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TEMPERATURE MONITORING SYSTEM FOR ELECTRICAL MACHINES WITH DATA STORAGE AND COMPUTER INTERFACE

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Abstract

Electrical machine rating is dependent on temperature. The rate at which heat generated in an electrical machine is transferred usually determine the life span of the machine. In this work a monitoring system has been presented. It consist of a power supply unit, the Real time clock unit based on DS3231 Integrated circuit, a 3V Cmos battery and 32 kHz Crystal Oscillator, a temperature sensing unit built around DS18B20 sensor, an analogue to digital converter integrated circuit (ADC0804) and a programmable control unit based on ATMEGA328P microcontroller. On test with an electric motor, a range of temperature measured over 30minutes at an interval of 1 minute were displayed.

Keywords: Temperature, Electrical machine, Heat

I. INTRODUCTION

Temperature play an import role in the performance of an electrical machine. In terms of the life expectancy, if the insulation temperature of an electrical machine rises by 10°C, the life expectancy shortens by half[1].An electrical device (machine) rating is define by its ability to extract the heat produced by its electrical and mechanical losses or its ability to operate at high temperature without damage because of its ability to extract the heat produce [2].
The standardized ambient temperature for electrical machine is 40°C at an expected life span of 20,000 to 40,000 hours [1]. The NEMA/UL letter insulation class for electrical machine are A, B, F, H, R and S with hot spot temperature of 105°C , 130°C, 155°C, 180°C, 220°C and 240°Crespectively[3]. Temperature above the standardized range is as a result of improper cooling and overload.
The winding resistance ofan electrical machine changes with change in temperature [4].

$$R_2 = R_1(1 - \alpha_1(T_2 - T_1)) \quad (1)$$

Where the resistance at an increased temperature$T_2$is R_2, R_1 is the resistance at the initial temperature T_1 and α_1 is the temperature coefficient of the material at T_1.
The increased resistance reduces the maximum output power capacity of an electrical machine. An electrical machine must be de-rated or operated at reduced capacity if the temperature exceed the operating limit[5].
In the conversion of electrical energy to mechanical energy, some losses occurs. They include theconductor material losses (copper or I^2R losses), the eddy current and hysteresis losses, bearings and ventilation losses[6]. These loses produce heat that raise the temperature of the electric motor.
The heat generated must be dissipated i.e. Heat energy generated (pdt) = heat absorbed by machine ($MCd\theta$) + heat dissipated from the surface area ($A\theta\alpha dt$) or

$$pdt = MCd\theta + A\theta\alpha dt \quad (2)$$

Where P is the power loss due to heat generated in watts, M is the mass of the active part of the machine in kg, C is the specific heat capacity of the material in joule/kg/°C, A is the surface area of the machine inmeterssquare, θ is the temperature rise above the cooling medium in °C and α coefficient of cooling in watts/m^2/°C.
By separating the variables in equation(2), stating the necessary assumptions and the initial conditions, the temperature rise of an electrical machine can be evaluated from the solution of the differential equation obtained. The solution as stated in equation (3) represents the temperature rise, where θ_F is the final temperature attained [7].

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$\theta = \theta_F(1 - e^{\frac{-t}{T}})(3)$

Most electrical machines are continuously rated i.e. they can deliver their maximum power for an indefinite period without exceeding their temperature limits. However, it is important to monitor the temperature of some machine under certain conditions to avoid insulation degradation and failure. In this regard, an electrical machine temperature monitoring system is well suited for the purpose.

Related Work

A computer based monitoring system was proposed for temperature and vibration analysis of electric motors. The system can help detect early damage to the electric motor by monitoring the patterns of temperature and vibration as they rise which is an indication of malfunction, if they exceed the normal limit. The system includes a temperature and vibration sensors, sensor amplifier, data acquisition and computer programmed with LabVIEW. The test results established that the temperature monitoring devices can detect any discrepancy in the motor which will cause a rise in temperature, if such increases exceed the limit that has been setup then the system will turn on the alarm and blinker [8].

A wireless fault detection system for industrial motors that combines Vibration, motor current and temperature analysis, with a remote motor condition monitoring was proposed and implemented through a wireless sensor network (WSN). It incorporates a graphic user interface to offers remote access to motor conditions and real-time monitoring of several parameters. The circuit was built around the LM35, ACS712 current transducer and MMA7260QT micro-electro-mechanical systems (MEMS) three axis accelerometer as temperature, current and vibration sensor respectively, an ATmega328 microcontroller that samples the sensors and the ATmega128RFA1 microcontroller that serves as the wireless module that controls and synchronizes the sensor data acquisition process. Various tests confirm the feasibility and usefulness of the system for the preventive maintenance of three-phase rotating machines[9].

II. PROCEDURE

The circuit consist of the power supply unit, the Real time clock (RTC) unit, the temperature sensing unit and the programmable control unit.

Power Supply Unit

The Power Supply Unit consist of a 240/12V, 1Amp step down transformer, four (4) 1N4007 diodes of PIV of 50V and dc current of 1A, an LM7805 voltage regulator for regulated 5Vdc supply, 2200µf and 10µf capacitors. The power supply unit is shown in figure 1.

