TEMPERATURE AND MAGNETIC FIELD MEASUREMENT ON ROTATING PARTS OF ELECTRICAL MACHINES

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ABSTRACT

This article is devoted to the description of optical fibre sensors used for temperature and magnetic field measurement for application on the rotating parts of electrical rotating machines. There are optical principles of temperature and magnetic field measurement further discussed in details and there is explained an application of chosen methods for making of a measurement device.

1. INTRODUCTION

The development of automation and the rising number of electrical machines which are connected to various human activities lead to the need to improvement of these electrical machines. However this activity is closely connected to gathering of data from current machines which are in operation now. Data gathering is not very important only for further development but it is a very useful instrument for machine servicing. Thus it is possible to make searching of failures easier but it is also possible to monitor machines on-line and to take a service action eventually. This approach is therefore useful for DCS systems.

This article deals with temperature measurement and measurement of a magnetic field on the rotating parts of the electrical rotating machines. It is essential to choose the right method of measuring of given values and then transfer them to further evaluation. It is overall a very complicated problem because there are a lot of negative effects inside the machine which have influence on the measurement chain. These effects are mostly magnetic field and centrifugal force. The next problem is to transfer the information from the rotating part to the stationary part. The last but not least problem is to transfer the data from the machine to further processing.

The main purpose of this article is to suggest a concept of measurement chain for temperature and magnetic field measurement on the rotating part of the electrical rotating machine and to introduce the principle of used measurement methods. There is further thought enclosed electrical machine and transfer of a signal will be provided by some kind of radio signal.

2. TEMPERATURE MEASUREMENT

Temperature measurement seems to be an easy application because there is no aggressive surrounding and not very large range of measured temperatures. But according to notated limiting factors there remain only a few possibilities.

The first point is proportions and enclosed surroundings which eliminates pyrometers and thermo vision. And because of the need of an electrical output (and of course the dimensions) there is no use of dilatation thermometer.

The next limitation factor is magnetic field inside the air gap. For this reason it is not suitable to use metallic resistive thermometers (for example metallic resistive thermometers have the resistive wire coiled into the spires which should function as inductivity).

For these reasons it will be useful to use semiconductor resistive temperature sensor or temperature sensor based on the optical principle (OFS – optic fibre sensor). The best choice from semiconductor sensors is the NTC thermistor.

2.1. NTC THERMISTORS

NTC thermistors have non-linear characteristic which can be described by equation:

$$R_1 = R_2 e^{B\left(\frac{1}{T_2}-\frac{1}{T_1}\right)} = R_2 e^{\frac{B(T_2-T_1)}{T_1 T_2}}, \tag{1}$$

We can take a logarithm from the previous equation and count B constant as:

$$B = \frac{T_1 T_2}{T_2 - T_1} \ln \frac{R_1}{R_2}. \tag{2}$$

Typical scale of B constant is 1500 – 7000 K and it is possible to find it in catalogue or by measurement from equations (1) and (2).Temperature T_2 is practically set as reference temperature 25 °C. It is useful to use polynomial approximation for temperature range -100 to 300 °C in accordance with:

$$\ln R_T = A_0 + A_1 \frac{1}{T} + \cdots + A_n \left(\frac{1}{T}\right)^n, \; T = \left[a_0 + a_1 \ln R_T + \cdots + a_n (\ln R_T)^n\right]^{-1}. \tag{3}$$

A third grade polynomial with omitting the cubic term is used in most applications.

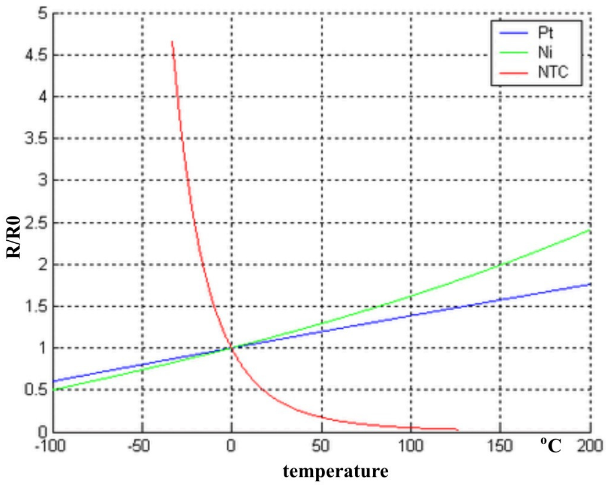

Figure 1: Thermal characteristic of metallic resistive sensors and NTC thermistors [4].

2.2. OFS (OPTIC FIBRE SENSORS)

OFS with direct parameters change of an optic fibre due to change of temperature use parasite characteristics (dispersion, attenuation, change of speed or light phase).This is made by inserting an optical fibre between two combs which cause optic fibre deformation and therefore also attenuation change. Thermally dependent element is there for example a bimetallic strip which is situated above one of the combs. Change of bimetallic strip bending lead to pressing of an optic fibre between the combs and that changes attenuation of an optic fibre (Figure 2).

