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RESEARCH ARTICLE

IMPLEMENTATION OF A LOW COST DISTRIBUTION TRANSFORMER MONITORING SYSTEM

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ABSTRACT

The main electrical stations in Nellore owns and operates over 60,600 Distribution Transformers (DTs) and loses over 10,000 DTs annually either with major or minor problems. At present, manual calculations or peak load analysis scheme was using by the electrical board to determine the transformer load conditions and effect the load growth and transformer losses, which is a difficult task and doesn't solve the problem of DT failure resulting from; load unbalance, over load, vandalism among others. Normally the efficiency of the transformer is 98% to achieve better DT performance in order to losses, a low cost monitoring system is required with commercial available systems with SCADA integration potential. The paper presents about a distribution transformer (DT) monitoring system implemented by monitoring load variations and relaying information concerning transformer load state, their losses and the whole data shares the information through the electrical lane. Furthermore, the system was able to store and analyze information received from the monitoring device concerning the transformer state. This system was able to benchmark the DT measurements to abnormal operation and take action before failure by giving alert or by open circuit of supply line. At that condition the current will be supplied through the load shearing methods. The future system will be integrated with a condition monitoring plug to ensure loss of life prediction.

INTRODUCTION

Distribution Transformers (DTs) are an essential part of the power network and their operation determines with a great deal the efficiency of the power system *(*Abdul and Abdul, 2004*)*. Although 300 million Indians have no access to power, millions more in the country of 1.2 billion people live with spotty supplies of electricity from the country's unreliable powergrid. (https://data.worldbank.org/indicator/EG.ELC. AC CS.ZS and https://www.Washingtonpost.com/graphics/ world/ world-without-power). Electricity board is expected to put more effort to increase the supply to the wider areas. It is also noted that even the connected consumers experience loss in supply frequently as a result of the unreliable power supply and the board is trying to reduce the black outs to a wider extinct. The main causes of unreliability in power supply include; (i) faults in DTs and feeders, (ii) vandalism of power supply equipment, (iii) failure of transformers, (iv) limited power available for dispatch. Recent statistics show that transformer failure due over load and deviation accounts for a considerable percentage of the causes of power outage to general consumers *(*3*)*. With a SCADA, there has been a great desire to explore other options such as designing a small scale system for DT monitoring and sending the data through integrated current lane to the SCADA system that is used for monitoring power transformers. The EDMI Distribution Transformer monitoring solution offer alert messages via email which could be quite a less responsive technique with no specific software application to analyse the information as it's received *(*http://www.edmi-meters.com/ SolProduct.aspx? SC= 1&SID=2*)*. Countries notably Thailand and South Korea have adapted to the design of customized systems for monitoring of DTs with the aim to prevent transformer failure through analysis of loading data obtained on a daily basis from the transformer. The Thailand project was created by Metropolitan Electricity Authority (MEA) Thailand. The purpose was to build a monitoring system for medium voltage DTs since Transformers' data is significant to load management and research about transformers (Wornpuen, 2012). Smarter systems have been built by companies that is Siemens; with a product named transformer monitoring and diagnostics system (TMDS™) built based on acceptable IEEE and ANSI standards. TMDS™ provides alarming and trending using models that work with rule based logic, derived from accepted IEEE/ANSI guidelines, to perform correlations on both measured and calculated data. Alarm messaging includes recommendations on maintenance activity as well as suggested loading should TMDS™ classify the observed deviation as severe enough that it may result in the damage or potential failure of the transformer (Siemens, 2014). A Notable feature well researched but not widely integrated in today's systems is to determine the expected transformer service life based on the present per-unit loading, oil and winding temperature (Kolyanga *et al.,* 2014). The purpose of this project was to design and implement a low cost DT monitoring system with a key interest in monitoring transformer load as it varies over time. Specific objectives included:

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- Design and prototyping of a monitoring relaying information concerning transformer load state through the lane;
- Design of software application with a database to record, analyse information received from the monitoring device concerning the transformer state. With additional calculation of the losses of the DTs.

MATERIALS AND METHODS

The design and implementation was mainly partitioned into two core activities that include;

- Hard ware system design and implementation
- Software system design and implementation

Hardware system design and implementation

The hardware system was built based as microcontroller based system interfaced with current sensor for measuring current in the Low Voltage (LV) phases of the transformer, an SD-card for data offline storage, a Liquid Crystal Display (LCD) for indication of variables during system configuration and a backup battery to allow for condition monitoring during blackouts so as to determine the cause and time of transformer outage. The hardware design proceeded with Computer 3D modeling software as shown in the figure 1.

