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IoT based smart Transformer Monitoring System with Sensor Integration and Fault Alert over Long Range Communication

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ABSTRACT

Transformers are often used in the process of transmitting and distributing energy. Their primary purpose is to reduce the main voltage. Because of this, customers are able to make use of a voltage that is lower. A system that monitors the various characteristics of distribution transformers is described in this research. This is in response to the fact that distribution transformers are more expensive in the electrical industry. An RTU, which stands for remote terminal unit, and a central unit are two distinct pieces of computer equipment. In this work, an embedded system is used to monitor and record critical operational parameters of distribution transformers. These variables include load current, voltage imbalance, temperature, and the growth or reduction in oil level. The proposed tracking system comes equipped with a single-chip microprocessor as well as sensor bundles that are capable of functioning independently. The aforementioned data is monitored by this device, which is located in close proximity to the distribution transformer. The parameter values that were received are then updated in the memory of the system when the processing has been completed. With the assistance of this technology, utilities will be able to make more efficient use of transformers and identify problems before they become more severe.

Keyword: - monitoring, Open circuit voltage, Earth Leakage current, Arduino microcontroller.

INTRODUCTION

The transformer is the most important component of the electrical grid. Because of this, it is essential to keep a close eye on it and ensure that it remains in excellent health. In the case that a transformer fails to work properly or there is an imbalance, the power system may be subject to significant interruptions. [1]

Development of a purpose-built Android application and system

As a result, in this particular circumstance, we want to build a system that is capable of continuously detecting when the transformer is imbalanced and then taking the right action. The system would also enable real-time monitoring of the transformer's attributes on computers and android devices, including voltage, current, temperature, and other parameters. Notifications would be sent out in the event that the transformer had a breakdown. Our project may be broken down into two divisions. Using the Arduino microcontroller, constructing a system that will automatically monitor and protect the transformer is the first step. Secondly, the development of a purpose-built Android application and system synchronisation with the Nodemcu (wifi module) for the purpose of real-time parameter monitoring and notification receiving.[2]

With the assistance of contemporary technology, it is feasible to make this method more efficient. It is imperative that humanity take quick action in order to protect V&I resources, since their availability is already restricted. Using the least amount of monitoring possible, the solution that has been presented helps save time. The purpose of this research is to provide a system that automates process control by using an Internet of Things (IoT) on mobile application. As a result, it is now much simpler to keep an eye on the transformer from a distance, and the need for human maintenance workers has been reduced.[3]

IOT-Based Transformer Monitoring System

The advent of the Internet of Things (IoT) in this era of hyperconnectivity has had a significant impact on the power sector, which is one of the industries that has been severely impacted the most. Due to the fact that they assist the transmission of energy from the point of production to the homes of customers, transformers are crucial components of the power system. [4] Dependability and stability of the electrical system are contingent upon the efficient operation of the components and the timely repair of those components. Transformer monitoring systems that are based on the internet of things (IoT) have emerged as a game-changing solution for the purpose of improving performance, avoiding failures, and optimising maintenance schedules.

An Internet of Things-based system for monitoring transmitters that includes the following: A system for monitoring transformers that is based on the Internet of Things (IoT) consists of a network of sensors, communication devices, analytics platforms, and visualisation tools that are all linked to one another. In order to collect, transmit, assess, and display data on the performance of the transformer, each of these components works in conjunction with the others. These are the primary components that make up a system of this kind: Sensors are: Sensors are strategically positioned on the transformer in order to detect key aspects such as temperature, oil level, pressure, humidity, gas concentration (for example, dissolved gas analysis), and electrical parameters (voltage, current, power factor). These sensors are used to detect crucial factors. More modern sensors may be equipped with extra capabilities such as vibration monitoring and partial discharge detection. These are two examples of additional capabilities. [5]

