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AN ELECTRO-OPTICAL TECHNIQUE FOR THE MEASUREMENT OF TEMPERATURE OF HIGH POTENTIAL BODIES

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Abstract

In this paper we have presented a low cost, simple and robust mechatronic system for the measurement of temperature in extreme conditions. It is specially designed for the protection of high potential parts of power transformers and switch gears under faulty operating conditions. It comprises of two parts i.e., temperature sensing part cum transmitter which contains one thermistor, one LED, current limiting resistance and 5V source which is well insulated and placed on the high potential part to monitor the temperature and indication system /receiver which consists of photo detector, current to voltage converter, amplifier and the indication system and is kept at appreciable distance from the high potential body. Output of the system is recorded and analyzed when potential of the hot body is increased from 50V to 250V.

Keywords

Remote measurement, Optical Fiber, temperature measurement, thermistor, optical technique

1. Introduction

The measurement and/or regulation of temperature is an important everyday application of transducers. Accurate temperature sensing mechanisms are also present in living organisms. Measurement and regulation of temperature are important functions in a wide variety of consumers, industrial and medical applications, covering a wide range of temperatures of interest. Its importance further increases when it has to be made under injurious conditions where the conventional methods fail. One of the burning topics is the measurement of temperature of high potential parts of the useful equipments like transformers generators, switch gears which play important role in the stable operation of such machines /equipments. Because, increase in temperature, beyond a certain limit, is due to over loading, friction and sparking in side the machine or chip. Some transducers are available, for non contact measurement, like fluoroptic temperature sensor and laser based temperature measuring system [1]. These transducers are costly as well as have complicated circuits and have limited accuracy. The system, to be used for the purpose must be capable of operating under extreme conditions, without affecting the real temperature, as well as must have the added feature of remote sensing with continuous monitoring at low cost. In this paper we have presented a low cost, simple and robust technique which can be used in extreme conditions. It is specially designed for the measurement of temperature of high potential parts of power transformers and switch gears. It has mainly two parts i.e., transmitter and receiver. The transmitter is installed over the high potential body during observation, while receiver is kept at a remote place for safe study and recording of temperatures.

2. Approach and methodology

Basically we want to measure the temperature of the body, at a high potential; in such a way that measuring instrument as well as the observer should not be in danger. For this reason we have employed optical isolation between the hot body and the display unit. To have remote measurement which becomes necessary in such cases, we have used optical fiber to transmit the data efficiently. Schematic diagram of the proposed system is shown in fig 1. In this system, basic temperature sensor is a thermistor which is connected in series with a 5V supply, an LED and a current limiting resistance. Output of the LED is taken through optical fiber to a remote place where it is optically coupled to a photo detector whose output is fed to a current to voltage converter, an amplifier and display system. When temperature of the hot body increases, resistance of the thermistor decreases and current passing through the LED increases. This increase in current increases the output optical power of the LED which is efficiently connected to a photo detector through multimode optical fiber and hence the output current of the photo detector increases which

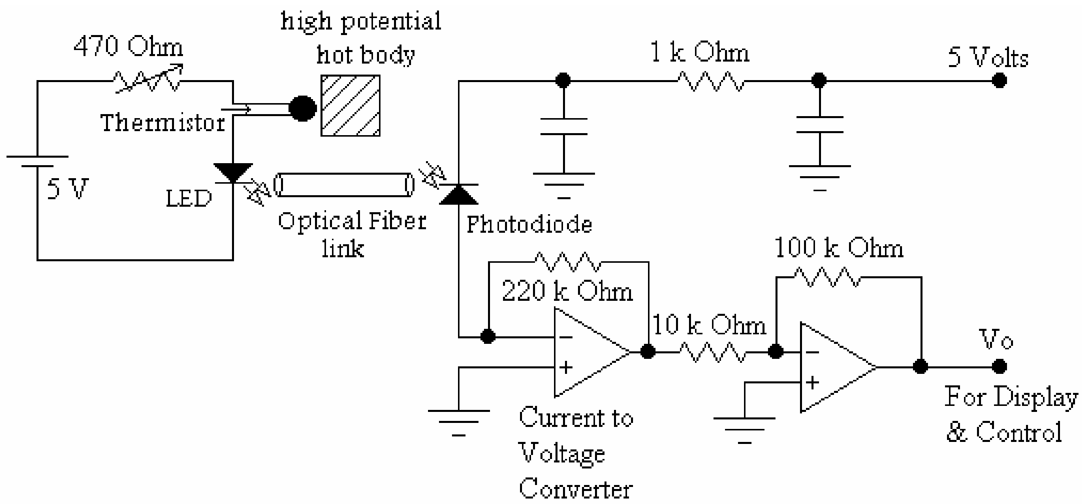

Figure 1- Schematic Diagram of the Temperature Measuring System

is converted into voltage with the help of current to voltage converter and amplified suitably to be interfaced with the display system. Transmitter circuit consists of thermistor, LED, suitable resistance and a 5V dc supply in a close circuit. Thermistor touches the hot body, and its resistance decreases as temperature increases. Hence current increases through the LED and resulting optical power, from the LED, increases. Expression for optical power may be given as follows.

