switchgear of the rail vehicle.*

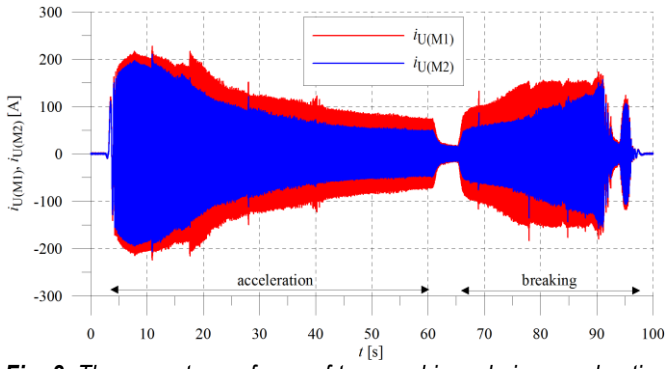

Fig. 8. *The current waveforms of two machines during acceleration and dynamic braking.*

The measurements were conducted remotely during 30 days of normal operation of the traction vehicle. Knowledge acquired from this measurements has allowed to reduce the number of hypotheses of failure to the one cause – in authors opinion the only right theses: the occurrence of mechanical resonances of the rotor. In the following part of article are some sample test results with description of the objects, which have been carried out. The same phase current waveforms of two machines which are powered by the same converter and driving the same axle are shown in Figure 8. The maximum value of both currents are different during acceleration and regenerative braking. It means that both machines are different loaded. A few periods of current waveforms during the dynamic breaking are shown in Figure 9. There are three currents of one machine and one (smallest) current of second machine. Both machines are powered by the same converter.

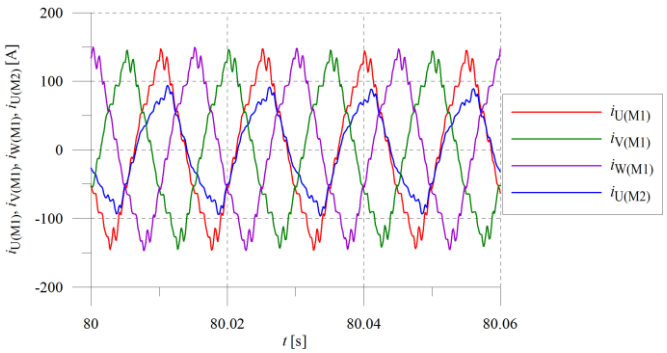

Fig. 9. *The current waveforms of two machines during dynamic braking.*

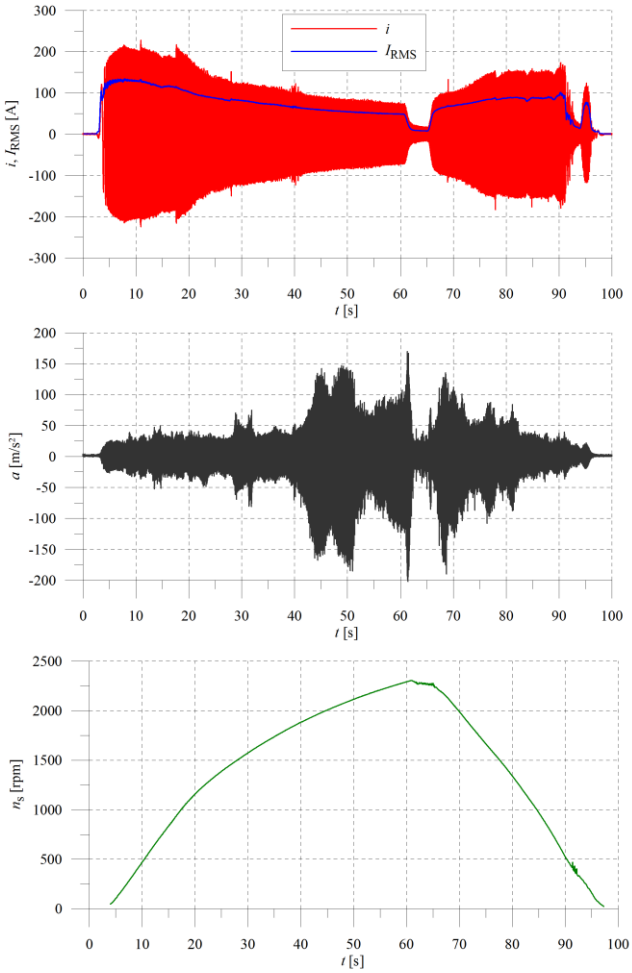

Fig. 10. *Registered values during the acceleration and braking of rail vehicle: a) the instantaneous and RMS values of machine current, b) the instantaneous values of the vibration acceleration, c) synchronous speed.*

The telemetry, multi-channel data acquisition system was use for registration the vibration occurring on machines for further analysis. In the Figure 10b is shown the acceleration of vibration registered in the same time as currents shown in Figure 8. There are marked the frequencies of highest values of vibration acceleration. There are an instantaneous and RMS value of current presented in Figure 10a, and rotational synchronous speed of machine in Figure 10c.

