Design and Implementation of Low-cost Remote Monitoring of Distribution Transformer with Consumer wise Energy recording, Load control & Power theft detection using Internet of Things

K. Dwarakesh¹ and C. Jeyasekar²
¹Assistant Professor & ²PG Scholar
Department of Electrical and Electronics Engineering
Bharath Institute of Higher Education and Research, Chennai

Abstract – Distribution Transformer is one of the most important equipment in power distribution network. They have a long life of 25 to 30 years; but they got failed in large numbers, within 3 years of commissioning, due to various reasons, causing huge economic and service impact on the distribution utilities as well as the power consumers. This paper is about design and implementation of low-cost remote monitoring of distribution transformer’s key parameters like current, voltage, oil level, oil temperature and winding temperature with remote recording of consumer’s energy consumption, load shedding of non-vital consumers during overload / cold load pickup (CLP) period, Energy theft detection in the distribution network and alerting during un-balanced load conditions. The parameters are sent to the IOT cloud and concern maintenance engineer will be alerted during energy theft and for any abnormal conditions using a dedicated mobile app. If any abnormality in winding temperature or an overloading situation occurred the microcomputer which is installed in the system will remove the non-vital consumers remotely thus controlling the overload on DT and reduces the winding temperature. In addition to this it is also monitoring the load voltage, load current and power consumption of individual consumer remotely. If any deviation noticed between distribution transformer’s feeder load and total authorized connected load it will alert the maintenance engineer through a power theft message to his mobile.

Keywords – Distribution Transformer, Node-RED, Overloading, Un-balancing, Power Theft, Cold load pickup, Remote Energy Monitoring, Oil Level, Winding Temperature, Current, Voltage sensors, Smart meters, Microcomputer, Relays, Blynk and Internet of Things.

I. INTRODUCTION

The failure rate of transformers in India is in the order of 12 to 15 % as against less than 1% in developed countries. In some states, it is in the range of 25%. Major failures that occur are mainly on distribution transformer of rating 11kv/433v. IEEE standards 100/1980 and 500/1984 allows maximum annual failure rate of 3% for distribution transformers [1]. The major causes of failure on this range of transformers are Un-balanced loading, Single phasing, Over loading (prolonged over loading), Power theft by hooking, Cold load pickup (CLP) current, faulty terminations, less maintenance, faulty earth connections, usage of repaired
Among the failed transformers, it is found that 30% of the distribution transformers failed due to overloading only [3]. In a distribution system, power theft by hooking is also one of the root causes of failure of a distribution transformer [2]. In addition to that power theft increases the overall distribution losses in a distribution system. Distribution transformers have a long service life if they are operated under good and rated condition. However, their life is significantly reduced if they are overloaded, resulting unexpected failures and loss of a large number of customers thus affecting system reliability. According to IEEE standard 57.100, the minimum expected life of liquid-immersed distribution and power transformers, operating at 30 degree centigrade average ambient, is about 20.55 years (180,000 hours) [5].

Hence it is necessary to monitoring the distribution transformer to avoid frequent failure and monitoring the energy consumed by various consumers to avoid power theft. Distribution Transformers are currently monitored manually where a person periodically visits a transformer site for maintenance and records importance parameters. This type of monitoring cannot provide information about occasional overloads and overheating of transformer oil and winding. All these factors can significantly reduce transformer life. Power theft in a distribution system should be detected in a right time to avoid unnecessary overloading of distribution transformer and commercial loss to the utility.

So, we propose an embedded system using microcomputer and sensors to monitor the load, oil level, winding/oil temperature of a distribution transformer continuously and the total energy consumed by each and every consumer on real time. The above data are constantly updated to the server using IOT. Based on the data's obtained from the sensors the controlling system controls the load when any abnormalities arise in the distribution system. This system will help us to identify problems before any catastrophic failure, thus resulting in a long-life service for transformers.

II. PROPOSED DT MONITORING SYSTEM

The system proposed in this paper focuses on autonomously monitoring the current, voltage, oil level and winding temperature of a distribution transformer with consumer end voltage, current and energy using IoT sensors and microcomputer. The main aim of this project is to design and implementation of a low cost IoT based online wireless monitoring of a distribution transformer with consumer wise energy recording. In order to reduce the cost of the system, IBM open source graphical wiring tool (Node-RED) is used.