Communication and Information Sharing Network: The Internet of Things (IoT) connection protocols, which include cellular networks, LRWAN (Long Range Wide Area Network), and Me-sage Queuing Telemetry Transport, make it simple for data to be sent from sensors to the central monitoring system.[6] Processing and Data Acquisition: A centralised data acquisition system receives data transmissions from sensors at predetermined times. This is made possible by advancements in wireless communication, which have made it possible to eliminate the need for complicated wiring and to remotely monitor transformers located in different parts of the world. A preprocessing step is performed on the data in order to remove any outliers and noise. Following this step, features are retrieved and transformed onto the data.[7] The application of modern data analytics methodologies, such as machine learning algorithms, allows for the evaluation of patterns in historical data, the identification of outliers, and the anticipation of potential failures or maintenance requirements. System Based on the Web: Many transformer monitoring systems that are based on the Internet of Things make use of cloud computing infrastructure in order to store, evaluate, and interpret huge amounts of data in a scalable manner. As a result of the portability, accessibility, and real-time information that cloud services provide, stakeholders are able to monitor the state of transformers from any place as long as they have an internet connection. Reporting and visualisation: [8] Data analysis may be used to get useful insights via the use of intuitive dashboards and visualisation tools. The use of predictive maintenance recommendations, trend analysis, alert notifications, and key performance indicators (KPIs) enables operators and maintenance personnel to make well-informed decisions and effectively prioritise treatments. This is made possible via the utilisation of these tools.

Objective

1. To investigate an Internet of Things (IoT)-based smart transformer monitoring system that integrates sensors and provides long-range fault alert communication.
2. To study on IOT-Based Transformer Monitoring System

METHODOLOGY

Proposed System Model and Specification

With the use of sensors and other hardware components, the distribution transformer readings will be regulated and measured by the Arduino mega in the proposed system..

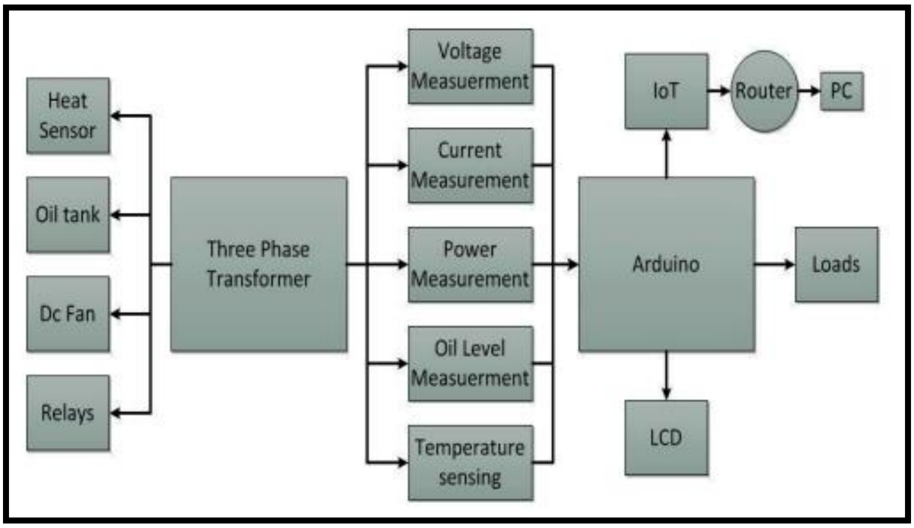

Fig.1 . System block diagram.

In order to transmit data to a server or website, the Arduino will connect all parameters to an ESP8266, which is then linked to the internet. Accessing and modifying the settings is a breeze when done online. The following is a list of the components that were used:.

Three Phase Transformer

This little transformer contains three windings for each phase, making it a three-phase transformer. Here are the parameters that were estimated for the three-phase transformer design:

- The core area, which is the product of the horizontal and vertical dimensions of the reel, is 8.75 cm^2.
- The ratio of 42 to the core area, which is 8.75 cm^2, is 4.8.
- The number of turns, denoted as N1, is 1056.
- The power, P, is 500 W (3 phase), which is equal to 288 W (single phase).
- The current, I, is 2.85 A (3 phase), which is equal to 1.6 A (single phase).
- The static power, S, is 1 kVA (3 phase), which is equal to 577 kVA (single phase).

