

Design and Implementation Smart Transformer based on IoT

Walid K A Hasan
Electrical and Electronics Engineering
Department
AlJabal AlGharbi University,
Ghiryan
Waleed82ly@yahoo.com

Abobaker Alraddad
Electrical and Electronics Engineering
Department
Higher Institute of Technology
Ghiryan
Alrdad@yahoo.com

Abdulfatah Ashour
Electrical & Electronic Engineering
Department
Higher Institute of Technology,
Ghiryan
fathialrabty@gamil.com

Yachao Ran
School of Engineering
Newcastle University
Newcastle Upon Tyne, UK
y.ran@newcastle.ac.uk

Mohamed A Alkelsh
Electrical & Electronic Engineering
Department
Gharayn University,
M.alkelsh@gmail.com

Reyadh A M Ajele
Electrical & Electronic Engineering
Department
Higher Institute of Technology,
Ghiryan
Riyadh_egeli@yahoo.com

Abstract—Power transformers, which perform the function of transforming the voltage levels, are one of the most important electrical equipments that are used in power transmission systems. Hence, it is mandatory to perform power transformer maintenance; as they are normally scattered geographically, it is impractical to do periodical monitoring due to insufficient manpower. As the reason above, transformer failure may occur which causes the transformer from network unexpectedly power shutdown. To overcome this shutdown from transformer failure of the adapter, a system for transformer monitoring and self-protection was proposed in case the maintenance is delayed. In this paper, the temperature and humidity within the transformer were monitored, in addition to monitoring the rate of loading on the transformer. By using the internet of things (IoT), a self-protection system is designed and implemented for the transformer. Where, if the transformer is not serviced quickly, the transformer will separate loads of low-importance (workshops, Homes,...) and it will keep the loads of high importance (hospitals,...) .and if the transformer is unable to feed the loads of high importance, in this case the transformer will separates all loads and stay in no-load status where the transformer monitor its parameters by itself, if all parameters of the transfoemer return to the normal level, the transformer automatically returns the loads in order of priority. All these components have been grouped and combined into one device. In addition the device is powered using an AC-DC adapter by an external power source

Keywords: *IoT ; GSM; Power Transformer; distribution transformer ; monitoring system ; humidity; temperature.*

I. INTRODUCTION

In today's world, the power system network of a smart grid holds the prime importance because of the high demand of quality power supply. It is usually done by deploying multiple approaches for monitoring, protecting and controlling mechanisms. In distribution networks, the distribution of transformer is an essential part. In the point of view of Libyan, the power system network can be monitored by such systems, which can be controlled in a certain degree. The average life of

transformers is 20-25 years. [1]. The transformers are mainly installed when their operational life is about to end. The monitoring methods currently being used are related with electrical parameters and those parameters does not give any idea about the condition of the distribution transformer internally. For such an important asset in power system, periodical maintenance is not sufficient. An online monitoring system is required, which base on the conditions to maintain the transformers. The condition of the equipment will be monitored remotely, in the mean time a maintain and control schedule can be arranged in real time. A doctor analyses different symptoms of a disease by understanding it before suggesting a cure. In a similar way, before making a proper decision, condition monitoring techniques use different parameters, both internal and external that are linked to a transformer, to predict its status of operation. Based on the severness which is the main feature in asset management, the decision can be used to schedule maintenance or removal and replacement. But existing monitoring device systems used for monitoring distribution transformer has some insufficiencies. Some are mentioned below.[2],[3].

The system used for detection is very inconsistent. The performance of a system depends on multiple factors such as unstability of a device, jamming capability of a device, result of accuracy in data when data is measured is low or there is no affect on another system.

The measurement system for a transformer only measures one parameter of a transformer such as current, voltage, power and phase. There are ways which detect more than one parameters, but the speed of testing is not so fast and it takes more time and operation parameters are long to handle with such speed.

Three-phase equilibrium of distribution transformers cannot be judged because monitoring centers will receive the detection data late.

The state of operation or guard can be monitored against power steal by the monitoring system, and the system is unable to monitor data of transformers related to users to reduce the costs.[1],[3].

