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An Efficient Management of Pole Mounted Distribution Transformersthrough Online Data Acquisition and Analysis

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ABSTRACT:*In both rural& urban areas in developing countries the use of pole mounted distribution transformers are familiar. There always has been a possibility for any of the three phases supply system under a substation to be overloaded. As a result the supply system falls down in an imbalance condition. That may cause in reaction accidents for any kind of abnormal conditions in pole mounted transformers. The aim of this project paper is to develop a device to get updated information about the current ratings, frequency, supplied power & other related ratings. In some country SCADA software based system is used for such kind of applications. Our purpose is to design a system as an alternative system of SCADA software based system. This system includes wattmeter, a new developed mobile app, microcontroller, ESP8266 module (or, GPRS/GSM shield, SIM card) etc. Every pole mounted three phase distribution transformer is given a definite SIM card to adopt a profile. In such wireless communication where the SIM card is coupled to the wireless communication device.*

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I. INTRODUCTION

Automation increases efficiency and increased efficiency reduces costs. Based on this theory proposed system can work on three basic functions data acquisition, data communication, and data presentation. This project relates the efficient management with the three phase pole mounted distribution transformer. A distribution transformer provides the final voltage transformation in the electric power distribution system stepping down the voltage used in the distribution lines to the level used by the customer. Its operation is performed by electromagnetic induction. It transfers energy from one circuit to another at the same frequency but with different values of voltage and current. If a distribution transformer is mounted on a utility pole, it is called a pole-mounted transformer. They have ratings less than 200MVA. As they have usually do not operate at full load, they are designed to have maximum efficiency at lower loads. To have a better efficiency, voltage regulation in the transformer should be kept minimum.

Figure (1): A Three Phase Pole Mounted Distribution Transformer

A distribution transformer is self protected. The pole-type distribution transformer is bolted directly to the pole. It is equipped with a low voltage circuit breaker, a surge arrester, and an overload warning light. The primary bushing connects a partial–range current–limiting fuse to prevent a violent failure of the transformer if

an internal faults develops. The transformer tank is grounded. Still there are happening unfortunate incidents. Obviously the transformer is under protection but there are so many reasons to occur unexpected mishap or an unfortunate incident resulting in damage or injury due to the failure of proper maintenance. In the digital era manual maintaining process should be replaced with the new system. To get a better secure lifestyle technical and time saving management system is preferable.

II. THE PROBLEM CAN BE RAISED WITH THE POLE MOUNTED TRANSFORMER:

There had been occurred a number of accidents that we still remember in Bangladesh from transformer blast. In 2010, fire occurred in the Nimtali area of old Dhaka is the recent occurrence which was started from an electrical transformer exploded.

The electricity has to flow at a constant speed which is analogous to frequency and at a constant depth which is analogous to voltage. When a transformer is flooded with 100 much electricity, the sudden surge can cause a transformer explosion. The crude mineral oil in transformer cools the circuits. If too much electricity flows through the circuits, they fry and melt falling in a shower of spark and setting the mineral oil a flame. Transformer oil combusts explosively and rocket transformer into the air. To prevent human created problems in such case a system need to be developed which can help to read the instant rating and send to the control office in real time to take necessary steps.

Bangladesh has faced such incidents several times. All happens despite protection devices and safety services are provided.

A transformer can explode or face temporary incidents because of any fault occurring in the three phases, overload condition, unbalance among the three phases, overheating of the transformer oil, excessive charge accumulation in the transformer core etc.

Figure (2): A Three Phase Pole Mounted Distribution Transformer Blasts

Any deviation in voltage and current waveform from perfect sinusoidal, in terms of magnitude or phase shift is termed as unbalance. The phases of power supply are 120 degree apart in terms of phase angle and same peak magnitude in ideal conditions when only linear loads are connected to the system. On distribution level, the load imperfections cause current unbalance which travel to transformer and cause unbalance in the three phase voltage. Even minor unbalance in the voltage at transformer level disturbs the current waveform significantly on all the loads connected to it. Voltage unbalance also disturbs the high voltage power system through the transformer as well.