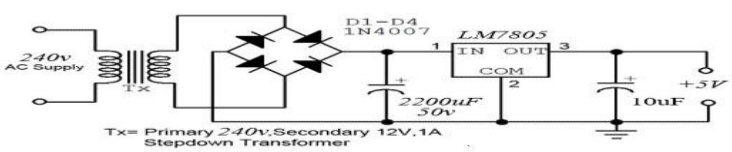

Figure 1. The power supply unit

Real time clock (RTC) unit

The Real time clock unit comprises of the DS3231 IC, the 3V Cmos battery, 32 kHz Crystal Oscillator and a pull up resistors of 10kΩ. According to the DS3231 datasheet [10], the DS3231 IC is a low-power clock/calendar with 56 bytes of battery-backed SRAM. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The real time clock circuit is presented in figure 2.

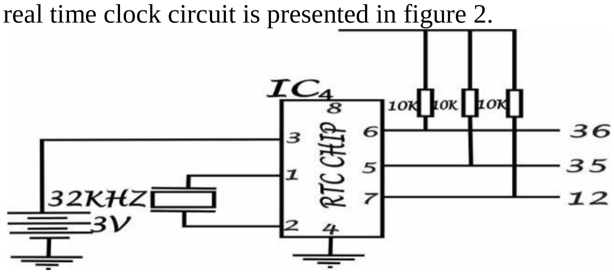

Figure 2. RTC unit

The temperature sensing unit

The temperature sensing unit comprises the DS18B20 or LM18B20 temperature sensor and Analog-Digital converter (ADC0804).The DS18B20 datasheet [11] indicates that thetemperature sensor can measure a wide range of temperature from **-55°C to +125°** with an accuracy of **±5°C and** is powered at a voltage rating of 3V to 5.5Vdc**. The sensor is connected as shown in figure 3 with IC_5 representing the temperature sensor.**

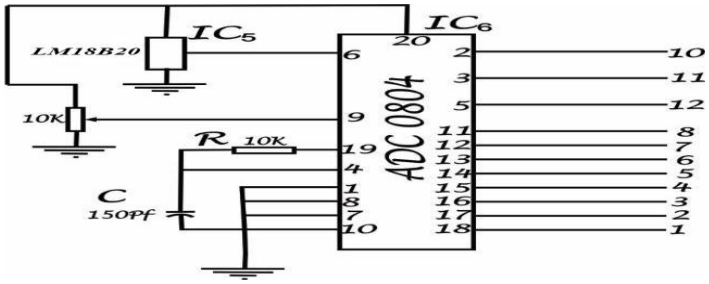

Figure 3. Temperature sensing unit

Analogue to digital signal conversion

The ADC0804 is an integrated circuit that samples the voltage from the temperature sensor and converts the analogue voltage signals into digital signals compatible with the microcontroller [12]. It takes about 110µs to convert an analogue signal into digital. The ADC0804 IC is embedded into the ATMEGA328P.

The clocking terminals (CLK IN and CLK R)pinare connected through a resistor and capacitor that are related by the expression presented in equation (4) [13].

$$f = \frac{1}{(1.1\,RC)} \quad (4)$$

To generate clock for the ADC0804 IC, the capacitance = 150pF and the resistor = 10KΩ

According to theATmega328P Datasheet [14],the ATMEGA328PIs a high performance, low power 8-bit microcontroller it has 32 x 8 general purpose working registers, 32K bytes of in-system self-programmable flash program memory, 1Kbytes EEPROM,2Kbytes internal SRAM and Write/erase cycles of 10,000 flash/100,000 EEPROM.

The control codes for the circuit is written on the programmable IC. The flow chat represent the algorithm of the code.The source code written in C^{++} programming language is sent to the microcontroller through the Universal Synchronous Asynchronous Receiver Transmitter (USART) communication cable protocol.

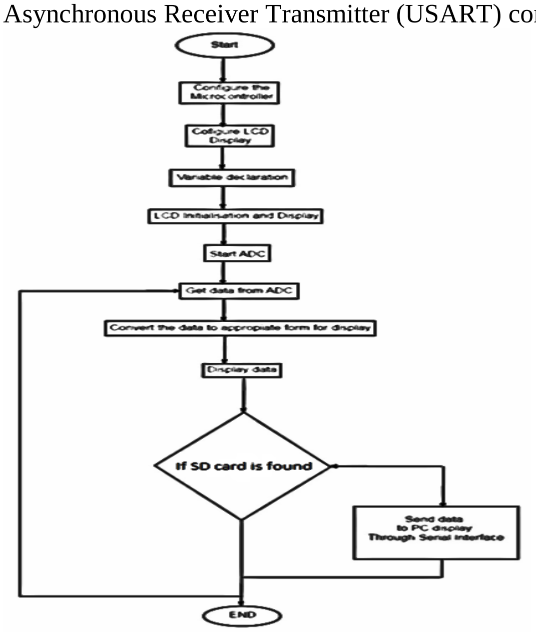

Figure 4.The flow chat of the control code

The microcontrollerisinterfaced with a computer to display and save the sets of temperature data with the help of the Universal Synchronous Asynchronous Receiver Transmitter (USART) communication cable protocol. The circuit also consist of an SD card reader/module of 5V, 200mA, interfaced with the microcontroller through a serial peripheral interface (SPI) communication protocol. It holds an external memory card. The card stores the set of temperature data at a preset interval of time.