For sending data, power carrier communication is used by many monitoring systems, but there are some disadvantages in using power carrier communication: serious frequency interference, when the distance increases the signal attenuation occurs, and large electrical noise would occur if load changes. Then for sending real-time data, if carrier communication is used, consistent good results are not guaranteed. Based on the requirements mentioned above, it is an increasing demanding need for a real time distribution transformer monitoring system. A system which detects all operating parameter operations and then send data to the monitoring center in real time. In result, key operational parameters are monitored to provide functional data for the life of transformers which helps to use the transformers in an optimal way and the asset which is in operation stays for a long time. It will also help to pick out problems before a failure, and by doing so cost can be saved and will achieve more consistency. It will be an attractive option due to extensive use of internet and wi-fi devices for sending data as well as for other network applications.[3],[4]. The rest of the paper will be organized as follow: : Section II presents some previous studies in smart transformer. Section III explains the proposed system with its tools. In section V the proposed system setup and implementation will be introduced. Sections IV the results and discussion of the proposed system will be explained. Finally, a conclusion and future work are given in Section VII.

II. LITERATURE SURVEY

Autors in [5] proposed a wireless transformer monitoring parameters. The most important purpose of this system is monitoring and controlling of transformer through RF module. By using a temperature sensor, microcontroller and RF transmission which is wireless communication, both monitoring and controlling can be done. The transformer has three parameters which are monitored i.e. voltage, current and temperature. The monitored data is then send to a remote location. The transmission between RF and client is done via controller.[5]

Sujatha et al. [6] suggested a GSM technique. This technique can be apply successfully for special protection systems. These systems are developed earlier and are based on communication. The proposed GSM technique can increase system's reliability during network interruptions. The GSM technique is independent of the distance parameter and increases the speed of communication. To meet the reliability requirement of the network, an authenticated hardware must be designed. The data acquisition from an electrical sensing system is done by an embedded hardware. The system sends data from one network to another and measures the change in parameters of transmission so that the entire process of transmission and distribution can be fully protected. GSM supports bi-directional communication as a message. The interpreter is used among many tools and systems is visually presented with basic software.[6]

Autors in [7] proposed a monitor and control system combined with the internet of things for distribution transformers. The proposed system sends SMS for further processing to a central database through the GSM modem. The system uses the combination of GSM modem, chip micro controller and different sensors to make an on-line monitoring system. The installation of the system will be at the site of distribution transformer and the parameters defined above are recorded by the analog to digital converter (ADC) in the embedded system.. The processing and recording of the obtained parameters is done in the system memory. In case of any deviation or if any unforeseen circumstances occur, the mobile phones will receive the SMS messages which has complete details about the deviation occurred according to the instructions that are defined in the micro controller.[7]

- Anirudh et el [8] suggested an advanced remote monitoring system. This system is proposed for distribution transformers. These transformers uses GSM communication network so the investment and operation cost is low. The installation and use of this system is easy too. To analyze the voltage unbalance condition, a novel software (DTMAS) has been introduced which is used for three different types of distribution transformers.[8]
- Bhakare Govind et al. [9] proposed a mobile embedded system. This system is used to monitor and record key operation indicators i.e. load currents, transformer oil and ambient temperatures of a distribution transformer. The online monitoring system combine GSM modem, an independent single chip microcontroller and sensor packages. the installation is complete at the site of the distribution transformers and the 8-channel ADC records the defined parameters mentioned above. The processing and recording of the parameters is done in the system memory. If any anomaly occurs, the mobile phones will receive the SMS by the system with complete details about the abnormality according to the policies embedded to the system EEPROM. The system also sends SMS to a central database for processing it further through a GSM modem. This mobile system will be helpful to use transformers in an optimal way and also problems will be identify earlier before the occurance of any failure.[9].
- Autors in [10] offered a past maintenance of transformers. This was built on a pre-determined schedule. As the communication technology is improving day by day, false transformer information can be received by the respective authorities remotely via GSM technology. This will help to solve the problem before converting fault in to a fatal condition. Depending upon fault analysis, transformer health monitoring kit based on a prototype model of micro-controller is developed in laboratory. Results are being updated on regular basis by using digital controller analysis. If any abnormality occurs, information is sent to the operators via GSM technology for possible remedial action.[10]

