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Wireless Sensor Network based Remote Monitoring System in Smart Grids

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ABSTRACT

In order to improve the efficiency and safety of the grid, monitoring and automating the system became mandatory. In Indian grids, the line parameters are not monitored continuously which results in conditions such as blackouts, overloading of the power system elements, such conditions can be avoided by timely monitoring the parameters and taking necessary actions to avert the future intolerable conditions on the line. This paper proposes an architecture for monitoring smart grid using wireless sensor network (WSN) technology. A miniature smart grid prototype and sensing module is designed and implemented to collect the line parameters like current, voltage and frequency. Using WSN technology, the collected parameters are communicated to a central monitoring unit at periodic intervals.

Keywords: Remote monitoring, Wireless Sensor Networks, Smart Grid.

1. INTRODUCTION

The power system at present is more vulnerable to a very minimal change in the grid. There is a huge power flow and congestion on the line. Because the line is highly interconnected, any change at one location can possibly affect the entire power system and the effect of local disturbance gets magnified over a wide range [1]. In order to avoid such damages that can even lead to black outs, there should be a two way communication between demand and generation so that there is continuous timely monitoring of power flow and in case of any change, the system should be in a position to self heal itself. Such a technology applied in power systems is a smart grid [2].

The smart grid is a combination of technology to bring the electrical power-grid up to date so that it can meet the current and future requirements of its customers. It is an electrical power infrastructure with electronic decision making units which make intelligent decisions about the state of the electrical power system to maintain stability.

Smart grid improves power quality, operating at an optimized efficiency thereby keeping the consumer and supplier well informed about the current situation. It can achieve two-way flow of electricity and information making the system automated. In order to achieve these tasks there is a need for communication, where the specification of communication varies depending upon the need i.e., wired mode of communication inside the substation; wireless for remote operations. For remote operations it is mandatory to use wireless technologies. Based on its application there are variety of communication protocols such as Home Area Network (HAN), Neighborhood Area Network (NAN) and Wide Area Network (WAN) [3].

Harsh environmental conditions, RF interference, high humidity levels and vibrations are the major challenges faced in wireless sensor networks. The communication technologies available for smart grids are GSM (Global System for Mobile communications), GPRS, 3G, WiMAX, PLC, Zigbee etc. Depending upon the range and the amount of data need to be transferred; wireless technology has been selected for

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each particular node i.e., for a range of 200 meters Zigbee's can be used; for a range of kilometers GSM can be used; for few thousand kilometers GPS can be used. Zigbee is relatively low in power usage, data rate, complexity, and cost of deployment. It is an ideal technology for smart lighting, energy monitoring, home automation, automatic meter reading, etc. [5]. Its technical advantages can be made to full use in smart grid applications like network safety management, operation and maintenance, information collection, security monitoring, parameter measurement, and user interaction. Zigbee is an economic, high-efficiency, low-rate standard for personal area network and peer-to-peer networks, which is working in 2.4GHz, 868 and 928 MHz with two-way wireless data transmission [6].

Wireless Networks are preferred in smart grids because of their easy installation process and the lesser requirement of maintenance. On the contrary, wired networks prove to be a liability due to their complexity and the need to be physically connected for a network to operate. In case of a grid, supposing the nodes are far away from each other, laying wire for networking is a tedious task when compared to a wireless network.

This paper proposes an architecture for remote monitoring system in smart grid using WSN technology with Zigbee as the mode of communication protocol. A sensing module is designed and implemented to measure the line parameters and transmit the information to a central monitoring system wirelessly. This smart-grid prototype with wireless sensor networks can be implemented for a real time substation and the customer nodes for a safe and reliable operation.

The paper is organised as follows: section II presents the proposed system architecture, section III presents the proposed wireless sensor networks, section IV discuss the implementation results and section V concludes the paper.

2. PROPOSED ARCHITECTURE

The remote monitoring system using WSN has a modular architecture as shown in Fig.1. The system to be monitored includes the line parameters like voltage, current and frequency. Sensor nodes consisting of Current Transducers (CT), Voltage Transducers (VT) and signal conditioning circuit are designed to acquire and filter the line parameters. The resulting signals after signal conditioning are processed and converted to a suitable form so as to transmit the data to the central monitoring station or the server by the wireless node.

