IoT Based Condition Monitoring System for Distribution Transformer

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Abstract

This paper presents a mobile embedded system that is designed and implemented to capture and record data, such as voltage, current, oil level, temperature, humidity, and total power of the transformer. Electrical networks in rely heavily on power transformers. As a consequence, dependability plays a key role. Power transformer maintenance is currently allocated by end users. In contrast, not many resources are available for online condition monitoring. A transformer's reliability and long life are the reasons for this. In light of this, online monitoring might be justified due to the failure costs that may be high.Through a Wi-Fi Module, a transformer operator can ask any related parameter value of transformer health through the system, even if the operator is not physically present at the transformer site. When transformer parameters exceed predefined limits, this system sends alerts. Monitoring the operating point of single-phase transformers using Arduino and GSM is done remotely. A 16x2 line LCD also displays all proposed parameters. Data from transformers are acquired remotely using a module in this system. SMS messages are sent to the system from the GSM modem to monitor transformer health. A system such as this will ensure smooth operations and prevent transformer failures. To enhance transformer reliability and prevent losses, GSM technology will be used to monitor transformer health in real-time and provide reliable services to customers.

Index Terms: IoT, GSM, Transformer, Monitoring, Sensors;

I. INTRODUCTION

Transformers may last a very long time if they are operated safely. If they are overwhelmed, their lifespan is drastically diminished. Transformer failure is typically caused by overloading and inadequate cooling. All of these things can shorten a transformer's lifespan. The primary issue with Transformer safety involves safeguarding them from both internal and external defects [1]. Temperature increases in the transformer fluid and windings result from overloading the transformer. Insulation will weaken if the transformer's winding temperature rises over the transformer limit. In addition to internal fault prevention, the transformer protection scheme also needs protection from overload and failures in the transformer.

One of the most significant emerging technologies, the remote monitoring system is utilized in several industrial applications. The suggested system is a compact design and development of single-phase client services. Additionally, switchgear, lines, cables, and generators can be monitored for condition, as well as transformers. To narrow down the scope of this thesis, the focus will be exclusively on power transformers, since they are comprehensive power components with many subparts and aging mechanisms. This thesis cannot cover all types of components, and to achieve this, this thesis will focus exclusively on power transformers [2]. Finally, condition monitoring is a key component of a long-term electrical network planning strategy known as the "smart grid". Intelligent grids are fully automated power systems that develop greater cost efficiency and reliability through the integration of information technology and communication technologies.

A) Condition Monitoring System Provider

Providing a monitoring system is the first link in the chain. A transformer condition monitoring system must be designed and produced by them. A condition monitoring product can be one of the specialties of these companies, which are often focused on automation technologies. Primary equipment manufacturers are typically well-connected to automation companies. This group can also include manufacturers of measurement sensors.

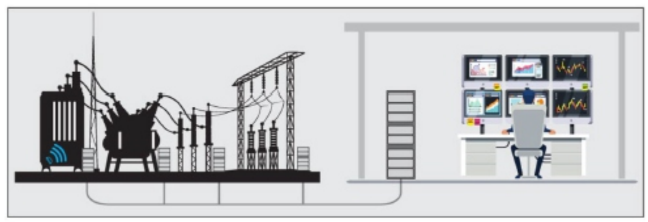


Fig. 1 Transformer condition monitoring in substation graphics [1].

B) Structure and Expectations

According to the research hypothesis, equipment that is already available on the market can be used to monitor power transformer conditions. In condition monitoring systems, generator step-ups and step-down transformers are monitored, so they work with power plants, distribution utilities, and substations. Parameters and evolving fault detection should come out of the system. At this point, the system doesn't need diagnostics or prognostic.

C) Problem Statement

Transmission lines, distribution lines, and generators are all connected to consumers through power transformers at the voltage levels appropriate for their use. Transformers form an electrical link between voltage levels in a power system, and they are also the most expensive parts of the system. The prime task of power system engineers is to focus on their performance and contingencies. Transformers are, however, subject to faults, which may result in their failure, just like all other electrical devices. The existing system is either too expensive or too complex for utilities to buy or operate since it is easier than designing your system. Most failures occur in distribution transformers because of the use of the load and this can be prevented using a simple and economical monitoring system.