Expression for LED forward current, I_F, may be written as follows [2];

$$I_F = \frac{V - V_{fw}}{R_{th} + R_t} \tag{1}$$

where, R_{th}= $148R_0$ x 10^{-8}. $e^{4000/T}$ is the resistance of thermistor for an ambient temperature of 25^0C and V_{fw}, is the forward voltage of the LED and R_T is the total resistance. When this current passes through LED, it produces an optical power which may be given by following expression [3'4]:

$$P_0 = KI_F = K[\frac{V - V_{fw}}{148R_0 10^{-8} e^{4000/T} + R_T}] \tag{2}$$

where K is a constant and I_F is the forward current of the LED. LED is coupled with the optical fiber and hence optical power passes through optical fiber to the photo diode on the other end as shown in Fig.1. Some power will be lost during transmission. However a portion of it will be converted into current by the photo diode and it will be directly proportional to optical power P_0, coupled to it and the detector photo current I_d may be given by following expression [5].

$$I_d = \alpha R P_0 \tag{3}$$

Where R is the responsivity of the photo detector and α is the loss factor due to transmission.

Substituting the value of I_F and P_0 from Eq. 1 & 3, we get,

$$I_d = \alpha RK[\frac{V - V_{fw}}{148R_0 10^{-8} e^{4000/T} + R_T}] \tag{4}$$

With the help of the current to voltage converter it will be converted into an output voltage V_0, given by following expression:

$$V_0 = I_d . R_0 \tag{5}$$

Where, R_0 is the feedback resistance of the current to voltage converter. Experimental results obtained with the system show that the non- linear ties of LED and photodiode are taken care of by the nonlinearity of the thermistor.

3. Experimental methods and results

The circuit of the thermistor and LED, shown in Fig.1, is fabricated on a small PCB. LED No.MFOE71 which can be nicely coupled with multimode, plastic optical fiber is used as the light source. Thermistor resistance and external resistance are so chosen that LED operates on the linear part of the characteristic between optical power and forward current of the LED. Hence operating current of, 30mA, at ambient temperature of 25^0C, is chosen for the LED. The PCB of the transmitter is so installed that thermistor remain in touch with the hot, high potential body. Optical fiber, after proper polishing, is installed in the LED and the other end is fitted inside the plastic case of photo diode, which is placed at a distance of 10 meters from the high potential body initially. PCB of the receiver circuit consists of a photo diode No.MFOD71, a current to voltage converter, an inverting amplifier and power supply to bias the Opamps and photo diode. Output voltage of the receiver is connected to a precision grade multimeter (Tektronix). Temperature of the high potential body is slowly increased and output of the receiver is recorded. Simultaneously, temperature of the hot body is measured with the help of a mercury thermometer and output of the receiver is calibrated in terms of temperature. Potential of the high potential body is increased in steps of 50V and experiments are repeated and average of a number of readings is finally entered in the table.. Results obtained are given in Table-1

Table 1- Experimental Results

Temp ^{0}C by Merc. Therm	Output Voltages (Volts)				
	50	100	150	200	250
16	0.600	0.600	0.602	0.604	0.605
22	0.635	0.637	0.640	0.640	0.641
30	0.710	0.710	0.712	0.711	0.712
38	0.790	0.790	0.792	0.792	0.793
46	0.880	0.879	0.879	0.882	0.882
53	0.940	0.939	0.941	0.941	0.942
68	1.090	1.092	1.093	1.098	1.100
74	1.150	1.150	1.155	1.158	1.158
82	1.240	1.247	1.246	1.250	1.252
94	1.330	1.328	1.335	1.337	1.340
115	1.450	1.455	1.458	1.459	1.462

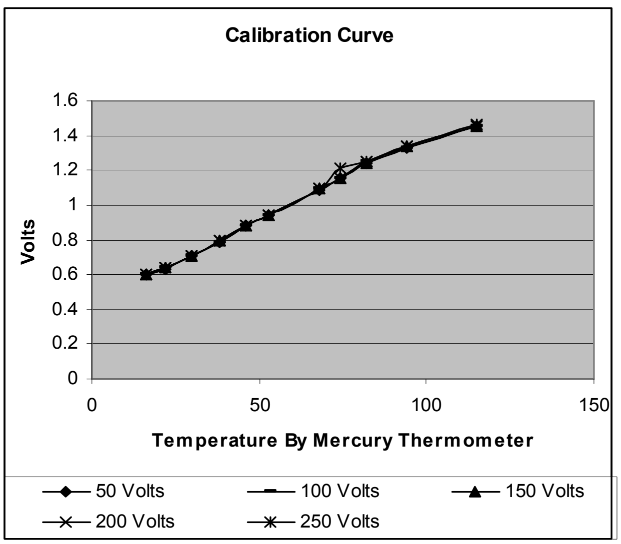

Figure 2 – Calibration Curve

The data obtained with the measuring system is given in Table-1 and graphical relationship is shown in Fig.2. It is appreciably a straight line relationship which shows that the output voltage is directly proportional to the temperature in the measurement range which is a highly desirable feature in a Mechatronic System. It can be easily adjusted to disconnect a system by operating a relay in a substation, under working conditions, before a serious fault may occur. It is a very important feature. It is observed that the effect of variation of potential of the hot body is nearly negligible because most of the components are insulated and signal is transmitted through optical fiber which has isolated the high potential body from the receiver. System is robust as well as precise in the measurement of temperature of high potential bodies up to the voltages of the order of 250V, according to the experiments.

4. Conclusions

A proto-type model of Electro-optical temperature measuring system is designed, fabricated and tested. Initially it is tested up to domestic supply voltages (50 to 250V) only due to the limitations of the laboratory. In this range, change in output voltage with change in temperature is appreciably constant. Long distance transmission can be tried with LASER and mono mode optical fiber and further work can target the testing of this system at higher voltages up to 11000V. It may have another very good application in the case of costly chips which are used in circuits and get heated up due to a number of reasons. This arrangement may also be used to save them before getting damaged due to over heating by disconnecting them before this situation.

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