The miniature smart grid prototype has been developed to implement the WSN technology. The proposed miniature smart grid prototype is shown in Fig.2. It consists of ac grid, solar node and wind turbine node. Each node developed consists of Current Transducer for current measurement, Voltage Transducer for voltage measurement and Zero crossing detector with microcontroller for frequency measurement. Total of 8 such sensor nodes has been developed to showcase the wireless sensor network.

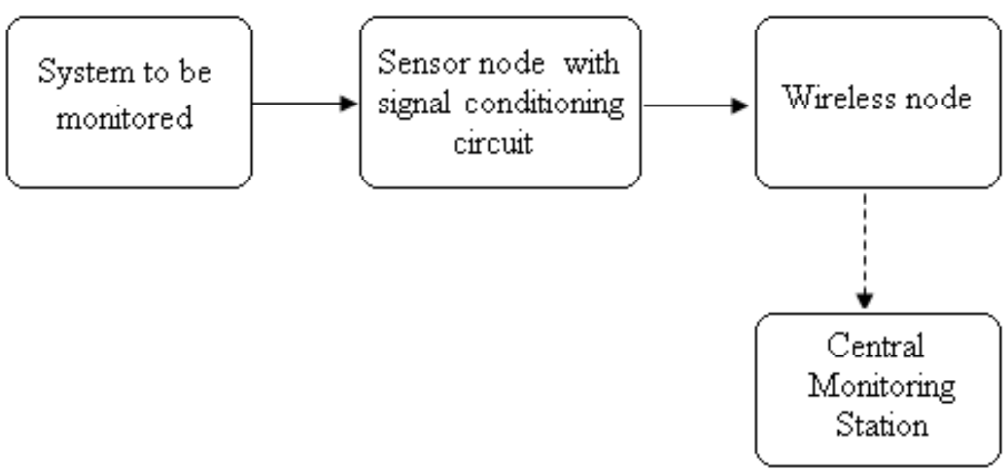

Figure1: Proposed system architecture

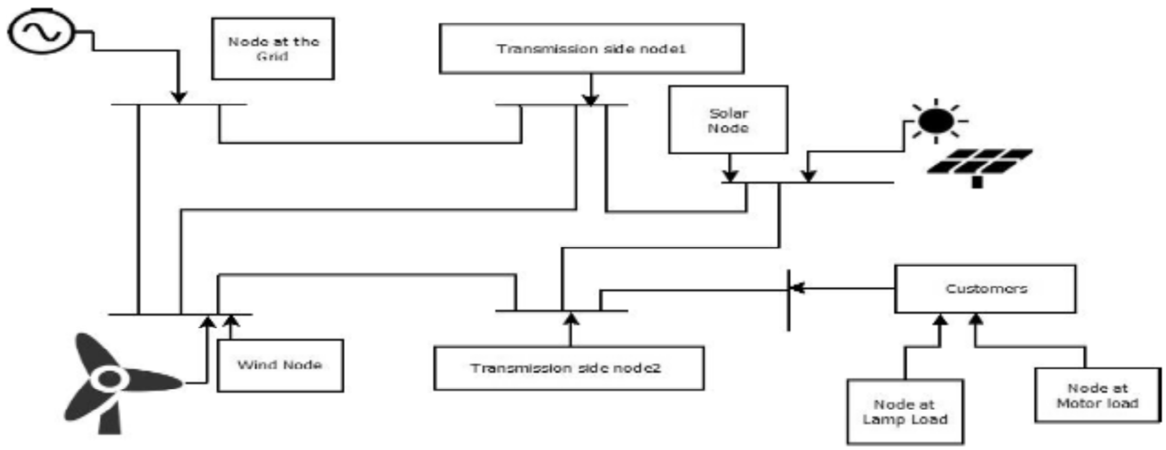

Figure 2: Proposed miniature Smart Grid

Central monitoring station is the combination of load dispatch center and power generation utility. This can be incorporated in National and Regional load dispatch centers (NLDC & RLDC) to avoid complexity. All the process involved in this node is automated thereby saving man power and making it cheaper than a manually operated system. Solar node is another node in the system, setup for the purpose of measuring the line parameters from the solar panel. The acquired data is sent to the central server, which monitors the data at all times. The wind energy node is located at the generation side of the micro-grid. The parameters such as voltage and current of these small scale generators need to be determined for the purpose of monitoring and analysis.