Practical imperfections result in unbalance such as

a. Any large single phase load, or a number of small loads connected to only one phase cause more current to flow from that particular phase causing voltage drop on line.

b. Switching of three phase heavy loads results in current and voltage surges which cause unbalance in the system.

c. Unequal impedances in the power transmission or distribution system cause imbalanced current in three phases.

d. A current leakage from any phase through bearing or motor body provides floating earth at times, causing fluctuating current.

e. Three phase equipment (i.e. induction motor with unbalance windings).
An unbalance of 1% is acceptable as it doesn't affect the cable. But above 1% it increases linearly and at 4% the de-rating is 20%. This implies that 20% of the current flowing in the cable will be unproductive and thus the copper losses in the cable will increase by 25% at 4% unbalance.
The resistance for negative sequence current is 1/6th of the positive sequence current which means a small unbalance in voltage waveform will give more current and thus losses. Transformer offers high reactance to negative phase sequence currents and thus reduces the level of unbalance on the other side of the system.
Ideally any distribution transformer gives best performance at 50% loading and every electrical distribution system is designed for it. But in case of unbalance the loading goes over 50% as the equipment draw more current.
Following data represents the efficiency of transformer under different loading conditions:
1. Full Load- 98.1%
2. Half Load- 98.64%
3. Unbalanced loads- 96.5%
For a distribution transformer of 200KVA rating, the eddy currents accounts for 200W but in case of 5% voltage unbalance they can raise up to 720W.

All fuses operate on an inverse time scale. The higher the fault current, the more quickly the fuse isolates the circuits. If there are shorts in the primary and secondary terminals, the fuse will blow. If the insulation is degraded between the coils arcing will occur. This will blow the fuse and the transformer stops permanently. So, a replacement is needed. In urban areas it takes small time but in rural areas it takes 1-2 days which can be the remarkable reason to stay back dated. Sometimes in rural areas people of lack of knowledge about the functions of fuses and transformers demand of high rated fuse for avoiding electrical interruption repeatedly. Some greedy or unskilled technicians do whatever they want in return of value or something else. For these corrupted people transformer blasts rather than fuse blows for over current. Either the illiterate people or the corrupted employees are responsible for the losses. We cannot controlcorruption smoothly but we can take steps to save the resources.

Some distribution transformer gets overloaded due to extensive use for agricultural purposes(i.e. water pumping). This happens because free electricity for the agricultural purposes is available only for short duration in a day. Transformer's life reduces and premature failure occurs. To reduce overload to transformers load shedding being one of the main approach. But we all know the disadvantages of load shedding. Its affects are remarkable.

During an internal arching fault, the high current generates an explosive pressure underneath the oil and oil are rapidly vaporized resulting transformer's metal case rupture and high voltage insulators may be ejected. As a result short circuits often cause progressive internal damage. So a previously –stressed transformer may catastrophically fail.
All the above mentioned problems result in damage either replacement or set up new equipment. Both cost high which is a remarkable drawback in economical development.

III. APPROACHES TO THE SOLUTION

a. Determination and Project Planning

A specific organization associated with electricity supply or a new organization can be established to implement the project for monitoring and maintaining purposes. The organization should be very clear and determined about the aim. For that reason it needs a proper planning. The planning includes financial planning, stuff planning, equipment selection, maintenance etc. Only an appropriate and successful planning can bring a successful outcome.

b. Stuffing

Stuff selection is very important step. In this project employee should be very vigilant and punctual. There will be some statutory regulations for every employee (i.e. Supervising and monitoring regular activities of the operating system, reporting regular process of work, confirming safety standards, keeping a smart phone to install specific apps, archiving and maintaining site documents etc.) There will be adequate stuff to visit site regularly.

c. Selection of Mobile Network Operator

This section is about choosing a mobile network operator which provides GSM, GPRS, UMTS etc services. In Bangladesh Grameenphone, Banglalink, Robi, Teletalk and few others are very familiar telecommunications company. The project head needs to decide which operator is more suitable on the basis of

financial planning. The share of Teletalk Telecommunication Company is owned by the state Government. It is preferable to deal with Teletalk service provider.

d. ***Management of Implements***

Proper management of implements should be examined. The arrangement of new developed and existing equipment needto be assembled. Analog devices will be replaced by digital ones as far as possible. The equipment which has more life time should be chosen. The following equipment and devices are needed for the project:

i. ***Wi-Fi module ESP8266/GPRS shield:*** The system needs an existing Wi-Fi module or GPRS shield to communicate and transfer data from each transformer to the personnel. The appropriate Wi-Fi module is ESP8266 for this project.

ii. ***New developed mobile App:***To monitor the ratings of each transformer a mobile App need to be designed for each employee working in monitoring section.