Relay

An Internet of Things (IoT) integration concept for better distribution A 5 V DC single pole double throw (SPDT) relay is a part of the transformer monitoring and protection system. It can be used to open or stop the circuit in reaction to pulses sent to the load. In order to manage and safeguard the transformer, the relay is an essential component. Efficient and remote monitoring of the transformer performance is made possible by the suggested system, which uses an Arduino or the internet for relay control..

Fig. 2. Relay arrangements.

Electrical Wire

A 7/29 wire gauge, commonly used for ordinary wiring, contains 7 gauges and 29 strands on the input side and 7/20 strands on the output side. The 20-meter-long wires are available in both black and red colours..[9]

Arduino Mega

A simple and versatile option for creating and producing a range of electrical devices is the open-source Arduino Mega, which is based on the ATmega2560 microprocessor. A reset button, an ICSP header, a power connector, a USB connection, sixteen analogue inputs, a sixteen MHz crystal oscillator, and four hardware serial ports make up the microcontroller. It also has sixteen digital inputs and sixteen analogue outputs. An AC-to-DC adapter or battery, as well as a USB cable for connecting to a computer, are all part of the starter kit. One of the best options for building and prototyping electronics projects is the Arduino Mega, because to its open-source architecture and extensive feature set..[10]

Power Factor Circuit

In order to find the power factor, one uses a circuit that measures the current and voltage, and then uses a zero cross detector to find the phase difference between the two.

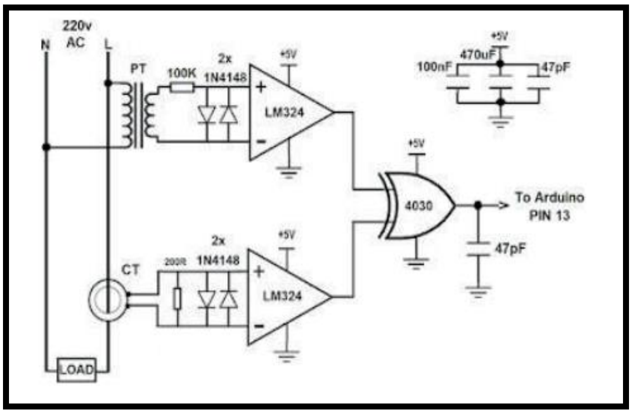

Fig. 3. Power factor circuit

Voltage Sensor

To find out if there is an over- or under-load, the ZMPT101B sensor detects the voltage. The sensor is comprised of a miniature potential transformer that reduces and rectifies the power supply voltage into DC voltages. These DC voltages are then linked to the analogue pin on the Arduino board..[11-13]

Current Sensor

A current sensor that monitors the system's RMS current and identifies overload circumstances is incorporated into the proposed system to guarantee the load and transformer's safety and integrity. In particular, the system makes use of a 5A ACS712 current sensor, which measures AC via the Hall Effect and has all the required electronics for current detection in a small module. This current sensor ensures precise current measurement and safeguards the load and transformer against any failures..

Temperature Sensor

The transformer is protected from overheating by the temperature sensor, which also keeps an eye on the humidity level..

Oil Level Sensor

To keep an eye on the oil level, an ultrasonic sensor is utilised. A little, medium, or full amount of oil is available..[14]

Oil Tank

The operation of the tank and the amount of oil within may be seen through a miniature tank. A valve on the 11-centimeter-long tank allows for the draining of the transformer's oil, which allows for varying quantities of oil..