Measured values of vibration acceleration frequencies was compare with theoretically calculated harmonic vibration frequencies and the natural frequencies measured during the laboratory tests. The results of every measure was very similar [1]-[6]. However, the

majority of electrical traction motors work with inverters and before analysis, signal should be filtered [9]-[11].

A similar analysis was done for similar engines but operated under different conditions (different track condition, lower speeds and different wagon structure). The results of measurements and registrations are shown in Figure 11. There are an instantaneous and RMS value of current presented in Figure 11a, acceleration of vibration in Figure 11b and rotational synchronous speed of machine in Figure 11c. In this case, there was no frequencies coincide with the resonant frequencies of diagnosed machine.

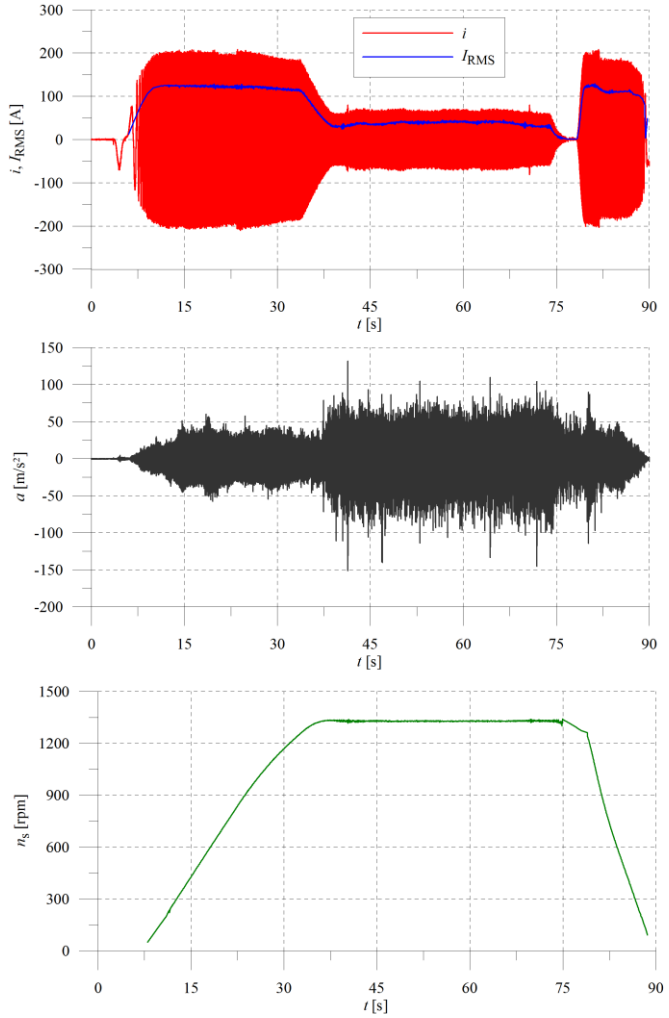

Fig. 11. *Registered values during the acceleration and braking of rail vehicle: a) the instantaneous and RMS values of machine current, b) the instantaneous values of the vibration acceleration, c) synchronous speed.*

CONCLUSION

Selected results of measurements, presented in this article, are an examples of a multi-faceted approach to the problem of test of electrical machines in industrial environment. Standard measuring and recording equipment, which are typically use in research laboratories does not work properly when tested objects are placed in industrial environment. In most cases the laboratory equipment is too expensive, or simply, too sensitive for that kind of usage. That situation requires more creativity from research team in the configuration of the measuring systems. The presented example of telemetry, multichannel data acquisition system is a solution of the one of the challenges that meet the research team to take the proper measurements in an industrial environment. To correctly register data and have remote control on the measurements, sometimes its needed to build special measuring and recording equipment. The usefulness of these solutions in practice is confirmed by the obtained results.

The authors currently work on the use of telemetry, multichannel data acquisition system as a tool for sensorless vibration diagnostic of electrical machines excited by permanent magnets. This is a new diagnostic method designed for surveillance of generators and machines with excitation from permanent magnets.

The usefulness of this type of vibration diagnostic authors see, among others, in small hydro and wind power plants and machines which are used as a drive in electric vehicle.

APPENDIX

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TELEMETRYCZNY, WIELOKANAŁOWY SYSTEM AKWIZYCJI DANYCH JAKO CZARNA SKRZYNKA MASZYNY ELEKTRYCZNEJ – PRZYKŁAD WYKRYWANIA USZKODZENIA PRĘTÓW W SILNIKU INDUKCYJNYM

Streszczenie

Uszkodzenia wirnika stanowią około 10% wszystkich uszkodzeń maszyn elektrycznych. Diagnostyka powinna się skupiać na tych uszkodzeniach, które występują najczęściej i które są najbardziej destrukcyjne i kosztowne. Artykuł opisuje interesujący uszkodzeń maszyn elektrycznych. Opisane maszyny są wykorzystywane jako napęd pociągu, natomiast pomiary były przeprowadzone w czasie normalnej eksploatacji pojazdu. Pomiary oraz rejestracje przeprowadzono przy użyciu urządzenia telemetrycznego, którego koncepcję opracowali autorzy pracy. Przedstawiono strukturę i zastosowanie urządzenia.

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