D) Research Objectives

The objectives of this paper are:

- Transformers must be equipped with an intelligent monitoring system capable of detecting faults and notified operators when they are likely to occur.
- Utilizing Transformer Monitoring sensors to detect incipient failures and determine remedies for handling such problems or faults.
- Under different operating conditions of load, the operator should be notified of any possible fault.
- We aim to provide the manufacturing industry and electric utility companies with early fault prediction and health monitoring at an affordable cost.
- Describe how condition monitoring is used in asset management.
- An explanation of how transformers age and fail.

II. LITERATURE REVIEW

Lars Ivar Condition Monitoring of Power Transformers in Digital Substations (2020). To determine if condition motoring systems can be applied to digital substations in transmission networks, a brief product survey was conducted on condition monitoring substations. Condition monitoring in digital substations is compared with time-based activities conventionally used in the analysis to analyze the benefits and drawbacks. It is evident that one monitoring system cannot be used on all transformers due to the different utilities, operational conditions, and transformer types. Over the lifetime of a transformer, the type and need for monitoring will likely faults in transformers before they cause irreparable damage by applying monitoring systems to them. The most cost-effective solution may not be condition monitoring systems, since they are a cost-added alternative [1]

Ateeq Rehman Load Sharing of Transformers for Intelligent Electric Power Management (2019). In this project, first, a methodology of transformer oil and winding insulation is implemented and a monitoring transformer insulation model is developed in MATLAB Simulink. The transformer insulation health is accurately estimated using the time-frequency spectrogram and FFT analysis. In the second phase, a PMU-based real-time monitoring PMU-based is presented to predict the transformer life accurately depending upon the width of SNR in the output signal of the transformer/ The current, voltage, phase angle, and frequency of a two-phase (alpha, beta) vector base transformer with 20/26 MVA, 132/11 KV are measured using PMU after being modeled with Matlab Simulink. With a 50 Hz system, PMUs can measure these parameters very quickly with a sampling rate of up to 50 samples per second. An accurate measurement of the signal-to-noise ratio (SNR) of the output signal is obtained by modeling a signal-to-noise remodeling. The existence of some inter-turn faults, degraded insulation, and hot spots within a transformer can result in harmonics and unbalanced voltage, current, frequency, and phase angle within the system. The transformer's impact is assessed using Matlab Simulink by applying different unbalanced conditions and harmonics. Based on the overall results, it can be concluded that the system is experiencing some noise and stress. [3]

Abdul-Rahman AI-Ali, Abdul Khaliq & Muhammad Arshad (2004) proposed an embedded mobile system that was developed and implemented to record key indicators of a distribution transformer, including load current, transformer oil, and ambient temperature. With the help of a GSM network, the designed system can record and send abnormal operating parameters information about the distribution transformer to a mobile device. [4]

Sachin Kumar B S and Dr. Nagesh Prabhu (2016) propose to develop proposes former remote monitoring system that is compact and develops a remote monitoring method. The operating point of three-phase transformers can be three-phase remotely using Arduino microcontrollers and Zigbee-based wireless devices. A Zigbee-based microcontroller called Arduino is used to monitor the transformer's 3-phase current, voltage, temperature, phase, and power. An LCD makes the system user-friendly by displaying the processed parameters. In this system, three-phase parameters are on a three-phase single microcontroller. [5]

D S Suresh, Pratibha T, Kouser Taj (2012) They explained what insulating oil does to a transformer, and how it can increase its lifespan. As part of the proposed work, sensors for sensing parameters of oil like moisture, temperature, and pressure will be built into transformers for condition monitoring. A wireless GSM network is used to transmit information about transformers monitored by a PLC system. [6]