Power Supply

The circuits in the proposed prototype can be reliably powered by a 5 V DC supply that can produce 500 mA. A voltage regulator IC 7805 limits the transformer's output to 5 volts; diodes, capacitors, and a voltage transformer make up the power supply. The suggested approach uses three independent power supplies—one for each phase—to provide a constant, rectified, and suitably shaped DC voltage output for the circuit, which is necessary due to the low current rating of the required supply..[15]

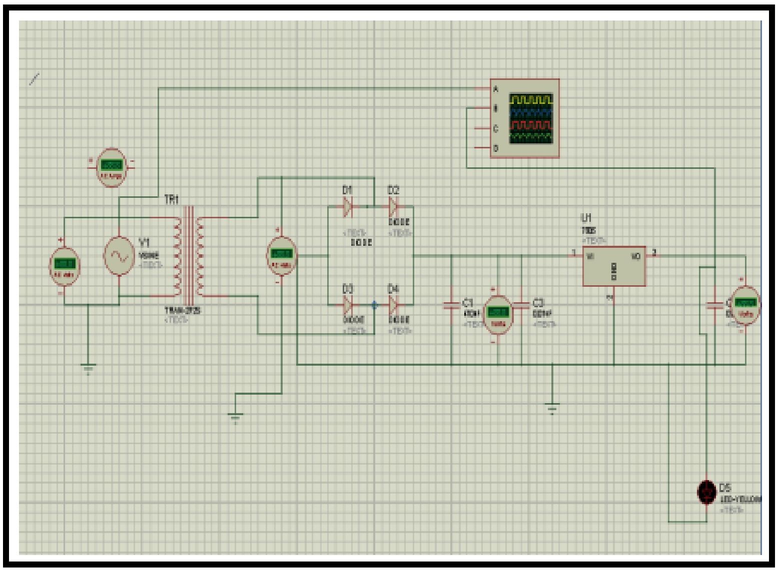

Fig. 4. Power supply circuit.

Liquid Crystal Display

Parameters, results, computations, and measured data are shown on the transformer's liquid crystal display (LCD). Twenty columns and four rows make up the dimensions of the LCD in question..

Vibration Sensor

When there is a mechanical vibration, the vibration circuit picks it up. Figure 5 shows that it features a piezo electric plate, a unique kind of vibration sensor.It takes the mechanical vibration and turns it into an electrical signal, often in the millivolt range, which is then put into a comparator to generate pulses. The controller receives this pulse.

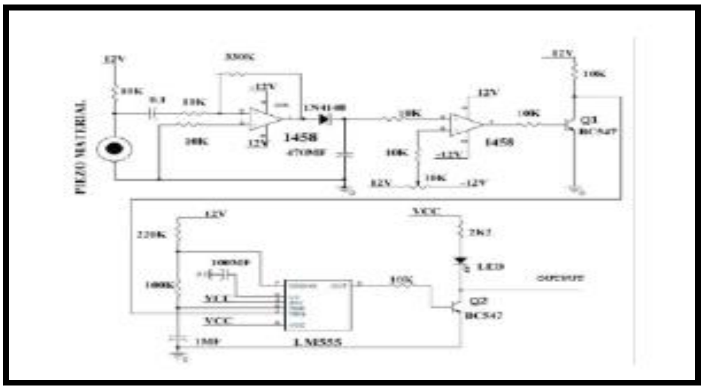

Fig.5 Vibration Sensor circuit

RESULT

Simulation Results

The several circuits utilised in the project are modelled using the Proteus program. A DHT11 sensor is used to monitor the temperature, which helps to detect cases of overheating by simultaneously measuring the humidity and the transformer's temperature. The cooling function of the transformer is shown by a little DC fan, which activates anytime the temperature rises over the typical range.[16]

Table 1 Faults And Conditions

No.	Parameter	Condition
1	Overvoltage Under voltage	> 240 V < 200 V
2	Overload	> 1.5 A
3	Over-temperature	> 35 °C
4	Oil level Empty	> 9 cm
5	Oil level Low	> 7cm & < 9 cm
6	Oil level Medium	> 4cm & < 7 cm
7	Oil level Full	< 4 cm

The power factor (PF) circuit may be modelled using three types of loads: capacitive, inductive, and resistive.
For different loads, the circuit results are computed.