iii. ***Modified version of microcontroller chip:*** A microcontroller chip should be modified in such a way that its input signals are analog but output signals are digital.

iv. ***Others:***Other equipment includes multi-meter, watt-meter, wiring apparatus etc.

e. ***Project Implementation***

Implementing a project costs high but obviously it can be reasonable. This cost is needed for only one time. That's why the authority should go through a formal budgeting process. With a strategic plan and strong personnel a proper infrastructure of the project can be possible.

f. ***Proper Maintenance***

A central location is necessary for proper maintenance. For that purpose a central control room will be set up where all the obligations regarding this project will be assessed. The responsibilities for proper maintaining will be integrated and centered in the central control room. The maintaining cost is lower than the implementation cost.

IV. DESIGN OF THE PROPOSED SYSTEM:

The design of the system describes some functions / equipments as shown in the Figure (2) and Figure (3) with their performance in the system.

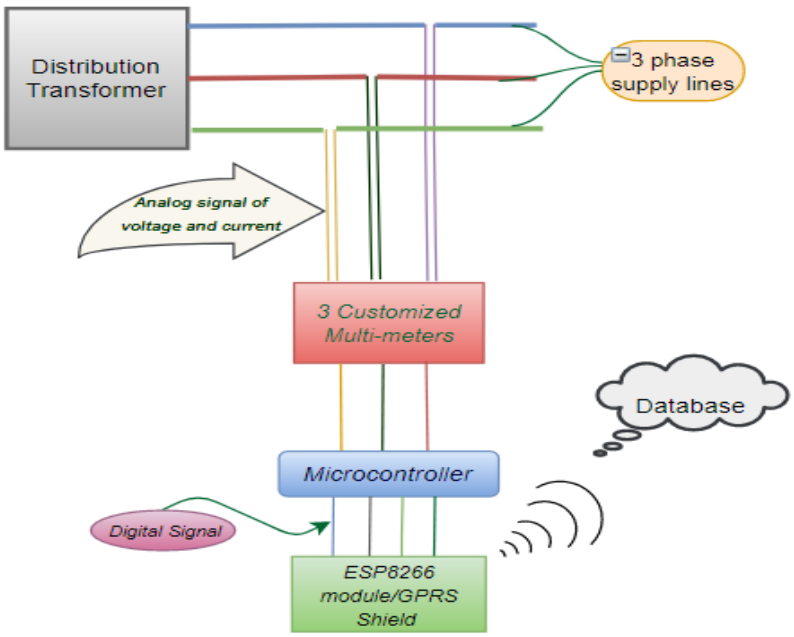

Figure (3): Block Diagram of the Proposed System

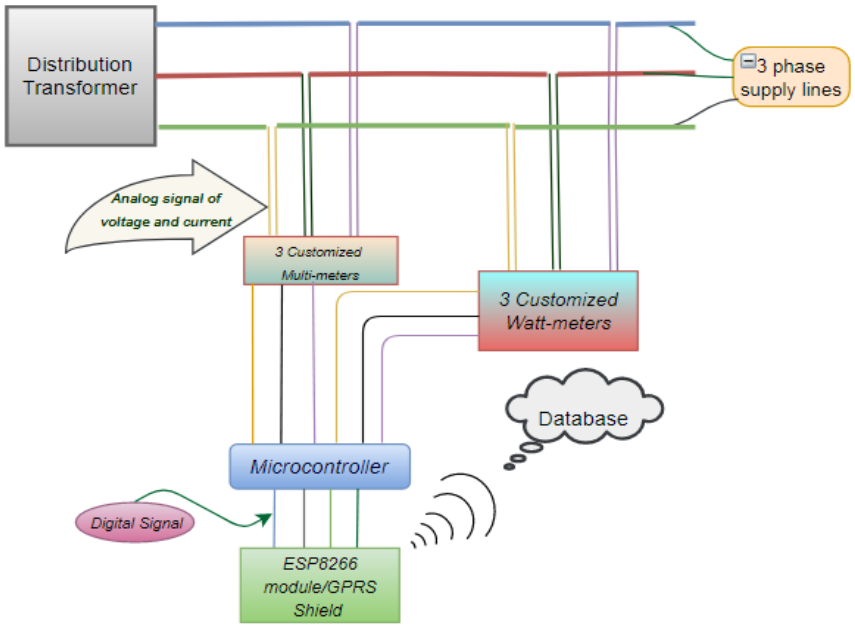

Figure (4): Block Diagram of the Proposed System with Wattmeter Connection

Theperformances of the equipment are described elaborately as follows:

a) Metering Section

Measurement meters are used to measure the supply lines' voltage, current, power, resistance etc. This section includes two types of measurement meters:

i. ***Multi-meter:***A customized multi-meter is connected to each phase of the power supply. It is designed to measure electric current, voltage, and usually resistance over several ranges of value. It performs several measurement functions in one unit. Analog multi-meters use a micro-ammeter with a moving pointer to display ratings. Digital multi-meters can also be used in this project. Here the system has used three different multi-meters to measure three phases' ratings individually. All the meters are set up in a single device with three displays for each for the purpose of reducing cost and space.

ii. ***Wattmeter:***A single wattmeter (dynamometer) can also be connected to each phase of the power supply for measuring the electric power. For the three phase supply three different watt meters are used and assembled in a device which shows power ratings over three displays. Later the information is sent to database individually. A digital wattmeter which is available in a purely electronic form. It measures accurate reading of power whose scale is uniform. So digital wattmeter is preferable to use.

The project can also be successful without using wattmeter. Wattmeter in the circuit costs more. So, it is preferable to avoid wattmeter. In that case microcontroller will be programmed in such a process to get power rating.

b) Microcontroller

A new version of microcontroller chip is designed and used in the system which is capable to convert analog input signals to digital output signals using the special assignments of power pins. This device is considered to be a computer on a chip. Microcontroller provides output signals to a display. The programming language used here is C++. The function of microcontroller is to take analog input signal and sends analog data to the serial monitor with tag and produce digital data after processing and then it sends digital data with tag to ESP8266/GPRS.Arduino software can be used in microcontroller.

c) ESP8266 Wi-Fi Module

The next most important equipment is used in the system is ESP8266 Wi-Fi Module. The ESP8266 Wi-Fi Module is a popular inexpensive Wi-Fi system on chip (SoC). The ESP8266 Wi-Fi shield surrounds the Wi-Fi SoC with everything it should need to operate and connect to a Wi-Fi network. It includes headers, some solder, and an Arduino.

Arduino is an open source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs (i.e. light on a sensor, twitter massage etc.) and turns it into an output like turning on a led, publishing something online etc.

Communication is initiated with ESP8266 using a set of AT commands (i.e. Basic: AT; Wi-Fi layer: AT+CWMODE; TCPIP layer: AT+CIPSSTATUS, Basic: AT+GMR; Wi-Fi layer: AT+CWLAP; TCPIP layer: AT+CIPSEND, etc). Using an AT command microcontroller with a UART (Asynchronous Receiver and Transmitter) can use the ESP8266 to connect to Wi-Fi network and interact with the rest of the internet world TCP (Transmission Control Protocol). ESP8266 is a cheap Wi-Fi module with UART and SPI connectivity. This can be integrated with Arduino. The software is used in ESP8266 is Circuito.io, Tinkercar, Fritzing to simulate. It may cost 5 dollars.

d) GPRS Shield

The GPRS shield can be used in replace of ESP8266 Wi-Fi Module. GPRS (General Packet Radio Service) shield is a new nonvoice value added service that delivers GSM/ GPRS performance for voice, SMS, data, and Fax in a small form factor and with low power consumption. IT is controlled via AT commands (i.e. GSM 07.07) and fully compatible with Seeduino/Arduino and Mega. The GPRS shield has 12GPIOs, 2 PWMs, and 1 ADC. It supports TCP Protocols. It costs 59.9 dollars.

e) Mobile App

A mobile App is designed to monitor the real time data. Every employee will install the app in their Smartphone to monitor the rating even they are not available in the central control room. The Programming language used in the App is Jason code. The functions are programmed in such a way that the App can calculate instant available data and processed for necessary unavailable data. It can calculate for every second. There is specific number for each transformer to check. This app can be developed in furtherif necessary. The working functions of the App are given below: (The mobile display shows as the following the numeric sequence from left to right.)