Vishwanath R, Akshatha V Shetty, Poonam, Shamilli, M Thanuja (2015) have proposed sending a message to the electricity board, they used a temperature sensor, pic microcontroller, LCD, and GSM board. GSM modems can be used to monitor temperatures, voltages, and currents of three-phase transmission lines to detect multiple faults. Through the use of GSM networks, this paper develops a system for monitoring transmission line faults. [7]

Satya Kumar Behera, Ravi Masand, and Dr. S. P. Shukla (2014) have proposed a PLC system that monitors the transformer conditions such as load currents, voltages, and temperature by implementing automatic control circuits. In this system, faults inside and outside of a transformer are monitored using a PLC. Distribution transformer voltage, current, and temperature are monitored and controlled by a PLC system. Transformer parameters are continuously monitored by the PLC system during operation. [8]

III. METHODOLOGY

The project comprises of construction and working of a bridge diode rectifier, current sensor, voltage sensor, capacitors, LED, transformer, Arduino, LCD Display, and Wi-Fi Module. The sensors have limitations so we step down the values of current and voltages to a level safe for us and the sensors. The main structure of the project is given in fig. 2. The transformer is supplied with 220 Volt. So, this transformer can be treated as a power transformer or a distribution transformer whose condition or parameters are to be monitored. So, then using different sensors, values of different parameters are taken like the voltage, current, temperature, Oil level, and Oil Humidity (parameters that are being monitored in this project). These parameters are then rectified through a bridge diode rectifier so that they can be controlled, monitored, and used for other purposes.

We have used two different modes through which parameters can be observed. One is LCD which will directly show us the values and condition of the transformer and other sources can be Desktop or Mobile applications. The Wi-Fi Module 8266 IC can be used to send data through the wireless mode of communication.

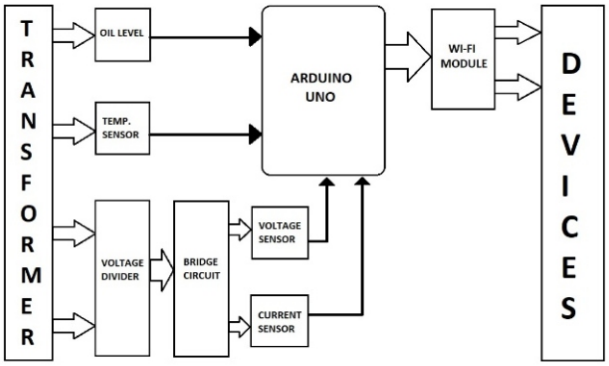


Fig. 2 Basic Layout of Circuit

IV. HARDWARE IMPLEMENTATION

A. *Arduino*

Atmega328P is the basis for the Arduino Uno microcontroller board. A 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header, and a reset button are all on board. It contains 14 digital inputs/outputs (out of which 6 can be used as PWM outputs), 6 analog inputs, 6 analog outputs, a PWM output, and a USB connection. With the kit, you can easily get started with a microcontroller connected to a computer via USB. A few dollars can replace the chip on your Uno, so you can start over if you mess up.

B. *Transformer*

This transformer has 230V primary winding and center-tapped secondary winding and can be mounted on a chassis. It is a 5Amp general-purpose mains transformer. A flying-colored insulated connecting lead is attached to the transformer. As a step-down transformer, it reduces AC voltages from 230 volts to 12 volts.

C. *8266 Wi-Fi Module*

A self-contained SOC with an embedded TCP/IP protocol stack, the ESP8266 Wi-Fi Module lets any microcontroller connect to your Wi-Fi network. By hosting or offloading Wi-Fi network applications, the ESP8266 is capable of supporting both hosting and offloading. Just connecting these ESP8266 modules to your Arduino device will give you almost as much Wi-Fi functionality as a Wi-Fi Shield. There is a growing community developing around the ESP8266 module, which is an extremely cost-effective board.

