An Experimental Setup for Monitoring Distribution Transformer Health

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Received 22 February 2021; Accepted 02 March 2021;
Publication 20 April 2021

Abstract

The Distribution transformers are the most expensive and important component which are used for transmission and distribution of electrical energy. It is imperative that the transformers function correctly without any faults, and should any faults occur, the same should be detected and corrected as soon as possible to prevent the failure of the power system to supply power. Health monitoring systems of distribution transformers are used to diagnose the distribution transformer and to deduce its working condition under the occurrence of incipient faults. This paper presents a model of a health monitoring system for distribution transformers in a laboratory environment. The proposed model ensures that faults do not disrupt the regular supply of power.

Keywords: Distribution transformer, Arduino Uno, MFM384-C, HYT939, Ultrasonic Sensor, SIM900a GSM Module, Thingspeak Server.

Distributed Generation & Alternative Energy Journal, Vol. 35_3, 195–208.
doi: 10.13052/dgaej2156-3306.3532

1 Introduction

In recent times, Electricity has become a valuable part of our lives and it is impossible to imagine life without electricity. It has become so important that generation of electricity has become a criterion to measure the development of a nation. This is because various industries are directly dependent on the production of electricity and almost every industry is dependent on electricity directly or in directly [1]. The Ministry of power holds the responsibility of generating power in India.

The transformer is a crucial segment of the power system. The incidence of faults in the transformer is infrequent. However, the development of faults in a transformer disturbs the entire power system. Hence it is mandatory to monitor its parameters continuously [2]. Constant surveillance minimizes outages and prevents interruption of power flow. There are numerous offline and online monitoring techniques available. In offline transformer Health Monitoring Systems [3], the transformer is temporarily shut down periodically to determine if it is in working condition. This method is tedious, takes more time, and is often a hindrance to the supply of power. Besides the disadvantages mentioned above, the time taken to transport the transformer oil from the location of the transformer to the laboratory often results in chemical reactions altering the composition of the oil. This leads to incorrect analysis. Online health monitoring, on the other hand, does not require a shut-down of the transformer, and sensors are installed on the transformer, and real-time data is obtained regarding the condition of the transformer [4]. Being highly accurate and economical eventually, makes online monitoring methods preferable [5]. Section 1 signifies the importance of switching to online health monitoring techniques from offline techniques for improving the performance of distribution transformers.

2 Experimental Description

Power Section 2 describes the experimental setup, which was assembled for the Health Monitoring of Distribution Transformers [6]. Arduino Uno is used as the central microcontroller to extract data from the various sensors. Arduino Uno is selected for this project because of its simplicity and affordability. Each of the data extracted from the sensors carries significance in the Health Monitoring of the distribution transformer, and failure to monitor them may lead to disruption in the supply of power to the consumers. The various parameters measured by the central microcontroller and their significance are further discussed in the sections below.

2.1 Transformer Oil Temperature

Section 2.1 briefs on the sensor used for measuring and scaling of temperature and humidity values obtained from the same sensor. With increase in transformer voltage or current, various pressures are act on the device, leading the temperature of winding and insulating oil increase. It further leads to heating other components or breakdown [7].

The temperature of transformer oil for a 125 W transformer varies from 400–600°C for various operating conditions of the transformer. The maximum allowable temperature of the oil is 650°C. An alarm is commercially set up at 70°Cand a trip signal is actuated at 850°C.

A general rule for setting temperature limit is to alarm at 80–90% of the maximum current and a trip setting at maximum allowable temperature as per manufacturer data sheet [8].

In case of a violation of the limits, the oil starts expanding. The oil can even lose its insulating property at higher temperatures. The breakdown of insulating oil is a function of hydrostatic pressure applied and the voltage in the windings of the transformer. If the insulating property of oil fails, it will start conducting, and hence the induction principle fails and causes short circuit fault.

2.1.1 HYT939 I2C Temperature and Humidity Sensor

Figure 1 shows the temperature and humidity sensor, which is used for measurement in the experiment. It has an integrated signal processing for measuring the physical parameters of relative humidity and temperature. It is an I2C compatible interface [9]. The I2C protocol address is 0×28, or an alternative address can be assigned. The mode of measurement is easily

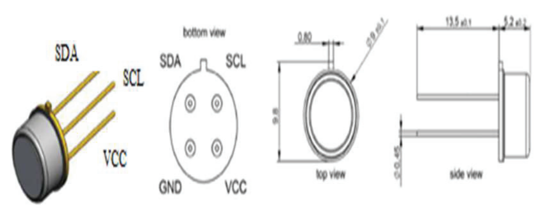

Figure 1 HYT939 sensor.

interchangeable and without adjustment as well as mechanically robust. It has excellent chemical resistance, dew formation resistance, and long-term stability. Humidity resistance is high for the sensor.