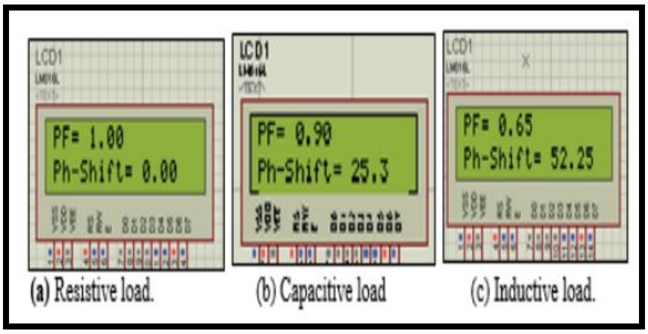

Fig. 5. The PF's performance at varying loads.

In the hardware part, the findings were confirmed to be almost the same as in the simulation, showing that everything went according to plan. Based on the assumption that a resistive load's power factor must be one, we tested the data with a bulb load and found that it behaved as predicted, confirming that we had accurately measured the power factor. We simulate the power supply that the project calls for in order to find out the precise voltage and current that it will provide. We test and replicate situations when the voltage is too high or too low.. [17]

The Internet of Things

IoT is a system which connects and talks to all devices as shown in structure of IoT . The embedded operating system has a capability to communicate with the internet or with the neighbouring devices. Internet of Things application is a basic block of IOT where all 'devices' talk to each other.

Level Measurement Using Float

The oil level in the sealed tank can be monitored using a transducer, with floats being one sort of sensor The resistance value changes in relation to the float as the water level changes; this approach operates on the idea of potential dividers.

THINGSPEAK

All of the services provided by this platform (thing speak) are designed to facilitate the construction of IoT purposes. You can design plugins, use it to collect data in real-time, and it integrates with social networks, online services, and APIs. You can also see the data visualised as charts. The "Thing Speak Channel" is the heart of any Thingspeak system.[18]

Earth leakage detection

In this circuit the earth leakage sensor is used to find the earth leakage or liquid content. Earth leakage sensor is a sensitive variable resistor. resistance value increases with respect to decrease in water particle content

DISCUSSION

IoT based online monitoring of transformer is helpful comparing to monitoring it manually and more reliable as it is impossible to measure the oil level at all times, oil temperature rise, ambient temperature rise, and load current manually. As abnormalities occur, it will automatically send data to the system in EB department, and they can take necessary action. Integrating IoT technology for improved distribution transformer monitoring and protection is a promising approach to enhance distribution transformers' reliability, efficiency, and safety and make their monitoring and protection faster than traditional methods. In this context, a prototype model has been developed, which employs the internet and Arduino to control the transformer remotely.[19-20].This sort of system is very valuable for a number of reasons, including the following:

1. **Enhanced Monitoring Capabilities**: Keeping an eye on transformers is often accomplished via the use of manual checks or periodic inspections; however, both methods may fail to detect issues with fluctuation or merging that occur in real time. The exact and continuous monitoring of characteristics like as voltage, current, oil level, and temperature is made possible by transformers that are connected with Internet of Things (IoT) capabilities. The capability to monitor in real time enables the early detection of any deviations from ideal operating conditions or anomalies, which in turn enables the prompt action to prevent failures or damage. This is advantageous since it allows for the early identification of any potential problems.

2. **Proactive Maintenance:** Internet of Things (IoT)-based transformer monitoring offers a number of advantages, one of the most important of which is the implementation of preventative maintenance processes rather than reactive ones. Analysis of the data that is produced by the transformer's embedded sensors may be performed in order to identify patterns, trends, and outliers, which enables predictive maintenance to be performed. When it comes to maintenance, the objective of predictive maintenance is to detect and resolve issues like these before they result in costly failures or downtime. It is because of this that the reliability of the transformers, their lifetime, the costs of maintenance, and the operational disturbances are all improved.