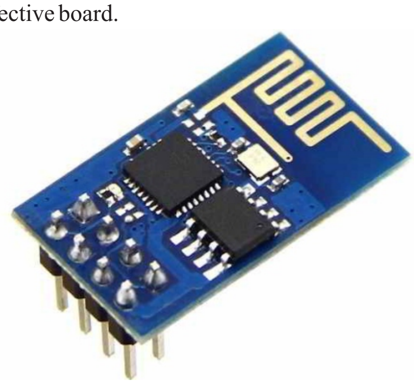


Fig. 3 ESP8266 Wi-Fi Module [9].

Fig. 4 A Typical Current Voltage Sensor [9].

D. *Current and Voltage Sensor*

There is an integrated low-resistance current conductor in the ACS712 that allows for low-resistance current measurement. This linear sensor is hall effect-based and has 2.1kVRMS voltage isolation. Technically, it's a current sensor that measures the current in a conductorbased on the current applied to it. Monitoring, calculating, and determining voltage supply are done with a voltage sensor. AC or DC voltage levels can be determined by this sensor. Sensor inputs can be voltages, while outputs can be switches, analog voltage signals, current signals.

E. *Oil Level Sensor*

An HC-SR04 is only limited to four pins: the power pin (VCC), the trigger pin (Trig), the receive pin (Echo), and the ground pin (GND). This sensor can be used for a variety of range-finding applications as we are using it here to measure oil levels.

F. *Temperature and Humidity Sensor*

A digital temperature and humidity sensor, the DHT22 is a simple, low-cost device. An input pin spits out a digital signal based on humidity and temperature readings from a capacitive humidity sensor and a thermistor. Taking data requires careful timing, but it's fairly simple to use. Using the library, you might get older sensor readings if you use this sensor for the first time after it's been used for two seconds.

V. PROJECT DESIGN

Here is the circuit simulation of the monitoring of the transformer health system with all essential components. Fig. 9 is the running simulation of Monitoring of the Transformer System where LCD displays all the sensor's responses with properly working. The circuit below has been designed using proteus.

Fig. 5 A HC-SR04 Ultra-Sonic Sensor for Oil Level [9].

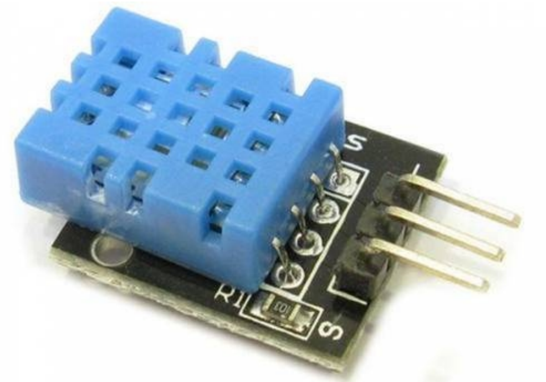


Fig. 6 A DHT22 Temperature and Humidity Sensor [10].

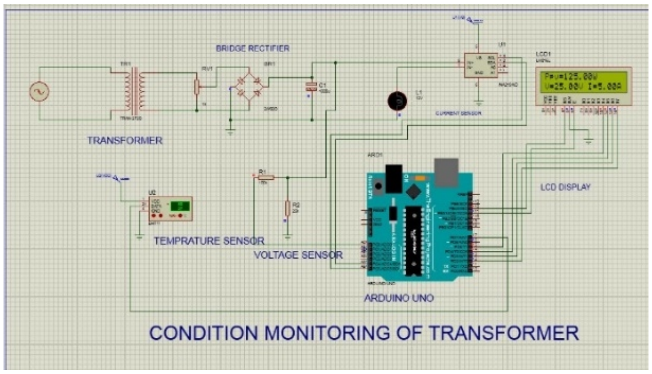


Fig. 7 Circuit Design Using Proteus

Here is the circuit simulation of the monitoring of the transformer health system with all essential components. Fig. 7 is the running simulation of Monitoring of the Transformer System where LCD displays all the sensor's responses with properly working. The circuit below has been designed using proteus.