Another individual system consisting of two GSM modules is developed. It has two nodes, one of which is connected to the load and the other to the central server. These nodes communicate with each other via SMS services. This system accounts for fault diagnosis.

2.1. Sensor nodes

Sensor node uses current transducer LEM LA-25 and voltage transducer LEM LV-20 for current and voltage measurements respectively. The block diagram of an individual sensor node is shown in Fig.3. The output of the CT will be accompanied with unwanted distortions. These signals have to be conditioned for the safety of microcontrollers. Op-amp circuits with gain adjustment are used as signal conditioning circuit. Zero crossing detector generates square pulses which is used by the microcontroller to determine the frequency of the system. After acquiring the voltages, currents and frequencies, the data are compressed in a specific format and sent through Tx pin. Tx and Rx pins of the microcontroller are connected to the wireless module.

2.2. Wireless nodes

The wireless node sends acquired data to the server or coordinator node. This prototype uses Zigbee modules and GSM modules for wireless communications. The proposed system will include data acquisition from 6 Real-Time Data Collection Units (RTDCU). Each node can sense the signal, acquire the data and transmit the data. All these nodes are interconnected using wireless zigbee and GSM modules. A star topology prototype, suitable for customer side load management has been developed. Zigbee networks are used for close range communications and GSM module has been used for long range communication process. This sensor node is located at the transmission side of the micro-grid. It measures parameters such as current, voltage and frequency. The acquired line parameters are sent to the server, at periodic intervals.

