

ELECTRONIC DEVICE FOR DIAGNOSTICS OF THE RESIDUAL RESOURCE OF THE ELECTRICAL INSULATION OF MACHINERY AND EQUIPMENT

Totio Iliev Iliev, Vladislav Tsvetanov Dimitrov

Department of Electronics, Technical University – Gabrovo, Street “Hadji Dimitar” No. 4, 5300 Gabrovo, Bulgaria, phone: +359 66 801064, e-mail: karadjov_st@abv.bg

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The resource of the technical objects (machines, machine systems, devices, tools, constructions and equipment is an important technical and economical parameter. Bearing in mind the current advance of science and technology, the process of forecasting the resource at the stage of operation is of considerable importance. Unlike the design stage, when the life expectancy of a set of yet non-existing technical articles is being calculated, the forecasting at the stage of operation is performed for specific, already existing items. Establishing the individual resource allows not only for the forecast of the possible defects and unforeseen occurrence of limit conditions, but also, as a rule, for the planning of the operation mode, the prophylaxis measures, and the spare parts deliveries. Moreover, the transition to individual forecasting results in increasing of the average resource of the machines, and enables the reasonable selection of the optimal operation period. The increase of the resource is in fact a serious reserve for savings of financial means, raw materials, energy and labour. The computerized processing of the data, obtained from the diagnostics system, allows for the graphical representation of the results and is a guarantee for the accuracy of the forecasts made. The device is realized on the base of a single-chip microprocessor, and is provided with specialized algorithmic and program software.

Thus, at every certain moment the working hours and the residual resource of the machinery and equipment, in dependence of the operation mode, can be read out and taken into account

1. INTRODUCTION

The analysis of machine and equipment temperature modes in most cases is directed to proving simplified methods and engineering ways for presetting of machine power and for checking of overheating conditions. As an admissible temperature mode shall be considered the mode where the insulation work duration is not less than the preset. During the machine operation there is a constant wearing of insulation related with its heating and the speed of this process is determined by the temperature mode character.

Besides during the insulation heating the limit admissible value should not be exceeded even for a short time because in this case it should be broken. If the machine works at constant temperature of insulation it is comparatively easy to determine the insulation aging process speed or the duration of its work. There are relations connecting the insulation work duration with certain constant level of temperature during work. According to [1] graphic presentation these relations can be presented as follows :

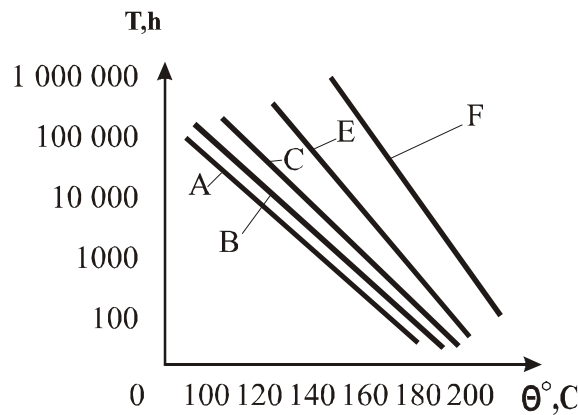


Fig.1. Relations of insulation serviceability duration and the temperature.

Most often the relation between the work duration and the temperature $T(\Theta)$ is approximated by the following exponent:

$$T = R \cdot e^{-\gamma(\Theta)} \quad (1),$$

where R is a constant coefficient, $\gamma(\Theta)$ – the function determined by the insulation class.

In most practical cases the electrical machines operation modes are such that during work the insulation temperature does not remain constant. Its changes can be big or small any way in all cases the curves from fig.1 cannot be used.

2. EXPLANATION

In case we have unfixed heat process, a quantity is introduced and it is opposite to the residual resource – insulation aging speed. According to (2) it is determined as follows:

The temperature range – the most endangered insulation point is divided in subintervals with step Δt . The average temperature θ_{pi} is determined for each interval:

$$\Theta_{cpi} = \frac{1}{m} \sum_{i=1}^m \Theta_i \quad (2),$$

and by it aging speed according to the formula:

$$D = T_e \cdot d_{cp} = \sum_i d_i \cdot \Delta t_i \quad (3),$$

where T_e is the operation duration; $d_i \cdot \Delta t_i$ – the wear of insulation for the time Δt_i of work with temperature θ_i .