V. RESULTS

The final assembly of the project is given below with each component installed.The project output is given the fig. 9 which is the face of LCD where we are observing different values such as voltage, current, power, temperature, humidity, and oil level.

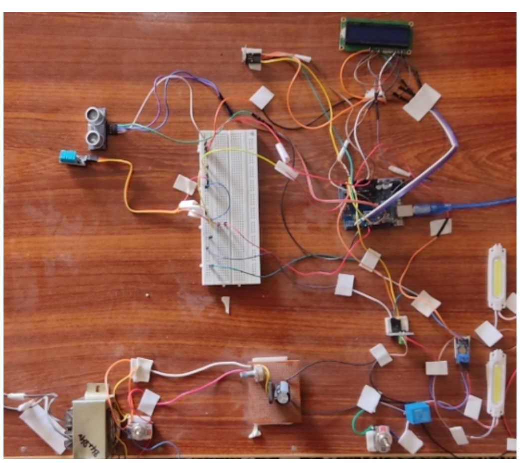


Fig. 8 Complete Hardware Module

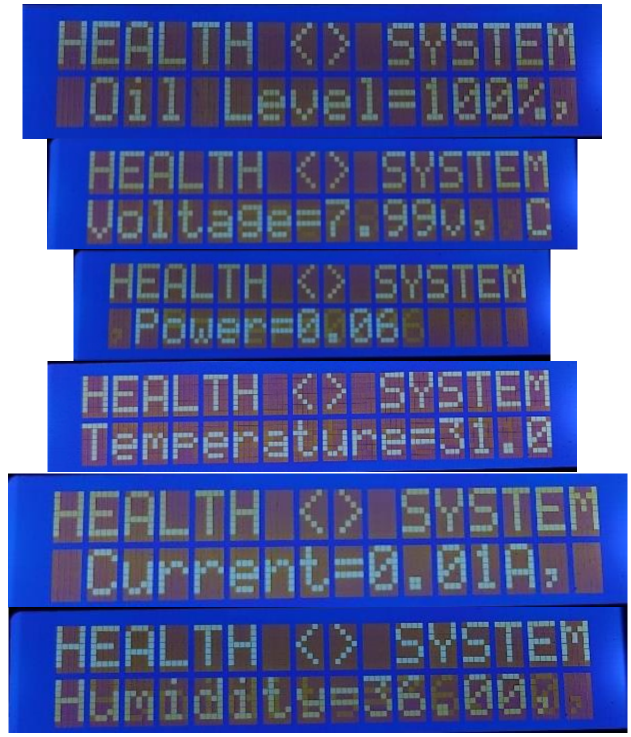
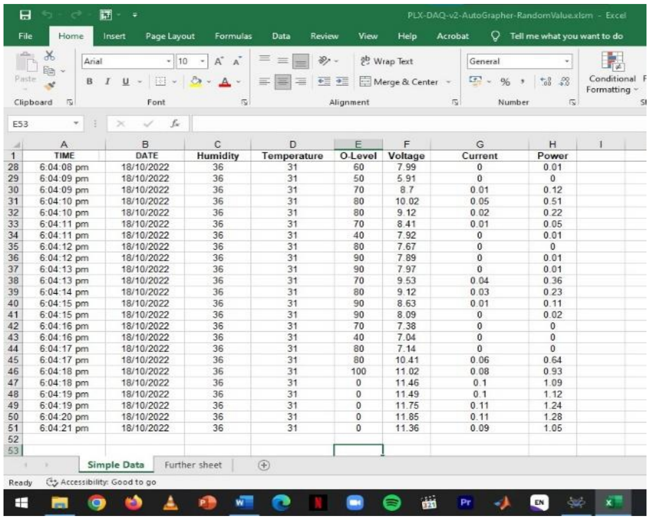


Fig. 9 Results obtained from Hardware

As shown in Fig. 10, Blynk offers mobile apps for monitoring parameters such as temperature, oil level, currents, humidity, and power. The Wi-Fi module needs to be connected to the Blynk server for this to work