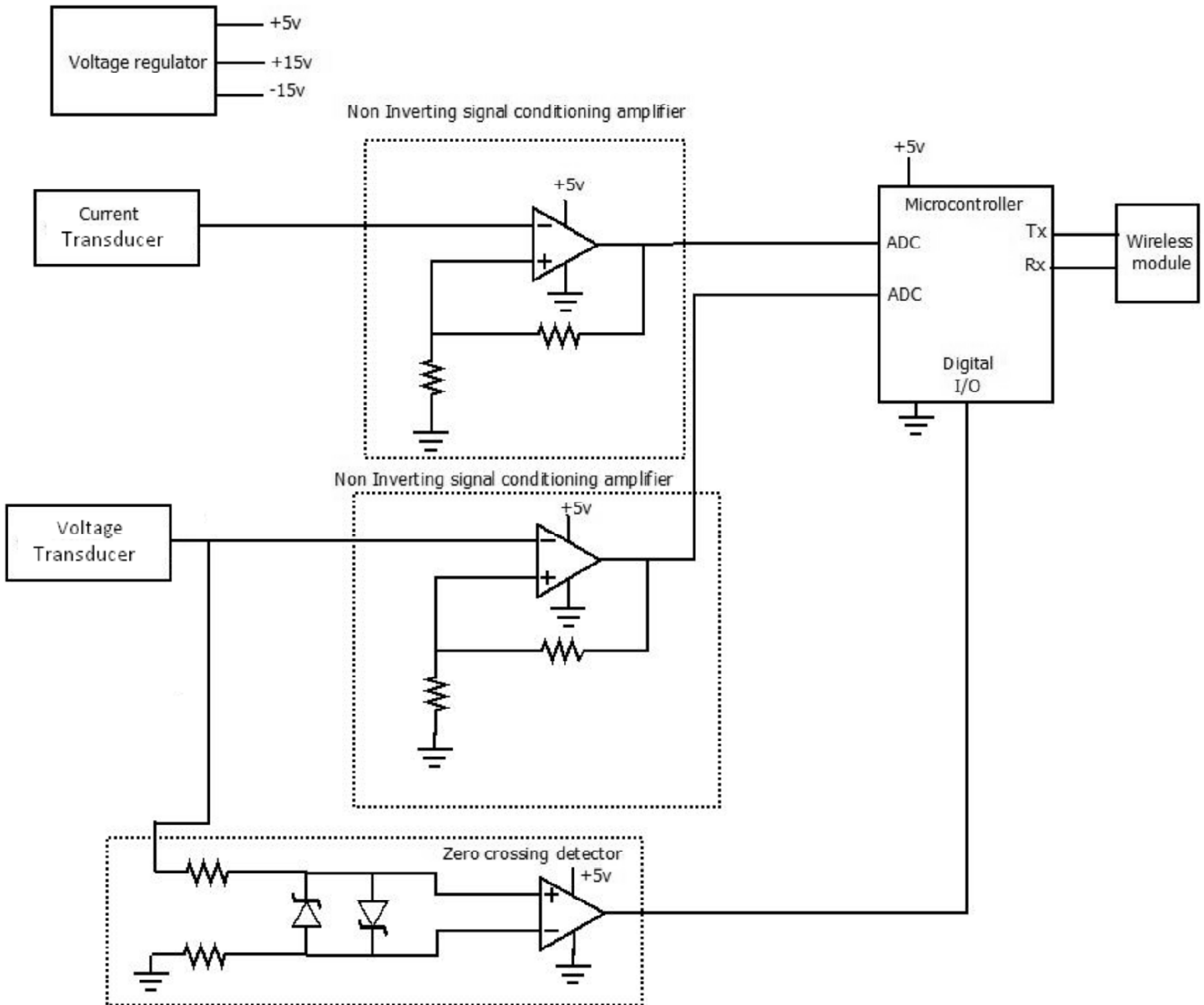

Figure 3: Block Diagram of Individual Sensor node

3. PROPOSED WIRELESS SENSOR NETWORK

There are two different networks created in this system. The first system is the implementation of a star topology as shown in Fig. 4.

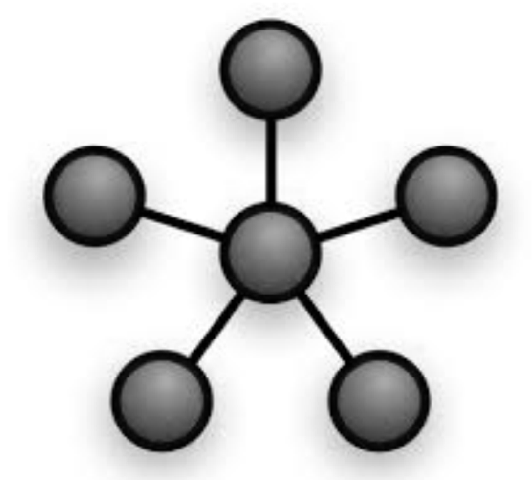

Figure 4: General Star Topology

A star network consists of a central computer, which acts as a conduit to transmit data to the other nodes. This node serves as the hub to which all other nodes are connected. The interconnection between the nodes is done wirelessly.

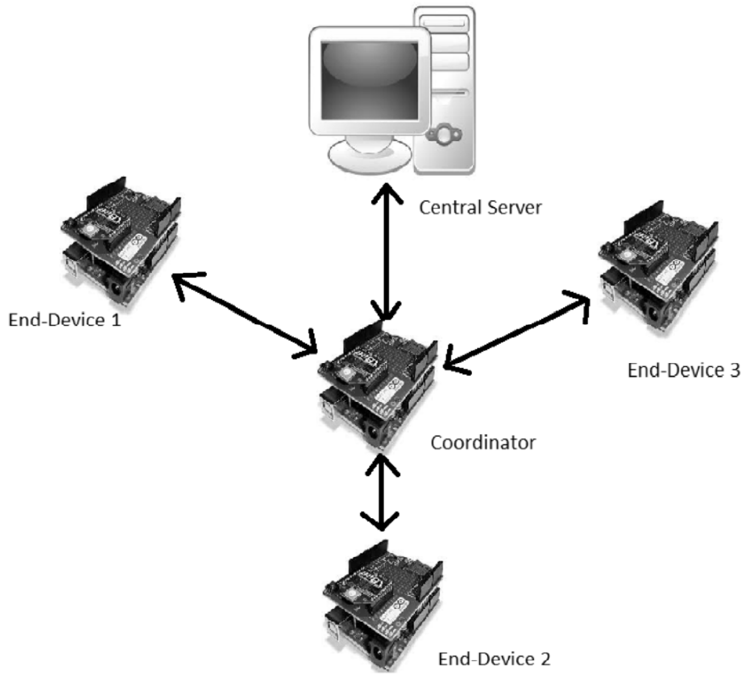

Figure 5: Star Topology of the implemented system

In the proposed system shown in Fig.5, there are 4 nodes in which 3 nodes are termed end devices (slaves) and one of them the coordinator (master). The end devices will acquire the line parameters from the 3 nodes in the system. Data acquired is transmitted in a wireless manner using Zigbee modules. The coordinator will be receiving data from all the end devices at the same instant and communicates with the main server. A delay of 2 seconds is given between the data transfer of sending and receiving, to avoid congestion of data reception.