The thermal life is determined by the relation:

$$T_{pi} = \frac{T_{pi}(\Theta_{cpi})}{1 + \sigma_i^2 / 2b^2} \quad (4),$$

where σ_i^2 is the average temperature quadratic deviation in the respective interval from the average temperature in it. It is determined by the expression:

$$\sigma^2\{\Theta\} = \Delta\Theta^2/3 \quad (5)$$

The residual resource T_{oi} i.e. the time from the examined moment to the probable first failure will be:

$$T_{oi} = T_{pi} - t_i = T_{pi} - \epsilon_i \quad (6),$$

where $\varepsilon_i = T_{oi}/T_{pi}$ is the relative residual resource .

The failure probability P_i can be treated as accuracy of prediction. It depends at the one hand on gamma percentage resource P_γ (usually $P_\gamma = 0,9 - 0,95$), and on the other hand – on the distance of the failure occurrence predicted moment from the examined moment. The prediction accuracy can be expressed by the a priori probability P_ε and the relative resource ε by the relation:

$$P_\varepsilon = 2[1 - \Phi(\varepsilon)] \approx 1 - \varepsilon \sqrt{\frac{2}{\pi}} \quad (8),$$

(at $\varepsilon < 0,5$) where $\Phi(\varepsilon) = \frac{1}{\sqrt{2\pi}} \int_0^\varepsilon e^{-\frac{t^2}{2}} dt$ is the tab-delimited integral of probabilities.

In this case $P_i = P_\gamma \cdot P_\varepsilon$ (9)

On the basis of the examined model a microprocessor unit is realized on the following block diagram.

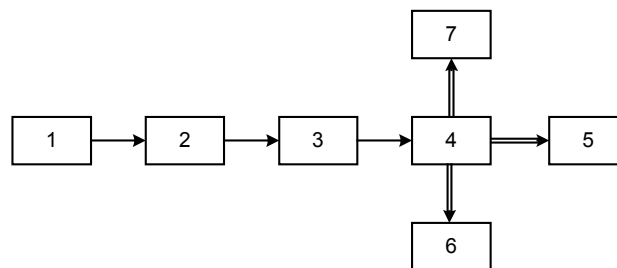


Fig.2 Block Diagram of the Device

The individual functional blocks are as follows:

1. Temperature Pick-up
2. Temperature Pick-up Amplifier
3. Filter for 50 Hz
4. Microprocessor
5. Interface for PC connection
6. External EEPROM memory
7. Digital Indication

The temperature pick-up is a thermal couple with a coefficient of change of output voltage 50,2 mV/C. It works in the temperature range from 0 – 250°C, and at maximal temperature the output voltage is 13,2 mV. A silicon diode is included at the cold end for thermal compensation. The influence of environment should be excluded in order to have exact measurements. For this purpose a resistive voltage divider is connected at the amplifier input. The thermal pick-up amplifier is made on the basis of operating amplifier OA LT1413. Its schematic diagram is shown in figure 3.

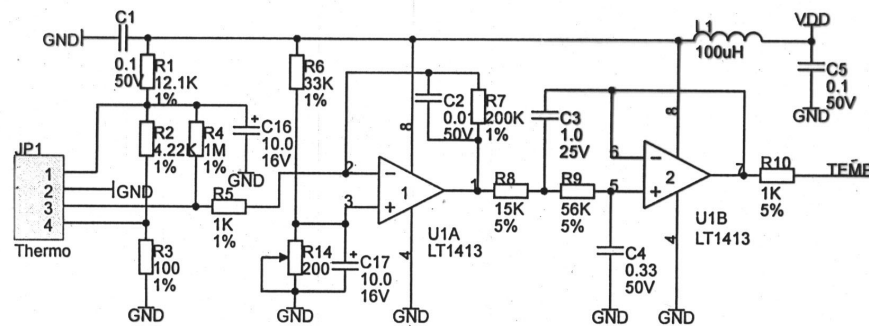


Fig. 3 Schematic diagram of Amplifier

The amplification coefficient can be changed by means of trimmer-potentiometer switched on the input. It depends on the thermal couple constant and in this case it is 400. The purpose is the amplifier output voltage to be able to change from 0 – 5 V, and this must correspond to the temperature change from 0 to 250 °C. The removal of 50 Hz frequency interference that can occur in the thermal couple chain and break the normal processor work is included in block 3. It is realized also with OA LT1413. From the filter output the signal enters the microprocessor which is shown in fig.4.

