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Wireless Sensor Network Based Electrical Transformers Monitoring in Small Cities

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ABSTRACT

Electric power distribution is an important issue in many countries. One of the most effective devices that has an efficient contribution of electrical power distribution is the transformer. Transformer is an electrical device that converting voltage level to another level with power conservation. Most parameters that affect transformer performance are Voltage, current and temperature. In this paper A wireless Sensor Network (WSN) model is presented to monitor these parameters. Arduino mega with XBee and Wi-Fi shields is used to upload sensors reading to monitoring room for transformers performance in a small city. A cluster of 6 transformers is served with one Wi-Fi device to upload readings to control room.

KEYWORDS: WSN, Transformers, RSS

1. INTRODUCTION

Electrical transformers are main key in electrical power distribution. The main function of transformers is down converting the level of voltage to be suitable for user voltage [1]. In small cities, transformers normally serves a limited number of houses, according to the transformer rating power and houses consumed power [2]. During operation, transformer temperature may be increased due to dissipated power, even there is a cooling oil, but high temperature still a risky environment. Overcurrent is another essential parameter should be monitored to overcome transformer fail. The most load related parameter is voltage drop or voltage rise thus each line voltage should be monitored to protect user home devices [3]. Figure 1 shows most common transformers connection through electrical power distribution system [4].

A WSN consists of multiple nodes which are connected together through wireless link. Each node contains a microcontroller device and sensors that are connected to it[5]. Cluster based WSN could be a single hop or a multi-hop network where each cluster

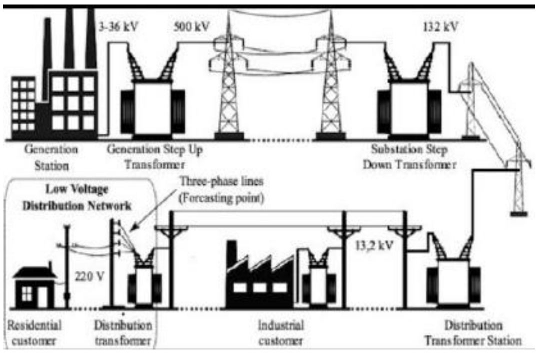

Fig 1: Common transformers of electrical power distribution system

contains several nodes could communicate with each other and send data to a central device known as head of cluster which can directly send the data to main monitoring room or to another cluster head.

Figure 2 shows the main architecture of WSN [6].

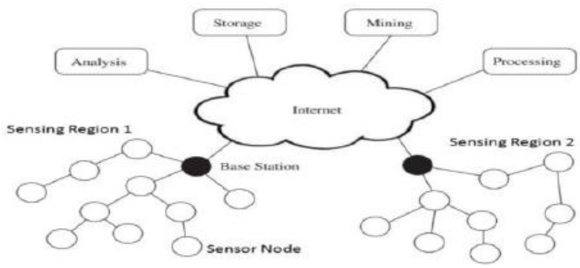

Fig 2: WSN main architecture

The main device in each node is the microcontroller. Microcontroller is responsible of taking the electrical signals which transmitted from the sensors, converting them to real equivalent measures and transmit these measures to another node or control room[7]. Some microcontrollers need a peripheral device that enables it to establish communication through internet or through a wireless channel. These peripheral devices are called shields. Another essential device in each node are sensors or transducers. The main function of the sensors is converting the physical properties or electrical specification to certain level of electrical signal, these signals can be interpreted for microcontroller which convert it to data. Commonly the physical channel between sensors and microcontroller is wire channel [8].

RELATED WORKS

A. P. Khandait *et. al.* designed a real time monitoring system to monitor transformer load current, voltage, temperature and cooling oil level by using IoT. In this work a SCADA system has been used to achieve data collection and send these data through the web using Adafruit web application [9].

Dnyaneshwar J. Mali *et. al.* introduced a transformer protection and control via IoT. A PIC16F877A microcontroller and GSM module has been used to control and send data to the monitoring station [10].

Sahil P. Jadhav *et.al.* proposed a GSM modem-based distribution transformers monitoring system to monitor transformers parameters using ATMEGA328 microcontroller through current, voltage, oil level and temperature sensors. The proposed system takes 5-10 second time to receive GSM message and deal transformer malfunction [11].

Christina Nicolaou *et. al.* proposed a low cost intelligent system to monitor transformers by using micro-electromechanical sensors. An adaptive triggering scheme has been used to adapt necessary measurement [12].

Jayroop Ramesh *et. al.* implemented an IoT based control and management system for power distribution transformers designed with SCADA. A detection algorithm for isolated forests has been designed and implemented and the data can be uploaded and analyzed in the cloud. The implemented algorithm can detect anomalous behaviour of the transformer [13].