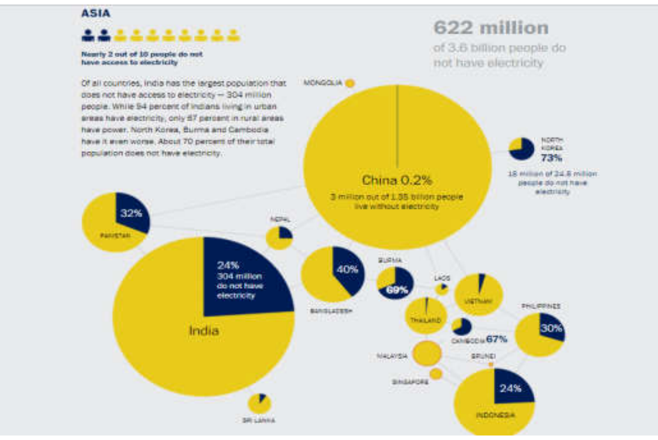

Figure 1. Total population in ASIA suffering without current

The design consists of a Remote Terminal Unit (RTU) and three Current Transducers (CTs). This was followed by a system block, schematic design of the system and then component selection based on the system requirements, flexibility.

System design

After development of the system layout, design preceded with a system circuit design; selecting and interconnecting the various components based on the system layout as shown in figure 2. The circuit consists current transducers (CTs) with a burden resistor connected across the CT outputs; the RMS to DC converter converts the AC voltage created across the burden resistor to its RMS equivalent DC voltage which is measured by the microcontroller that was to be programmed to process data measured from the CTs periodically and relay the information back to the monitoring system via Lane communication. With the circuit designed, component selection was the next phase.

Component selection

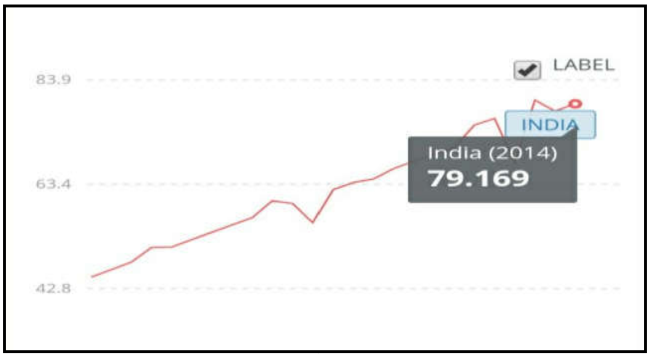

Figure 2. Database from the World Bank Stating about increase in utilization of current in INDIA from (1990-2017)

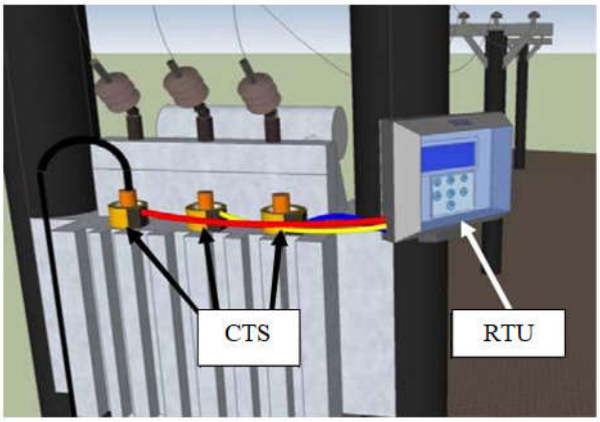

Figure 3. Distribution transformer condition monitoring hardware set up design

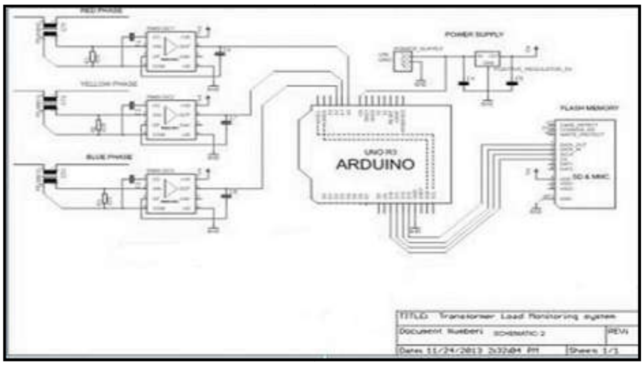

Figure 4 . hardware circuit Design

- Microcontroller: The Arduino development and prototyping board was selected as the hardware system central processing unit. This was to be programmed using the Arduino Integrated Development Environment (IDE) *(8)*.
- Current sensor: Current is calculated by varying the value of the shunt resistor slightly varies with its temperature which is desirable in applications involving high voltage loads. Allegro ACS712 device which provides an economical and precise way of sensing AC and DC currents based on Hall-effect (http://www.allegromicro.com)
- LCD display; the LCD display selected was a 16x2 monochromatic parallel LCD based on the HITACHI driver for easy interfacing with the microcontroller.

- Flash memory; the flash memory card interface was designed using an SD –card slot built using the SPI communication protocol for direct communication with microcontroller *(8)*.
- Battery: a 12V 4Ah sealed lead acid battery was selected for use with the device after measurement of device power consumption.
- Enclosure: A safe enclosure was obtained for safe storage and protection of unit components at the time of field testing.