It measures a temperature range of $-40°C$ to $125°C$. The humidity measuring range is 0%RH to 100%RH. The operating voltage range varies from 2.7V to 5.5V. A precisely calibrated HYT939 delivers an accuracy of $\pm 1.8\%$ RH and $\pm 0.2°C$ (i.e.) its resolution for humidity and temperature are 0.02%RH and 0.015°C respectively. Long term drifts for humidity and temperature are 0.5%RH/a and 0.05K/a. It is ideal for sophisticated environments and medical systems.

2.1.2 Scaling of measurement values

T_{raw} and RH_{raw} are the digital 16-bit values submitted by the sensor corresponding to the temperature and humidity of the surrounding which is to be scaled using the below formulae.

Humidity values will be calculated as

$$\mathrm{RHActual}[\%] = \frac{100}{214 - 1} * RH_{raw}$$

Temperature value will be calculated as

$$\mathrm{TActual}[°\mathrm{C}] = \frac{165}{214 - 1} * T_{raw} - 4018$$

2.2 Oil Level Sensing

Section 2.2 summarizes the usage of an ultrasonic sensor for measuring and scaling the values of the transformer oil level. The oil in the transformer serves two purposes. It is used for insulating as well as cooling purposes. The desirable properties of transformer oil are high thermal conductivity, chemical stability, and dielectric strength. The level of transformer oil is used to detect faults in a transformer [10].

2.2.1 HC-SR04 Ultrasonic sensor

Figure 2 is an Ultrasonic sensor module. It consists of 4 pins, namely V_{CC}, Trig, Echo and GND. It is generally used to measure distance or sense objects. It includes an ultrasonic transmitter and a receiver. The transmitter emits an ultrasonic wave, which is reflected in the presence of an object. The reflected wave is received by the receiver, and the distance is computed.

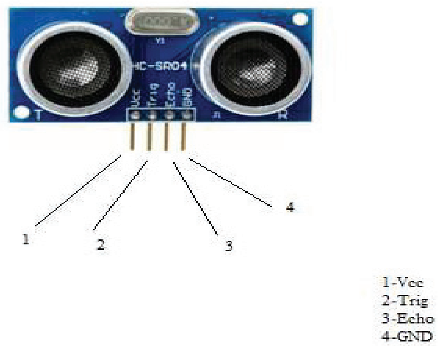

Figure 2 HC-SR04 sensor.

Ultrasonic ranging module HC-SR04 provides 2 cm – 400 cm non-contact measurement function. It can measure as low as up to 3mm. Its operation is not affected by sunlight or black material like sharp rangefinders.

2.2.2 Scaling and measurement of values

The universal speed of Ultrasonic wave at room conditions is 330 m/s. The circuitry inbuilt on the module will calculate the time taken for the wave to reflect and turns on the echo pin for that same particular amount of time, this way we can also know the time taken [12].

Knowing the velocity of wave travel and the time taken between transmission and reception gives twice the distance.

$$D = \frac{V}{2 \times T}$$

where D is the distance between the sensor and the object
V is the velocity of the wave
T is the time taken for the wave to travel from the sensor to the object.

2.3 Measurement of Electrical Parameters

The occurrence of the fault of a transformer is unusual as it is a static device and is oil-immersed. The typical faults are open circuit, overheating, and winding faults. It is necessary to monitor its parameters and keep them under restricted values [12]. For the measurement of electrical parameters, MFM384-C meter is used, which has been explained in Section 2.3.1.

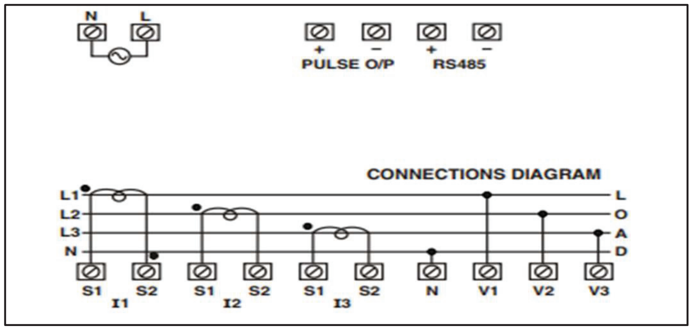

Figure 3 MFM384-C setup taken from SELEC MFM384-C Operating Instructions [11].

2.3.1 MFM384-C Multifunction meter

MFM384-C, shown in Figure 3, is a multifunction meter which is used to measure electrical parameters such as voltage, current, frequency, power factor, power, and energy [14]. RMS and average values of voltage and current, and active, reactive, and apparent values of power and energy are displayed [15]. The current is also displayed in bar graph format. The meter has a liquid crystal display with five lines for displaying each of the parameters.