A user-interface is created for the purpose of continuous monitoring. The values received by the central server are processed and computed for the power in each node. In the occasion of an abnormal condition, a fault diagnostic system is implemented.

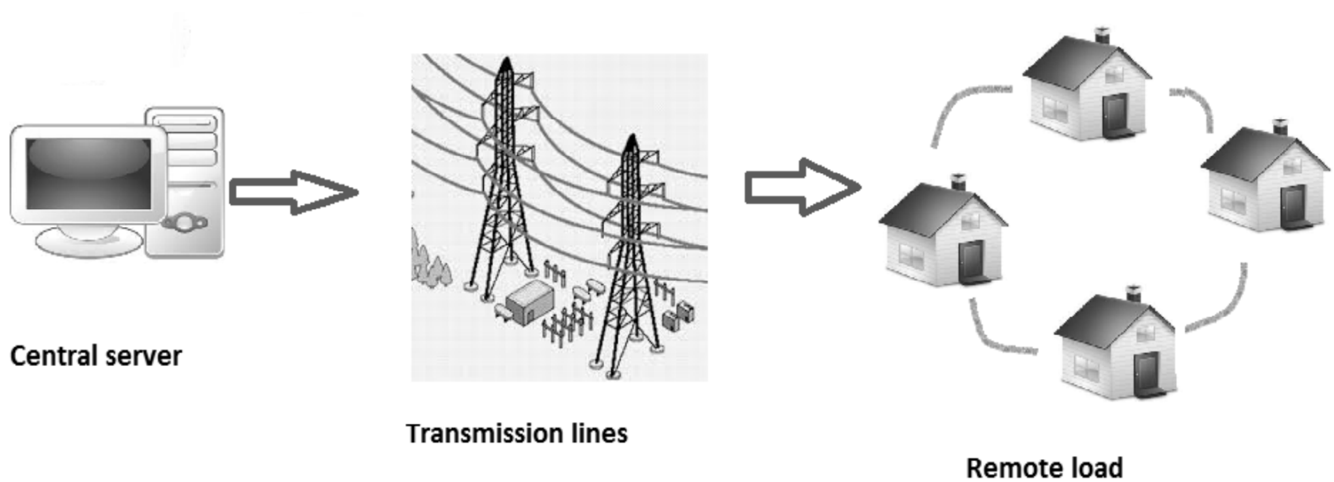

Figure 6: GSM Network

The system shown in Fig. 6 comprises of precisely two nodes, each with a GSM module. This method of communication can be used in systems that operate over a long range of distance.

One module is prearranged to remain at the server side, whereas the other module can measure the parameters at the load side. The sensed values are sent to the central server. This makes the system a Wireless Sensor Network, wherein, data acquisition, monitoring and fault diagnosis is done.

4. IMPLEMENTATION RESULTS AND DISCUSSION

A completely wireless smart grid network, consisting of 6 nodes are designed, implemented and tested for real time. The network is much more concentrated on customer side solutions. Load dispatch control according to the available power has been done using these wireless networks. The implemented prototype of the proposed architecture is shown in Fig. 7 and Fig. 8.