III. SYSTEM ARCHITECTURE

As the world is emerging so fast, for each transformer, its monitoring and taking instant steps when any fault occurs is the first and foremost challenge. To keep a transformer in a better state, various of factors are required to be measured and monitored. But doing it manually, by deploying a person at each sub-station is costly and difficult to work out. In addition, it may lead to human error during measurements. This paper proposed a real time IoT based solution to the problems mentioned above. The system uses sensors to collect the main transformer's factors and in the mean time the monitoring is done remotely using web based wireless applications.

A. Objective of the Problem

- Self-protection in the case of overload on the transformer and the separation of the full and inform the maintenance teams.
- No wires are required in the proposed system. As a result avoiding power or data loss
- Detect of the faults in real time base on current, voltage and temperature.
- Monitoring multiple transformers remotely.
- The use of WiFi achieves more accuracy and fast response in fault monitoring.
- Increase system reliability and stability by the monitoring system.
- The system prevents faults and losses of the power supply which significantly benefits utility consumers
- Overcurrent, overtemperature are prevented using this technique.

B. Proposed System Architecture

Normally the transformer failures occur due to the over voltage fluctuations and over current fluctuations, overheating and spark, etc. We can develop systems to reduce the faults respectively. The parameters of the transformer like voltage fluctuations, current fluctuations, temperature, oil chamber moisture and spark are monitored remotely through NodeMcu. The sensors sense the change in current levels, temperature, oil chamber moisture and then forward the information of the transformers using WiFi module. This data can be accessed remotely by an android application via a thingspeak.com email and display on it respectively. The maintenance of distribution transformers can be achieved by implement the system proposed by this paper. In addition, NodeMcu checks the oil chamber moisture, current, voltage, temperature, status of the transformer. Alert pin of the NodeMcu is activated, and if the load current is over transformer capacity, the buzzer will generate beep sound and optical alert with different colors (red and green). Finally, the NodeMcu checks the status of the transformer in the case of overloading. If an overload occurs, the NodeMcu disconnects some of these loads according to a self-defined strategy by relays. The proposed system architecture is depicted in the Fig. 1.

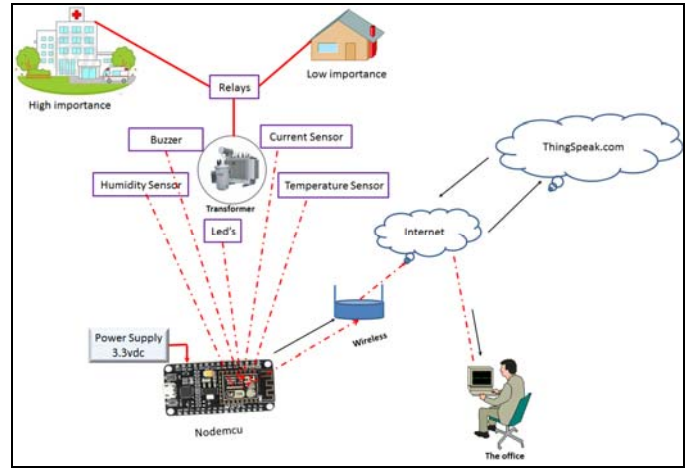


Fig. 1. Proposed system architecture

C. Basic Block Diagram of System

The Fig. 2 block diagram represents the monitoring device mounted near the transformer. The components in the block diagram monitor various parameters associated with the transformer. Fig. 3 shows the circuit diagram of the proposed system. Fig. 4 shows the circuit diagram of the proposed system by using fritzing program.