The terminals of the 3 Current transformers are connected to I_1, I_2 and I_3. N is the neutral connection and V_1,V_2 and V_3 are the three voltage inputs. The meter consists of auxiliary input, RS485 communication and Pulse output terminals.

The meter has a keypad which comprises of six dual function keys, labeled as V, I, VAF, PF and E. These keys can be pressed to read the corresponding meter parameters and to change the settings of the meter. The register address list of the readable parameters of the meter is shown below in Figure 4.

2.4 SIM 900a GSM

Section 2.4 describes the data transfer process using GSM. Figure 5 shows a GSM SIM900a module, which is used to upload the measured data to the Things peak server. GSM or global system for mobile is a digital technology that uses a combination of time division multiple access (TDMA), frequency division multiple access (FDMA), and frequency hopping for wireless communication purposes such as transmitting mobile voice and data services at frequency bands ranging at 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz with date rates from 64 kbps to 120 Mbps. It mainly works to sample,

Modbus parameter SELEC

MODBUS register addresses list

Readable parameters from MFM384:

Address	Hex Address	Parameter	Length (Register)	Data Structure
30000	0x00	Voltage V1N	2	Float
30002	0x02	Voltage V2N	2	Float
30004	0x04	Voltage V3N	2	Float
30006	0x06	Average Voltage LN	2	Float
30008	0x08	Voltage V12	2	Float
30010	0x0A	Voltage V23	2	Float
30012	0x0C	Voltage V31	2	Float
30014	0x0E	Average Voltage LL	2	Float
30016	0x10	Current I1	2	Float
30018	0x12	Current I2	2	Float
30020	0x14	Current I3	2	Float
30022	0x16	Average Current	2	Float
30024	0x18	kW1	2	Float
30026	0x1A	kW2	2	Float
30028	0x1C	kW3	2	Float
30030	0x1E	kVA1	2	Float
30032	0x20	kVA2	2	Float
30034	0x22	kVA3	2	Float
30036	0x24	kVAr1	2	Float
30038	0x26	kVAr2	2	Float
30040	0x28	kVAr3	2	Float
30042	0x2A	Total kW	2	Float
30044	0x2C	Total kVA	2	Float

Figure 4 Register address list of MFM384-C from the SELEC MFM384-C Operating Instructions [11].

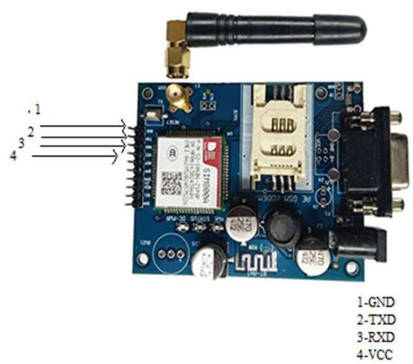

Figure 5 SIM900a Modules.

quantize, and reduce the data, and through a channel sends two different streams of client data, within its allocated time slot. The frequently used GSM module is the SIM900a GSM module.

A GSM modem requires a SIM card for it to be operated and can be connected to a computer through USB, Bluetooth, etc. There are two defined modes in SMS specification in which the GSM module operates which are SMS text mode and SMS PDU mode(Protocol Data Unit). GSM can be operated in normal, power down and minimal functionality mode. Under normal operation mode, the functions available are GSM/GPRS SLEEP, GSM IDLE, GSM TALK, GPRS STANDBY and GPRS DATA. The GPRS DATA function handles GPRS data transfer (UDP or TCP or PPP) in progress. The network settings, date rates of uplink or downlink, and the GPRS configuration, determine the power consumption.

GSM module is often interfaced with the microcontroller (like PIC, AVR) through the level shifter IC Max232. The SIM card mounted GSM module receives digit command from any cell phone as SMS and sends the data to the microcontroller [12]. While the program for the microcontroller is executed, the GSM modem receives a "stop" command for developing an output at the microcontroller, whose contact point is used to disable the ignition switch [17].

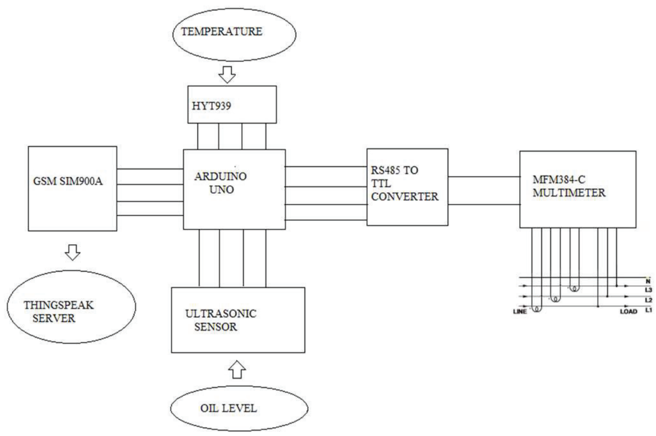

Figure 6 Block diagram of the setup.