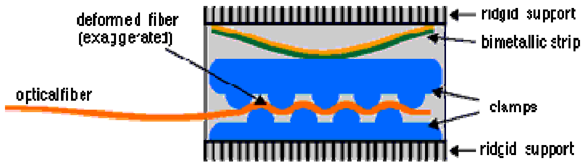

Figure 2: Thermal sensor using deformation of an optic fibre due to thermally sensitive component. [7].

OFS with indirect parameters change of an optic fibre is dependent on change of material features in the end of an optic fibre. This is provided by setting a transparent temperature sensitive layer to the end of an optic fibre. The optic fibre is finished by reflexive metallic layer. Change of thermally sensitive layer leads to change of phase between the light reflected on the transparent temperature sensitive layer and the light reflected on the metallic layer.

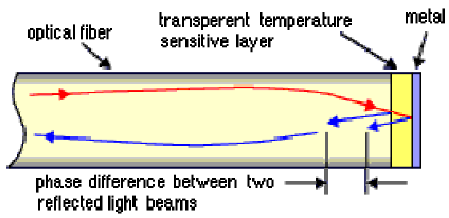

Figure 3: Temperature sensor using change of transparent temperature sensitive layer in the end of an optic fibre [7].

3. MAGNETIC FIELD MEASUREMENT

3.1. HALL PROBE

Hall probe is based on so-called Hall effect. The Hall effect principle is based on silicon slice with four contacts and through two of them flows current i_x. Carriers are due to Lorentz force fluctuating from direct way and that leads to generating electric field (Hall tension U_H). Hall effect can be described as:

$$U_H = \frac{R_H}{d} i_x B_z , \tag{10}$$

where U_H is Hall tension, R_H is electrical resistance of silicon slice, d is silicon slice thick, i_x is flowing current, B_z is electromagnetic induction.

3.2. OFS (OPTIC FIBRE SENSORS)

These sensors are based on the deformation of optic fibre and therefore also on the change of attenuation in specific optic fibre.

Figure. 4 is an example of magnetostrictive layer (c. 10 μm, Ni and its alloys, metallic glasses) for magnetic field intensity measurement. This magnetostrictive layers has effect on an optic fibre (mechanical tension) which leads to attenuation of light passing through an optic fibre. Sensitivity threshold of these OFS is in rage from 10^{-7} to 10^{-10} A and 10^{-12} to 10^{-14} T to 1 m of optic fibre to frequencies up to 101 kHz.

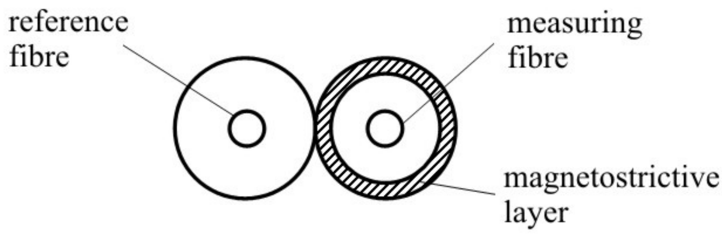

Figure 4: OFS for magnetic field measurement with phase modulation of passing light.

4. CONCLUSION

Because of the facts above it was decided that the measurement of temperature and magnetic field will be based on OFS. These sensing fibres has 0,1 – 0,5 mm in diameter so they perfectly fit the small size requirement. The range of measured temperatures is from -40 to 300ºC which is quite suitable for this application..Magnetic field will be measured also by magnetic field OFS. Both sensors will be placed (glued) on the rotating part of an electrical machine and the light from the sensors will be further linked by optic fibres.

On the specific place on the rotating part of electrical machine will be than laser diodes glued which will transmit light further to optic detectors (diodes). These detectors will be glued on the static part of electrical machine. These detectors will transmit received light further out of the electrical machine. Supplying of these optic components will be provided by power source from the magnetic field inside the electrical machine.

The majority of electrical machines is run up to the speed of 3000 rpm so there should not be any problem in processing the signal from optic components.

Light will be processed outside the electrical machine (the signal is able to bring out wherever you want) to avoid problems with metallic conducting and the necessity of processing of a signal inside the electrical machine. On the electrical machine cover will be placed a box with processing and unification circuits.

The next intention is processing the measured data. It should be wireless transmitting of measured data from the electrical machine to PC. This wireless signal will be most probable Bluetooth, Zigbee or GSM. This kind of a signal will be considered later according to environment and electrical machine. Outgoing data will be possible to receive by a specific kind of system (PC, cell phone, etc.).

It is also considerable to process output of this device for wired transmission. It is for example bus like Profibus, Industrial Ethernet or ASi. These types of busses are supported by a wide range PLCs which are used along with frequency converters for drives control. This kind of transmission will be effective for PLCs controlling the drives with temperature evaluation. On the other hand wireless transmission will be effective where only monitoring of temperature and magnetic field is needed.

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