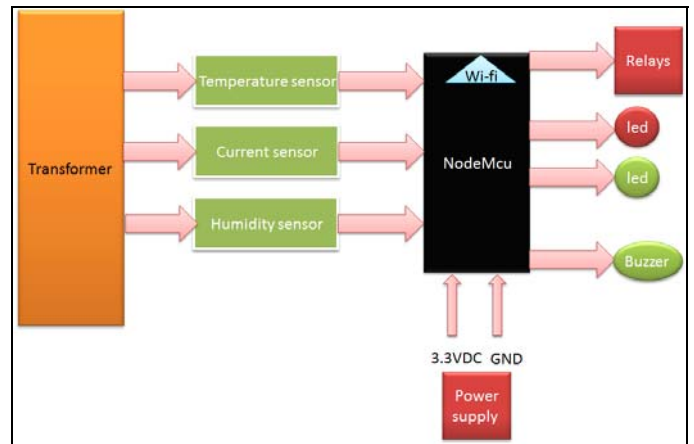


Fig. 2. Block diagram for monitoring transformer

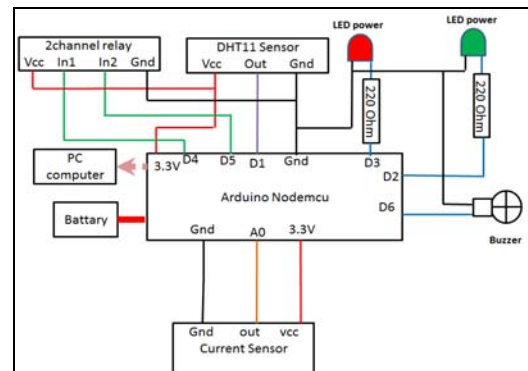


Fig. 3. Circuit diagram of proposed system

D. Hardware Requirements

1. Nodemcu : NodeMcu is an open source IoT platform. It has a board nodemcu, which is a WiFi development board of 24GHz. It depends on ESP-12E. It follows a programming language and technology of LUA. Nodemcu is considered as a combined unit and on the board, all resources are available. With the projects that are based on arduino or the projects using board for development which require available input/output pins, NodeMcu is very easy to supplement as shown in Fig.4 below.

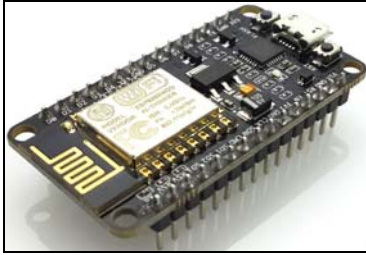


Fig. 4. The nodemcu chip

Main Features:

- Tools such as node.js which are modern development tools achieve the best results immediately by taking advantage of NodeMcu.
- The foundation of Nodemcu is mature ESP8266 technology. There are support resources available online.
- NodeMcu board has ESP-12E serial WiFi. This board is combined with various of resources i.e GPIO, PWM, ADC, I2C and 1-WIRE.
- NodeMcu has CP2102 USB to TTL serial circuits that are reliable industrially and these circuits support all platforms.[11],[12]

2.Current Sensor: In the proposed system, the current is measured by using sensor ACS712, as showed in Fig.5. The sensor provides accurate current measurements in terms of both AC and DC signal. Overall power consumption of the system is thus monitored. The sensor produces output voltage proportional to sensed current, based on the Hall Effect principle. In ACS712 sensor, 5V of supply is connect to Vcc and negative 0V is connected to GND. Once powered, Vout produces output represents the current going through the sensing pads. A $(V_{cc}/2)$ will be produced if the load is in OFF state. ACS712 is able to provide bilateral current measurement, i.e. voltage bigger than 2.5V ($V_{cc}/2$) indicates one direction, otherwise indicates the current in another direction.

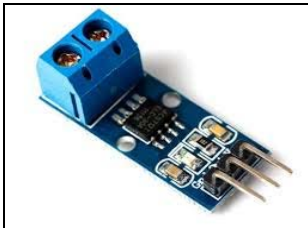


Fig. 5. ACS712 hall effect current sensor

3. Temperature and Humidity sensor: In this project the DHT11 is used to measure the temperature, humidity and it is shown in Fig. 6. The DHT11 temperature range is from 0 to 50 degrees Celsius with +2 degrees accuracy. The humidity range is from 20 to 80% with 5% accuracy. For the sampling rate, the DHT11 is 1Hz or one reading every second, and the DHT11 has a smaller body size. The operating voltage of both sensors is from 3 to 5 volts, while the max current used when measuring is 2.5 mA.[11],[12].