3. **Remote Accessibility and Management:** By using IoT technology, transformer systems may be remotely accessed and managed. Operators may have access to analytics insights and real-time data from any location with an internet connection via cloud-based platforms or remote monitoring tools. Because it removes the requirement for physical presence for monitoring and troubleshooting, this remote accessibility is especially useful for transformers situated in distant or inaccessible places. Because operators may respond instantly regardless of their location, remote management capabilities also provide for faster reaction times to warnings or alarms.

4. **Data-driven Decision Making:** By producing a large amount of data, transformer monitoring systems that are based on the Internet of Things (IoT) make it possible for operators and maintenance personnel to make decisions based on the provided information. The examination of trends in historical data and performance metrics may provide operators with a better understanding of a number of topics, including the potential for optimisation, the effectiveness of maintenance strategies, and the allocation of resources. A additional guarantee of adherence to industry standards and regulations is provided by the availability of comprehensive data, which reduces the requirements for reporting and audits with regard to regulatory compliance.

5. **Integration with Smart Grid Infrastructure:** Transformer monitoring solutions that are based on the Internet of Things make it easy to integrate with bigger smart grid infrastructure and energy management systems. This is a significant advantage. The electrical grid is comprised of distributed generation, renewable energy, and demand-response systems, all of which have the potential to collaborate with one another as a result of implementation of this integration. In order to meet the increased use of renewable energy sources and electric vehicles, utilities may enhance grid resilience, efficiency, and sustainability with the assistance of Internet of Things technology. This will enable utilities to better support the use of electric automobiles.

CONCLUSION

Integrating IoT technology for improved distribution transformer monitoring and protection is a promising approach to enhance distribution transformers' reliability, efficiency, and safety and make their monitoring and protection faster than traditional methods. In this context, a prototype model has been developed, which employs the internet and Arduino to control the transformer remotely. The proposed concept can also be implemented using old methods such as GSM, but the internet is the preferred choice due to its availability and lower cost. Although other protection and monitoring techniques are available, they have the limitation of reprogramming. The objective of the proposed prototype system is to simplify, enhance, and accelerate transformer control. This low-cost approach benefits electric companies and consumers in developing countries. The Proteus software simulates the proposed prototype model, verifying its authenticity using the hardware results. To ensure the safety and security of the system parameters, the system findings are displayed in multiple ways (e.g., on an LCD, in the system bar, and on the internet). Furthermore, the proposed work could be improved by incorporating power factor improvement using a capacitor bank to maintain the power factor of the supply.

REFERENCES

[1]. Sajidur Rahman, Shimanta Kumar Dey, Bikash Kumar Bhawmick, Nipu Kumar Das,"Design and implementation of realtime transformer health monitoring system using GSM technology", International Conference on Electrical, Computer and Communication Engineering (ECCE), IEEE 2017.

[2]. Rohit R. Pawar, S. B. Deosarkar ,"Health condition monitoring system for distribution transformer using Internet of Things (IoT)", International Conference on Computing Methodologies and Communication (ICCMC),IEEE 2017.

[3]. Majid Ali, Adnan Yousaf, Fuad Usman, "Designing and simulation of load control & monitoring system through Demand Side Management technique",8th International Renewable Energy Congress (IREC), IEEE 2017.

[4]. Kazi Ahmed Asif Fuad, Md. Maruf Ibne Hasan, Laila Nawsheen Manzoor, Mohammad Abdul Mannan, "Design and simulation of centralized load controlled automated power system network (CLCAPSN)", IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), IEEE 2015.

[5]. Qin Zhou, Zhengqui, "Research and implement of cost-effective remote transformer monitor system", International Conference on High Voltage Engineering and Application, IEEE 2012.