III. METHODOLOGY

This system consisted of three main blocks namely the monitoring block (oil level sensor, winding/oil temperature sensor, current, voltage and energy sensors or smart meters), the control system (microcomputer and relays) and the communication block (ADC convertor, WIFI module and IoT platform). The block diagram of the system is as shown in figure 1. The oil level sensor continuously monitoring the oil level of the distribution transformer and gives
analogue output to the respective oil level. The RTD temperature sensor monitoring the oil/winding temperature of the distribution transformer and gives analogue output. These analogue outputs are converted into digital outputs by an ADC converter.

The current and voltage sensors are monitoring the secondary side load current and voltage of the distribution transformer as well as the load current and voltage of the individual consumers. The total energy export from the distribution transformer are monitored by an energy sensor or recorded by a smart energy meter. Just as the individual energy consumption of all consumers are monitored by energy sensors or recorded by smart meters. All sensors are interfaced with the microcomputer unit. This Wi-Fi enabled microcomputer can be easily connected to personal computers by using web HMI to monitoring the parameters remotely.

The consumer’s connected load details and the vital and non-vital load details are fed into the microcomputer. And all the digital values obtained from the sensors are fed into the microcomputer for further processing. The microcomputer analyses all the values with the set values. If any abnormalities arise, the microcomputer alerts the maintenance engineer and automatically controls the loads to restore the distribution transformer normal condition in auto mode. These controls can be done by the maintenance engineer in manual mode. The microcomputer compares the total energy export from the distribution transformer with the energy consumed by all the customers. If any deviation arises it will give ‘Power Theft’ alert to the maintenance engineer.

The microcomputer is programmed using Node-RED software to perform all the above tasks based on the requirement of the concern maintenance engineer. All the data are uploaded on to cloud using WiFi modules instantly and continuously.

So, the maintenance engineer can easily monitor and control everything at everywhere through his personal computer by using Node-RED or his mobile by using Blynk server with the help of Internet of Things. In addition to that, the loads in the distribution system can be easily controlled by the microcomputer in auto mode or maintenance engineer in manual mode during over loading condition thus the winding temperature is controlled with the help of inbuilt relays. If any one of the consumers don’t pay the bill that load can also be disconnected remotely by using this system.
Fig. 1. Block diagram representation of proposed distribution online monitoring.
IV. RESULTS AND DISCUSSION

This paper consists of two sections software and hardware. In software section all tests are done in Node-RED software and the simulation was done in Node-RED and the simulation result is as follows. Temperature alert message if temperature increases beyond the set point range. Power theft alert message if any deviation comes between energy export in distribution transformer and total energy consumption. Inrush current is controlled when cold load pickup condition by switch on the consumer one by one in auto mode. Over load is controlled by switch off the load which consumes excess energy more than the connected load. Un-balance alert message if load is un-balancing. Oil level low alert message if the level comes below the set level. The Node-RED dashboard for this project is as follows.

A. CONTROL WINDOW

![Control window of DT monitoring](image)

Fig. 2. Control window of DT monitoring
Fig. 3. DT monitoring window

Fig. 4. Consumer wise energy monitoring

Fig. 5. Oil level low alert message

Fig. 6. R phase overload alert
Fig. 7. R phase load control

Fig. 8. Monitor and control

Fig. 9. DT Monitoring Window
The prototype hardware model of the above project was tested in a single phase 230/5 V transformer with three connected load and the system worked perfectly. It gave the alert messages while overloading and un-balance loading. It also detected the power theft and gave alert message. The load was controlled during cold load pickup period and over loading period.

V. CONCLUSION

This paper developed an automated system based on the concept of Internet of Things (IoT) that continuously monitored the important parameters like current, voltage, energy, oil level, winding temperature of a distribution transformer with consumer wise energy. It successfully monitored and controlled the loads during overload period and detected the power theft. The proposed system can always be improvised and taken forward to distribution network of any dimension.

VI. REFERENCES

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