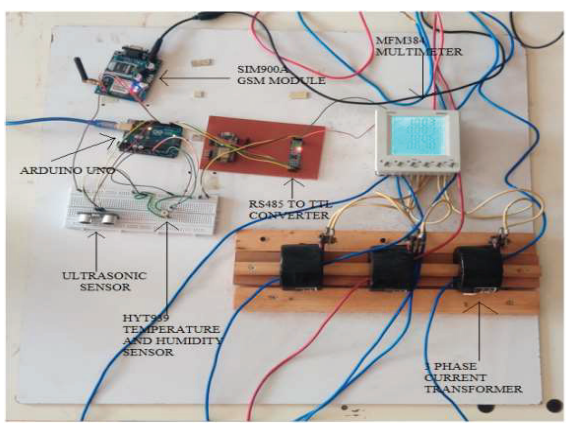

Figure 7 Experimental setup.

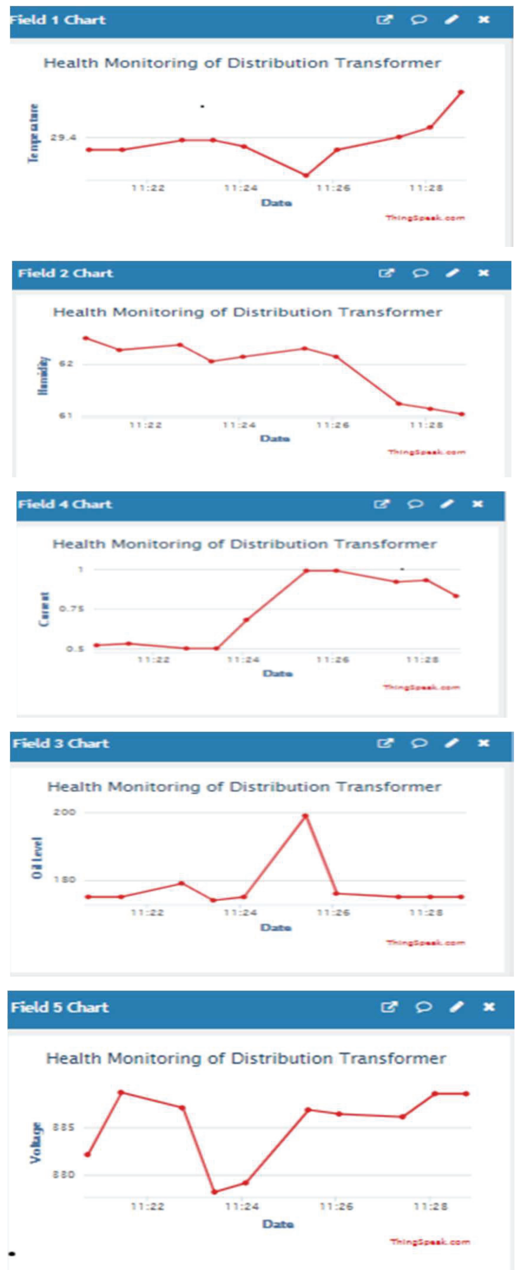

Figure 8 Experimental results.

The GSM modem sends ‘ALERT’, a programmed message only if the input is driven low, based on which the user sends the above command.

3 Experimental Setup

The Experimental Setup of the proposed health monitoring system for distribution transformers is shown in Figure 7 along with the block diagram in Figure 6. The Arduino Uno acts as a central microcontroller and is interfaced with the various sensors necessary for the health monitoring system. The Arduino Uno has 13 digital pins and SCL, SDA ports for I2C communication, which is necessary for the Arduino to be interfaced with the HYT939 temperature sensor. The RS485 to TTL converter is used for interfacing the central microcontroller with the MFM384 for measuring the voltage and current values. The ultrasonic sensor is interfaced with the Arduino in order to measure the oil level of the transformers. The GSM module is used to send data to the Things peak server in the place of a ESP8266 as GSM module does not require Wi-Fi to function and as such can be used in remote places with no Wi-Fi. The 3Ø current transformers are used to measure the current in the power system by stepping down its value as the current values in the power system are too high for the MFM384-C to measure.

4 Experimental Results

The results obtained by plotting the various parameters measured with time in Thing speak are given in the Figure 8. The system was connected to a variable resistive load which was receiving current from a 3Ø power supply. The load was continuously varied after each reading and the resulting current and voltage along with the other measured parameters are plotted in the Thing speak server.

5 Conclusion

In this paper, the monitoring of a distribution transformer in an laboratory environment has been presented. This technique, if implemented, can replace the current outdated methods of offline transformer health monitoring and may even prove to be more economical in the long run.

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Biographies

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