Fig.10 Result image from mobile phone



	TIME	DATE	Humidity	Temperature	O-Level	Voltage	Current	Power
28	6:04:08 pm	18/10/2022	36	31	60	7.99	0	0.01
29	6:04:09 pm	18/10/2022	36	31	50	5.91	0	0
30	6:04:09 pm	18/10/2022	36	31	70	8.7	0.01	0.12
31	6:04:10 pm	18/10/2022	36	31	80	10.02	0.05	0.51
32	6:04:10 pm	18/10/2022	36	31	80	9.12	0.02	0.22
33	6:04:11 pm	18/10/2022	36	31	70	8.41	0.01	0.05
34	6:04:11 pm	18/10/2022	36	31	40	7.92	0	0.01
35	6:04:12 pm	18/10/2022	36	31	80	7.67	0	0
36	6:04:12 pm	18/10/2022	36	31	90	7.89	0	0.01
37	6:04:13 pm	18/10/2022	36	31	90	7.97	0	0.01
38	6:04:13 pm	18/10/2022	36	31	70	9.53	0.04	0.36
39	6:04:14 pm	18/10/2022	36	31	80	9.12	0.03	0.23
40	6:04:15 pm	18/10/2022	36	31	90	8.63	0.01	0.11
41	6:04:15 pm	18/10/2022	36	31	90	8.09	0	0.02
42	6:04:16 pm	18/10/2022	36	31	70	7.38	0	0
43	6:04:16 pm	18/10/2022	36	31	40	7.04	0	0
44	6:04:17 pm	18/10/2022	36	31	80	7.14	0	0
45	6:04:17 pm	18/10/2022	36	31	80	10.41	0.06	0.64
46	6:04:18 pm	18/10/2022	36	31	100	11.02	0.08	0.93
47	6:04:18 pm	18/10/2022	36	31	0	11.46	0.1	1.09
48	6:04:19 pm	18/10/2022	36	31	0	11.49	0.1	1.12
49	6:04:19 pm	18/10/2022	36	31	0	11.75	0.11	1.24
50	6:04:20 pm	18/10/2022	36	31	0	11.85	0.11	1.28
51	6:04:21 pm	18/10/2022	36	31	0	11.36	0.09	1.05

Fig. 11 Values of quantities generated in the form Excel sheet

Fig. 11 shows us the results obtained from the excel sheet. In modern power systems, we need to continuously monitor the condition of certain equipment such as the equipment of this thesis. The project is integrated with excel through PLS-DAQ software which is an open-source application. All the values are being continuously monitored and an excel is being generated. Moreover, the excel report clearly shows the condition and data of certain quantities of the transformer against date and time giving us a completely automated system. If a certain fault or abnormality occurs, we would know exactly at which moment that certain fault occurred.

VI. CONCLUSION

This paper is aimed to provide a broad understanding of the workings of online continuous condition monitoring technologies. In terms of maintenance and reinvestment, it is intended to create a guide that can be useful to asset managers. It has been shown that utilities can use the monitoring facilities and methods for designing systems to build their own systems "in-house". Various utilities, in-house conditions, and power sources will have different effects. A single monitoring system cannot meet all monitoring needs due to the transformer's design. Transform the transformer changes in monitoring changed their lifetime. Detecting faults on transformers with monitoring systems can prevent irreparable damage before it occurs. Despite this, condition monitoring systems are not always the most cost-effective option as they are a cost-adding alternative.

Based on the discussion and conclusion, some considerations for further work and evaluation comprise the following:

- Other components of the power system can also be monitored for condition. Due to their many parameters, subparts, and monitoring facilities, transformers were used in this paper. Others may include switchgear banks, power cables, capacitor banks, and electrical machines.
- To Transfer Data over large distances, new protocols and methods should be put into practice.
- To test reliability and cyber security measures for transformers using substation architecture, a condition monitoring testing facility can be created.

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