There is an alternative LCD screen. The microcontroller manipulates the input from the ADC and RTC chip and outputs binary coded outputs. An ADC of 10-bits resolution (BCD) is used to convert the signal from the microcontroller to a form that can be displayed on a liquid crystal device LCD. The complete circuit diagram and the pictorial diagram of the implemented circuit is illustrated in figure 5 and 6

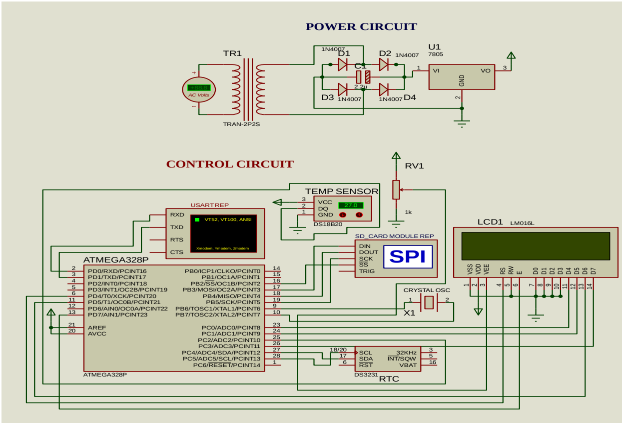

Figure 5. Complete Circuit diagram

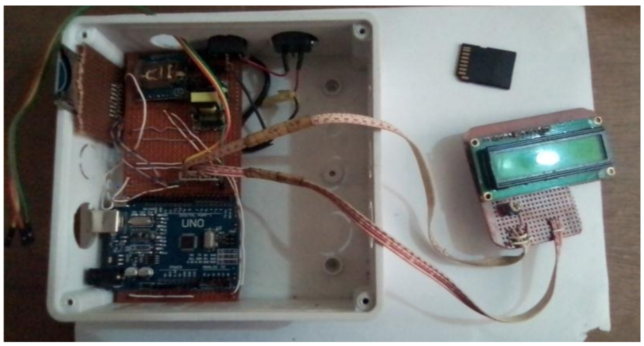

Figure 6. Pictorial diagram of the implemented circuit

III. TEST AND RESULTS

The temperature of a three phase, class B, 50Hz, 380V, Star(Y) – connected electric motor was tested on no-load condition with the implemented design. The sensor was inserted into to winding of the motor. The motor was test over a period of 30 minutes. The results obtained at intervals are displayed on Table 1.

Table 1. Test results from a 0.75kw motor.

TIME (Mins)	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TEMP (°C)	**30.37**	30.81	31.19	31.56	31.94	32.63	33	33.38	33.69	34.06
TIME (Mins)	**11**	12	13	14	15	16	17	18	19	20
TEMP (°C)	**34.38**	34.69	35	35.31	35.61	35.94	35.25	36.56	36.81	37.06
TIME (Mins)	21	22	23	24	25	26	27	28	29	30
TEMP (°C)	37.31	37.63	37.88	39.06	38.32	38.7	39.01	39.35	39.71	40.02

A graph of the temperature against time is presented in figure 6.

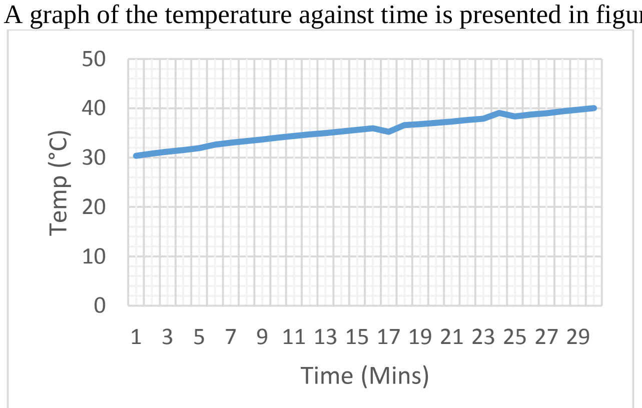

Figure 6. Graph of Temperature against time.

From the graph, the temperature rises to 40°C in 30 minutes from an initial temperature of 30°C. A 10°C rise in temperature was recorded in 30 minutes. The results displayed shows that the system can adequately sense, record, store and display temperature of an electrical machine.

IV. CONCLUSION

A temperature monitoring system has been presented. It can sense, record, store and display the hot spot or winding temperature of an electrical machine. This work can be adopted as the basis for further studies on the effect of temperature on electrical machine in equatorial regions. This may involve real time monitoring of a machine for a period of time to obtain data for a broad based analysis of the effect of ambient temperature on an electrical machine. From the results obtained from the temperature monitoring system, a 10°C temperature rise in the winding of an off load induction motor was recorded in 30 minutes.

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