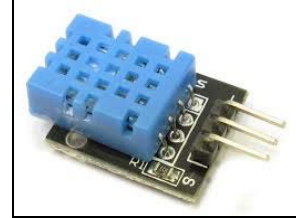


Fig. 6. DHT11 temperature and humidity sensor

4.Relay: The relay is an electromagnetic device. It is used to separate two circuits electrically and connect them magnetically. Relays are very useful and makes it possible that one circuit can switch the other while both are not linked to each other as shown in Fig.4. Relays are used mostly to combine an electronic circuit to an electrical circuit so that the electric circuit works at very high voltage. There are three contactors in basic relay: normally open (NO), normally close (NC) and common (COM). When there is no input state, the COM is connected to NC. When the operating voltage is applied to relay, the relay coil gets charged and energized and COM changes to NO contact. A relay runs by an electric current which is small and can turn on or off a much larger electric current. The core of a relay is an electromagnet. And it is shown in Fig. 7.[12],[13].



Fig. 7. The relay devices

5.LED's: The LED is a light source and light is created by using semiconductors and electroluminescence. Light emitting diodes are of two kinds: LED and OLED. The difference between LED and EL lamp is that a small crystal of semiconductor having reflectors and some other parts are used so that the light brights and focus point will be a single point. The OLED and EL lamp have very similar designs, the flat sandwich materials. However, at the layer that emits light, the LED and EL lamps use organic (carbon) molecules.And Fig. 8 shows the LED..[11,14].



Fig. 8. The LED light

6. Buzzer: A buzzer or beeper is an audio signalling device. It is either mechanical, eletromechanical or piezoelectric. Buzzers and beepers can usually be found in alarm devices and timers, or to be used as a confirmation of user input such as a mouse lick or keystroke as shown in Fig. 9 below.[11,13]



Fig. 9. The buzzer devices

7. Power supply: In this project uses a 3.3V adapter to feed the main controller (NodeMcu).[13,14].

E. Software Requirements:

1) *Nodemcu software:* The code is generated and debugged using the IDE language 2017 environment. Codes are written in a Arduino 1.8.5 software. High and Low sensitivity of the sensor, buzzing unit, LED and relay are embedded. The major component of the program is in the control unit of the micro-controller. The reason of choosing IDE is because of its speed, stability and universal availability Fig. 10 shows when the code is running.

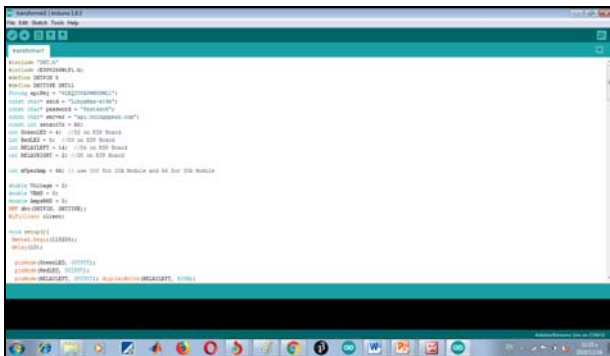


Fig. 10. Running of the code

2) *Internet of things (IoT):* The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Fig. 11 shows the main interface of thingspeak.com.[4].

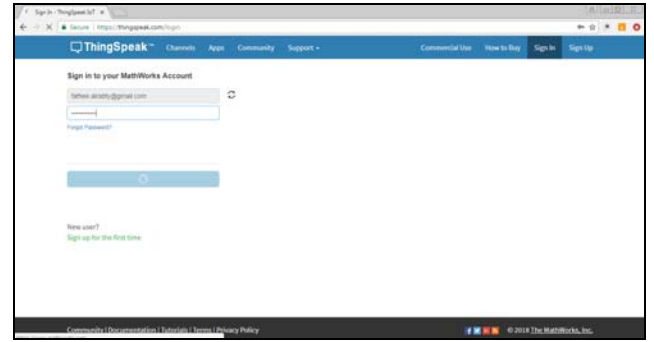


Fig. 11. The main interface of thingspeak.com.