V. WORKING PROCEDURE

In our developed system Data acquisition, Data transmission, Data presentation are functioned. The designed system is capable to measure, monitor, gather, process, and display the real time data. It also records into a profile. If any kind of unbalances happen in the phases like current rating of a single phase becomes high, the system is designed to inform at once. The ratings will be sampled and stored and then sampled data will be stored into the serial monitor. All the information will be transferred through the GPRS System or after retrieving data microcontroller will send the digital data with tag to ESP8266 module which will transfer info to database like central database, personal database, free database (i.e. Google firebase). Either Mobile or microcontroller will be designed in such a way that unavailable data will be retrieved calculating the available data. When the operator reviews the data and discover any disturbance, they will take steps to solve the problem. All pole mounted distribution transformers will be observed from a central control room (CCR). The personnel at work will monitor the ratings through a MIN number using SIM card mounted inside the implemented device or the wireless system. Who are not available there also can be updated by notifications of installed mobile app regarding all transformers under a specific zone.

The system will be implemented beside or below the transformer assuring clearance.

VI. ECONOMIC EFFECTS:

The economic conditions can be examined by summing up the project implementation cost and the operating cost:

a. Economic effects are described below when the project uses Wireless system:

The project implementation cost:

1) Arduino Nano (Microcontroller)= BDT 450
2) ESP8266 Wi-Fi module=BDT 380
3) Three multi-meter customized=BDT 1500
4) Wi-Fi router=BDT 1500

The total implementing cost is about BDT 3,830～BDT 4,000. With three customized wattmeter (BDT 2700)total implementing cost is about (BDT 3,830 +BDT 2700)= BDT 6530

This cost is needed for only one time for each transformer.

The operating cost:

Monthly internet expenses are BDT 350 or few more. If the Government invests operating cost (especially monthly expenses and Wi-Fi router cost) will be lesser.

b. When the project uses GMS/GPRS Shield:

The project implementation cost:

1) Arduino Nano(Microcontroller)= BDT 450
2) GMS/GPRS Shield =BDT 4,500
3) Three multi-meter customized=BDT 1500

The total implementing cost is about BDT 6,450～BDT7,000. With three customized wattmeter (BDT 2700)total implementing cost is about (BDT 6,450+BDT 2700) = BDT 9,150

The operating cost:

Monthly SMS expenses: Each SMS cost is BDT 1

If 30 engineers at work in a day for 24 hours (1 hour pulse), the cost will be BDT (24× 30 × 1)= BDT 720. For 1 month it costs BDT (720 × 30) = BDT 21600.If the Government invests operating cost will be lesser.

From the economic calculation it is shown that the project we are saying to be planted is economical. If we use the alternative system rather than this system will cost more (i.e. SCADA Software based system). If we use ESP8266 we can get all information for 24 hours 7 days as much as users we serve. The system works based online real-time database. If we use SIM card based system, for smaller user requirements the operating cost will be lower and for the massive user requirement the cost will be extremely high. In case of establishing GPRS shield it will cost more for each system than ESP8266 module. So using ESP8266 module reduces cost than GPRS system.

For SCADA operator for each transformer we need individual PLC device which can provide all information. The total implementing cost is 10 times higher than our proposed system.

VII.SOCIAL AND ENVIRONMENTAL EFFECTS:

People of our country especially students will learn about a new system and its implementation. They will work for the betterment of the country people and invent new technologies for removing sufferings. In the education system, students are only involved with their departmental courses which cannot enhance the knowledge about other important topics and branches. That's why they are not well acquainted to the creativities which are possible for mutual contribution of few branches of engineering such as robotics, electro-mechanical system, IT, Data and network communication, web development, android apps etc.This project will encourage them to get involved with other branches of engineering and interconnect among them.

With the project network and communication systemof our country will be developed. That's how it will be another important approach for our Government to build digital Bangladesh.

As we know about the accidents happened over the country related to transformers, everyone wants to get rid of the problems. No one wants sufferings. So the sufferings of the rural and urban people will be reduced even small if this project is implemented. No more death will occur if the control system is developed as well.

VIII. DISCUSSION:

At comparatively lower cost, better service can be the best choice of the service providers. A distribution transformer must be protected from violent explosions. To observe human created imperfections as well as

sudden developed and slow developing faults the project provides the best services. Human created imperfections and slow developing faults can be overcome easily by implementing such project.
If a small step saves thousands of lives and huge values, it should be adopted for the mankind. A distribution transformer costs (3-5) lac whereas this project costs a few thousand. So burning a transformer is huge loss than implementing a management system.

IX. CONCLUSION:

Not only to stay safe from incidents but also it will be an important step in building efficient power system in developing countries.. The Government can play an important role to set up and develop the project providing economic help. Hope that this project implementation will be successful.

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