2. SYSTEM INMPLEMENTATION

The implemented system of WSN for monitoring electrical transformer consists of Arduino Mega 2560 microcontroller, current sensors, temperature sensors, voltage sensors and Wi-Fi shields. The rating of the monitored 3- phase transformers is 100 kVA, each line has rating current of approximately 150 A.

The overload current is 125% of rating current, in this case is about 190A

The implemented system consists of clusters, each one responsible of 6 transformers covering 2500m2 area. Each node in tis cluster collecting the data from the 3-phase transformer and send it to the main node in the cluster, which upload these data to control room to display them. The brain of the node is Arduino Mega 2560, which consists of 54 digital I/O pins basically specified for receiving and transmitting data. The first sensor in this system is the current sensor CS-200A. Three current sensors are used for each transformer to collect current information from each phase [14].

When the current accedes overload value, an alarm will be sent to the control room in case fuse fail. Temperature is an effective parameter that cause transformer malfunction. Temperature monitoring is a valuable protection method that increase lifetime of the transformer. To monitor the temperature of the transformer, an LM35DZ sensor is used [15]. This sensor achieves sensing temperature range (-55-150) C^0, actually low temperature has a negligible effect on transformer performance, but high temperature leads to transformer mal function. The voltage in each phase of transformer should not swing in high range, so a voltage sensor type ZMPT101B is used to monitor the r.m.s value of each output phase of the transformer [16]. After collecting all necessary information about transformer performance, Arduino sends the collecting data to the central device (node) by a wireless channel provided with XBee shield. The XBee 802.15.4 modules ensure channel establishment as point to point or point to multipoint communication [17]. The central node contains the same component of any node with one addition which is Wi-fi module ESP 8266 that connected to the central router. Figure 3 shows the block diagram of a single node.

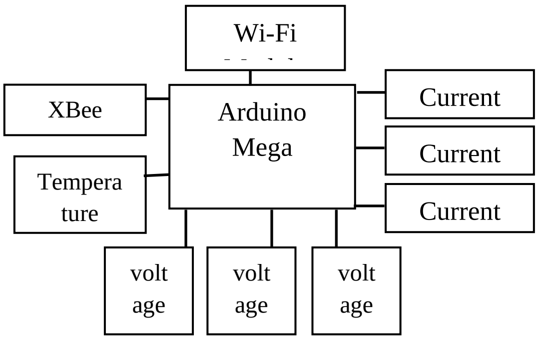

Fig 3: WSN main Node

3. SYSTEM RESULTS

Two types of clusters have been taken into consideration, low buildings density and moderate buildings density. The main effect with these densities was on communication between nodes in the cluster due to multipath effect, where multipath model for free space has been considered. Figure 4 illustrates the received signal strength (RSS) at the central node of the cluster in low building density.

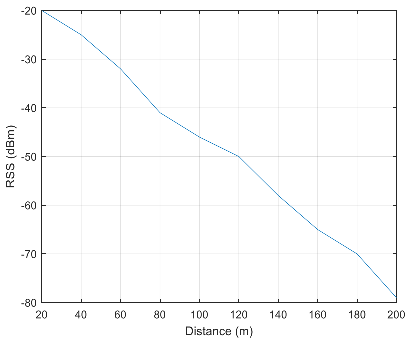

Fig 4: RSS in low

Figure 5. shows RSS in the central node of moderate density of buildings.

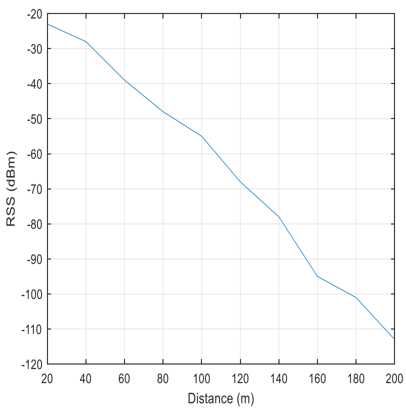

Fig 5: RSS in moderate

The above results show that RSS value decreased with increasing the number of buildings in the cluster due to multipath which leads to increase the pathloss exponent.

The average measured values and real values of a single node for 12 hours of operation at heavy load time is shown in table 1.

The measured and real parameters of the system have high accuracy which gives a robustness for the system.

Table 1. Monitored parameters of the system

parameter	Temperature C^0	Current (A)	Voltage (V)
Real value	52	146	216
Measured value	51	146	212
Percentage error	1.92%	0%	1.85%

4. CONCLUSION

WSN is an effective methodology to monitor electrical transformers performance in low voltage distribution network. The implemented system is low coast, robust and reliable. The measured values are so close to real values where the maximum percentage error is 1.92%. RSS is building density dependent and it can be affected by the weather, however this effect is low and can be negligible.

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