IV. WORKING PRINCIPLE

All the sensors integrated into the transformer unit are interfaced with Node MCU to receive and process the substation parameters. The micro-controller forwards data to cluster-based data aggregation sink, which here is a cloud service as showed in Fig. 12. Next, the data is forwarded to a predefined web application and then could be access remotely. In addition, the status of each transformer is extracted and forward to the same web application along with the parameter values. In addition to this. The status of each transformer is extracted via web application and it is also notified along with parameter values.

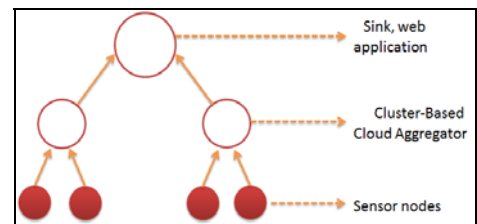


Fig. 12. Cluster-based clouddata aggregation

V. RESULTS

In this section, the reactor unitprototype of the proposed system is shown in Fig. 13, and the data displayed on web application is shown in Fig. 14.

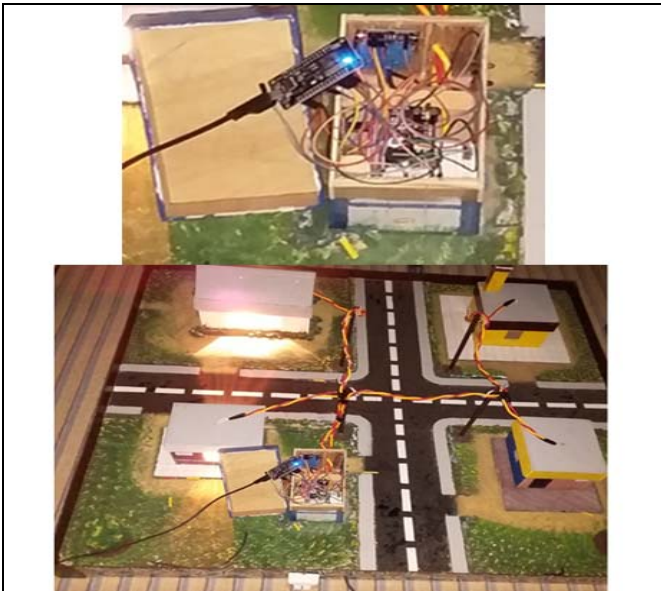


Fig. 13. The reactor unit prototype

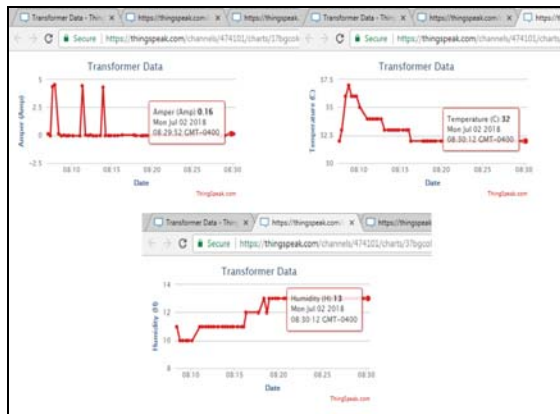


Fig. 14. Transformer status is displayed on web application

The figure above shows how to obtain the data of the transformer directly, so that any change in the control switch parameters is taken directly without delay by the operator (human) and the maintenance team is sent directly to the specified transformer. If the maintenance team is delayed, the transformer will self-protect by separating and reducing some low-priority loads gradually, and if parameters do not stabilize, the transformer it separates itself completely until the arrival of the maintenance teams.