[6]. Vadirajacharya. K, Ashish Kharche, Harish Kulakarni, Vivek Landage "Transformer Health Condition Monitoring Through GSM Technology", International Journal of Scientific & Engineering Research Volume 3, Issue 12, December-2012

[7]. Anurudh kumar1, Ashish Raj2, Abhishek Kumar3, Sikandar Prasad4 & Balwant kumar.5 "Method For Monitoring Of Distribution Transformer",1,2,3,4 &5 Dr. M.G.R, Educational and Research Institute, University, Chennai600095.

[8]. Karpagam.P 4 M.Chindamani 1 , Anitha.S 2 , Dhanalakshmi.A 3," Intelligent Load Shedding for Distributed Generating System" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Volume-5,Issue10,Pages 8213-8219,2016

[9]. A. Z. Loko1, A. I. Bugaje2, A. A. Bature3 "Automatic Method of Protecting Transformer Using Microcontroller As An Alternative To The Fuse Protection Technique", International Journal of Technical Research and Applications e-ISSN: 2320-8163, Volume 3, Issue 2 (Mar-Apr 2015), PP. 23-27.

[10]. Karpe S R1, Sandeep Shelar2, Shraddha Garkad3, Shruti Lakade4 "Fault Detection and Protection of Transformer by Using Microcontroller", International Journal of Modern Trends in Engineering and Research.

[11]. R. Murugan and R. Ramasamy, "Failure analysis of power transformer for effective maintenance planning lectric utilities," Eng. Fail. Anal., vol. 55, pp. 182–192, 2015.

[12]. A. C. Nishant, "Failure Analysis of a Power Transformer Using Dissolved Gas Analysis – a Case Study," Int. J. Res. Eng. Technol., vol. 3, no. 5,pp.300–303,2014.

[13]. D. M. Mehta, P. Kundu, A. Chowdhury, and V. K. Lakhiani, "DGA diagnostics save transformers - Case studies," in 2015 International Conference on Condition Assessment Techniques in Electrical Systems, CATCON 2015 - Proceedings, 2016, pp. 116–120

[14]. M. Mostafaei and F. Haghjoo, "Flux-based turn-to-turn fault protection for power transformer", IET Gener. Transmiss. Distrib., vol. 10, no. 5, pp. 1154-1163, 2016.

[15]. C. Meyyappan and C. S. Ravichandran, "Performance Analysis of Fault-Tolerance Techniques Towards Solar Fed Cascaded MulNlevel Inverter," 2021 InternaNonal Conference on Computer CommunicaNon and InformaNcs (ICCCI), 2021, pp. 1-7, doi: 10.1109/ICCCI50826.2021.9402705.

[16]. Subramanian, G.K., Meyyappan, C," PLC based industrial trash barrel" International Journal of Innovative Technology and Exploring Engineering, Vol. no9 pp. 3422-3425

[17]. Smys, S., Abul Basar, and Haoxiang Wang. "Artificial Neural Network BasedPower Management for Smart Street Lighting Systems." Journal of ArtificialIntelligence 2, no. 01 (2020): 42-52.

[18]. Bhalaji, N. "EL DAPP–An Electrıcıty Meter Trackıng DecentralızedApplıcatıon." Journal of Electronics 2, no. 01 (2020): 49-71

[19]. D. Martin, J. Marks, T. Saha, O. Krause, G. Russell and A. Alibegovic-Memisevic, "On the development of power transformer failure models: An Australian case study," 2017 IEEE Power & Energy Society General Meeting, 2017, pp. 1-5, doi: 10.1109/PESGM.2017.8274571.

[20]. C. Antoun, "High Voltage Circuit Breaker and Power Transformer Failure Modes and Their Detection," 2018 Condition Monitoring and Diagnosis (CMD), 2018, pp. 1-6, doi: 10.1109/CMD.2018.8535655.