Component integration

The components were inter-connected with the aid of additional material to form the system unit based on the schematic design after careful analysis. The current sensors were connected to the analogue inputs of the Arduino. The SD-card socket was interfaced with the microcontroller via the Serial Peripheral Interface (SPI) for data storage *(8)*; the 12V battery was connected through a 9V regulator to supply the Current sensor and the microcontroller.

Software Design

The software was designed using with C programming language and Arduino. Programming of Arduino and Interfacing it with sensors are the main part of software design. In order to allow for easy access of transformer records a basic control window was developed to input the transformer details.

Application development

The data is monitored time to time and the data is stored up to a particular time. At the time of fault condition the software is programmed in such a way that an alert will be sent to the sub-station or to the nearer feeder and the monitored data is be transmitted through the lane. So that the nearer sub-station will be alerted and can check the transformer up to that condition the current will be transmitted through the back device.

System features

The features of the designed prototype include the following:

- Transformer loading measurement: Mainly storing information concerning transformer loading as it varies over time. The software application classifies transformer load in terms of days on which the loading was measured and percentage of load relative to the transformer ratings.
- Transformer deviation/imbalance measurement: The imbalances in the current ratings, voltages temperature and oil levels will be calculated in addition to these the software application can also measure if there is any losses that leads to damage of transformer. The losses are calculated by using monitored values. In case of any faulty condition the software is programmed in a way that it will give alert.
- Utilities map Application interface for viewing multiple transformers during the monitoring to allow for easy identification and access of transformer data during analysis.

System Process Flow

This was developed to aid in system programming as shown in the flow chart in figure 8.

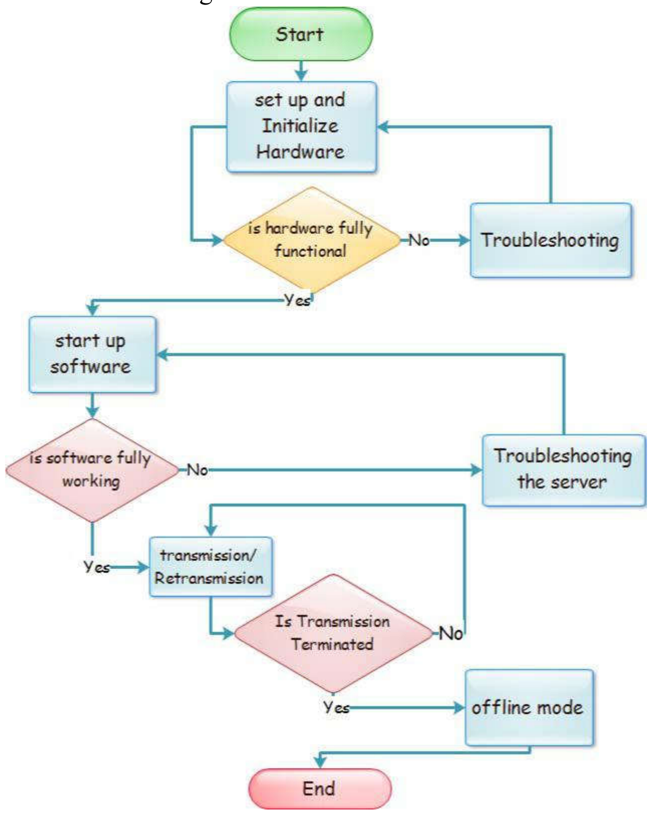

Figure 5. Process flow during start and monitoring

With the hardware initialized fully, the software would be started up after which transmission of data would be initialized. Process would then proceed with transmission and retransmission of data until the end of the monitoring period where data would be analyzed.

RESULTS AND CONCLUSION

The system was used to monitor the distribution transformer and results are taken based on the field work in the electrical substation on the date of Tuesday, 27 May 2018 the results obtained.

Current deviations

Deviation Result

The deviation results are as follows:
Maximum deviation: 74%
Time of Max deviation: 5:00AM
Minimum deviation: 46%
Time of Min deviation: 18:00PM

According to the data obtained by the current deviation the current load will be more on the early mornings and the usage of the current by the loads will be low in the normal evenings. Sometimes this data will be also changes due to the occasions or any unexpected meetings. The current passes commonly through the phases of (R Y B) but the load utilization will not be same in the 3 phases; utilization of the loads through the phases will be always fluctuated. Through the monitoring system we can also find the losses in distribution transformer. Normally the efficiency of the transformer will be around 98%

if the efficiency decreases below the percentage the monitoring system will be alerted as it makes losses to the system and some amount of power will be exhausted.

Conclusion

By the continuous monitoring of data day to day and by the monthly report of the transformer data the condition of the transformer will be maintained by necessary precautions and steps. By the comparing with the peak load analysis and direct analysis this method will give exact data and temporary solution for the losses in the transformer and helps to improve the efficiency and life time.

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