VI. CONCLUSION AND FUTURE WORK

The paper has proposed a system which is very cost effective and replaced the error prone that would occur by manual transformer monitoring scenario. The system provides a cloud-based storage and is available through a web application where the data is accessible remotely, as well as self-control system in transformer loads. There are visual and auditory alert mechanism to notify substation status. Furthermore, the system provides a pathway to undertake necessary measures in case of emergency for the transformers. The proposed system significantly saves cost as well as improving reliability.

In future, the system can be enhanced with additional features for automation of the tasks at transformer like a GPS module can be included in this system for location status of each transformer is extracted. In addition the security of data transmission should be considered.

REFERENCES

- [1] Mir, S. H., Sahreen Ashruf, S., Bhat, Y., and Beigh, N. Review on Smart Electric Metering System Based on GSM/IOT. *Asian Journal of Electrical Sciences*, 8(1), 1-6, 2019.
- [2] Yamuna, R., Geetha, R., Gowdhamkumar, S., and Jambulingam, S. Smart Distribution Transformer Monitoring and Controlling using IoT. *International Research Journal of Multidisciplinary Technovation*, 1(4), 1-6, 2019.
- [3] Sohrawy, K., Minoli, D., Occhiogrosso, B., and Wang, W. A review of wireless and satellite-based m2m/iot services in support of smart grids. *Mobile Networks and Applications*, 23(4), 881-895, 2018.
- [4] W.Hasan, J. Agbinya, and G Y. Tian. A Survey of Energy Efficient IOT Networks in Cloud Environment. Accepted and presented in International Conferences On Cyber Security and Communication Systems, MIT Melbourne, will be published in Communications in Computer and Information Science Series (CCIS), Springer, 2018.
- [5] V. Shinge, O.Shukla, P. Panday, and M.Chaple "Wireless Transformer Parameter Monitoring System Using RF Module". *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering* Vol. 4, Issue 4, April 2016.
- [6] M. S. Sujatha., M. V. Kumar, "On-Line Monitoring and Analysis of Faults in Transmission and Distribution Lines Using GSM Technique", *Journal of Theoretical and Applied Information Technology*, ISSN: 1992- 8645, E-ISSN: 1817-3195, 30th November 2011, Vol. 33 No.2.
- [7] S.Sivaranjani, M.E., S.Lokesh, M.Vignesh, N.Vijayaragavan, and S.Goutham. "IOT Based Distribution Transformer Monitoring System". *International Journal of Current Trends in Engineering & Research (IJCTER)*.-ISSN 2455-1392 Volume 3 Issue 3, pp. 43 – 50, 2017.
- [8] Kumar, A., Raj, A., Kumar, A., Prasad, S., and Kumar, B. "Method for monitoring of distribution transformer". *Undergraduate Academic Research Journal (UARJ)*, ISSN, 2278-1129, 2012.
- [9] B. Govind A, D. Nilesh P, and S. Pawar. "GSM Based Distribution Transformer Monitoring System". *IJARIE*. Vol-3 Issue-3 2017 ISSN(O)-2395-4396, 2017.
- [10] K. Vadirajacharya, A.Kharche, H.Kulakarni, V.Landage. "Transformer Health Condition Monitoring Through GSM Technology". *IJSER journal*-ISSN 2229-5518. Volume 3 Issue 12.
- [11] Hobson, A "Instrument Transformers" *IET Journals & Magazines* Volume: 91, Issue: 20 January 2010.
- [12] Don Wilcher, "Learn Electronics with Arduino", illustrated Edition, Apress, 2012 [8] Yashavant P.Kanetkar, "Let us C", 12th Edition, BPB Publications, 2010.
- [13] Y. Gadallah, M.Tager and E. Elalamy, "A Framework for Cooperative Intranet of Things Wireless Sensor Network Applications," Eight International Workshop on Selected Topics in Mobile and Wireless Computing, The American University in Cairo, pp. 147-154, 2012.
- [14] Electrical4u. electrical4u.com. [Online] 2011. <http://www.electrical4u.com/differential-relay/>.