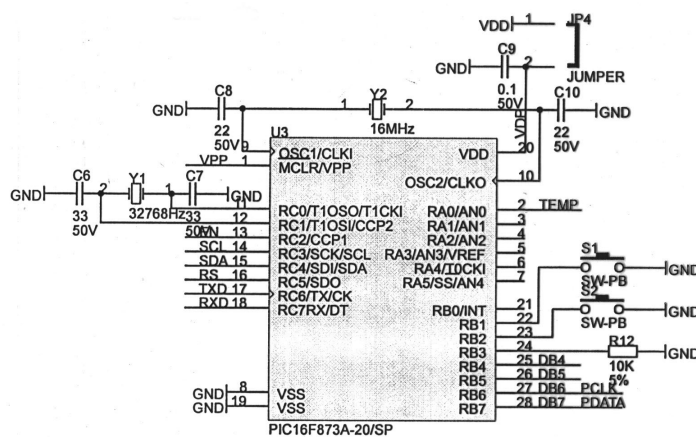


Fig. 4 Microprocessor Type PIC16F873 of MICROCHIP company

This is type PIC16F873 of MICROCHIP company. It is equipped with 10bit ADC and therefore additional switching of ADC is not necessary because it can cause complication of the diagram. It has two serial interfaces MSSP, USART, which enables PC connection for further data processing. The operating frequency is 20 MHz. There is FLASH program memory for data 192 bit, internal EEPROM memory 12kb, where mathematical expressions are entered, three timers, clock for real time. The work with the clock is extremely simplified – only 35 instructions are used. The quantity of connected external elements is minimal. Two external quartz resonators are engaged respectively on 16MHz and 32768Hz, one of them determines the operating frequency and the other one determines the time for realization of measurements. There are two buttons for programming – one for selecting the respective mode and the other one for confirmation.

Block No5 is a serial interface for reading the personal computer data by means of dedicated software and its schematic diagram is presented in figure 5.

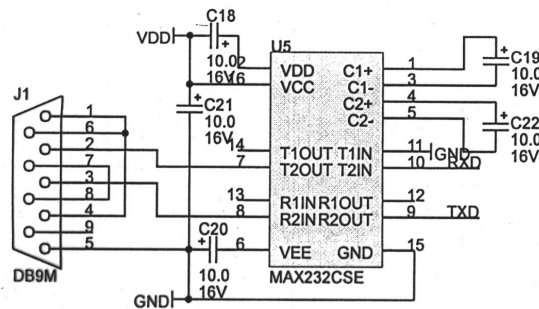


Fig.5 RS232CSE Interface

The RS232 interface is realized by MAX 232 CSE integrated circuit. Block No 6 is a buffer or an external EEPROM memory. It consists of 3 parallel connected memories type ST 24E256B1. One is for entering the reported values of temperature and the other two are for entering the measurements results. Six measurements of temperature are realized within an hour. Every hour the average temperature is estimated, the parameters are calculated and the results are stored. The memory contains 4096 cells providing possibility for 682 hours work or the memory capacity is 28 days. Then the data must be transferred to personal computer in order to clean the memory. The memory is shown on fig.6

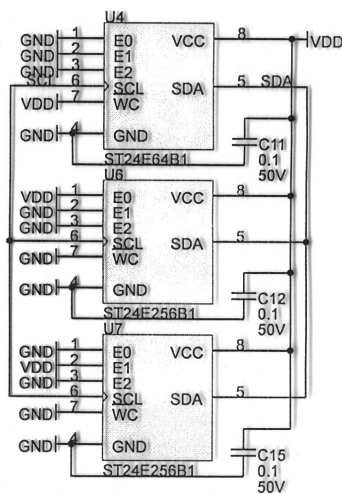


Fig. 6 EEPROM memory type ST24E256B1.

During the measurement on the screen are shown the worked off hours, the memory cell where the data are recorded, the measures temperature and the calculated parameters from the last calculation whose values appear every 4 seconds so that they can be visualized. Block No 7 is LCD display 2 rows of 16 symbols. The schematic diagram of the display is presented in fig. 7.

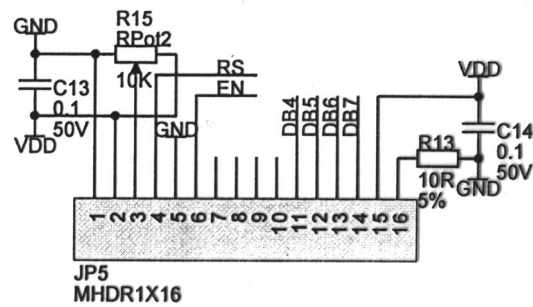


Fig.7 LCD Display

3. CONCLUSIONS

The device realized on the basis of the described method enables data storing and backup as well as the statistic processing of obtained results by means of direct connection with PC. The equivalent residual resource can be measured any time and according to these values we can judge the machine technical modes and load. On the basis of this we can receive information for other influencing factors. The device is mobile – it can be installed on all type of machines taking into consideration the insulation class. Placing such device on all machines in a production ensures possibility for work in a network. Thus planning of business and repair activities can be realized and this will reduce considerably the production costs and increase the duration of machine and equipment life.

4. LITERATURE

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