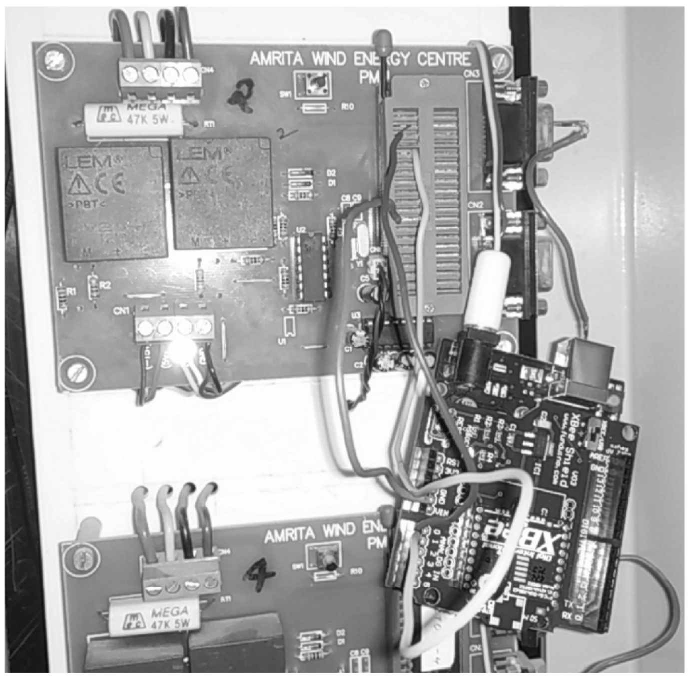

Figure 7: Individual sensor node

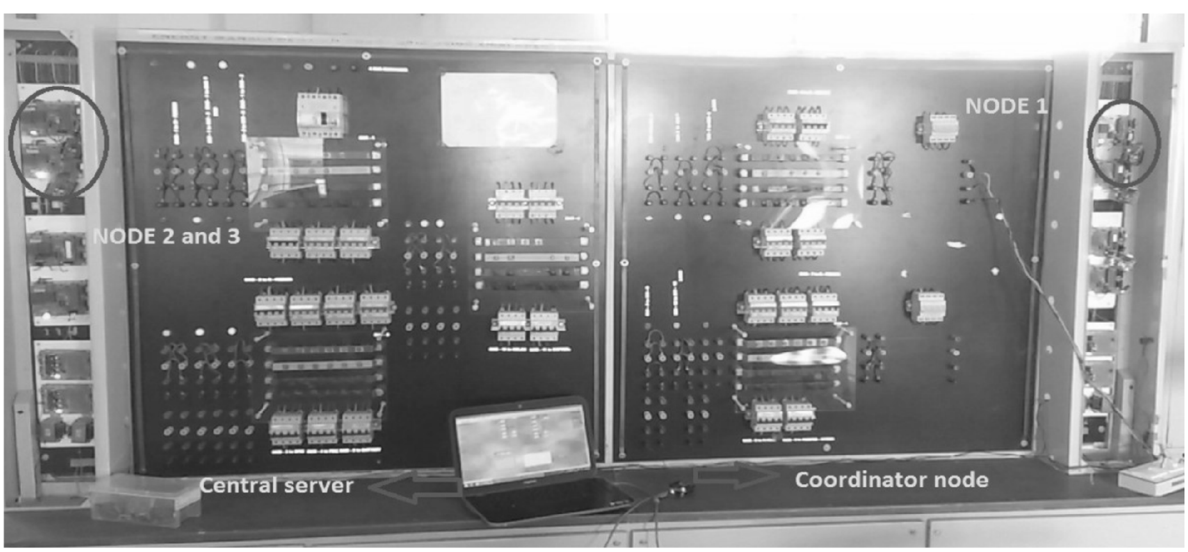

Figure 8: Smart grid prototype with implemented wireless sensor nodes

The parameters being measured have a significant effect on the fidelity of the system. Furthermore, the method of measurement of parameters, show the feasibility of a wireless system. Due to usage of Zigbee modules (2.4GHz band) for transmission of data, the speed of data transmission is very high and reliable. The GSM setup consisting of two nodes is a half-duplex mode of communication. The prototype in this project deals with monitoring a load, controlling and isolating under the occasion of a fault. As a prototype, the implementation is done on a single phase load, similarly, the concept can be applied to the larger industry on a bigger scale.

The interface developed for monitoring, shown in Fig.9, is an added aid to the network system. It simplifies the monitoring and control process. The employee at the substation can view the parameters on a continuous basis, and he/she is notified in the case of any fault condition. The node which identifies the fault condition does not transmit data to the server. With this information, the location of fault can be spotted, thereby achieving fault localization.

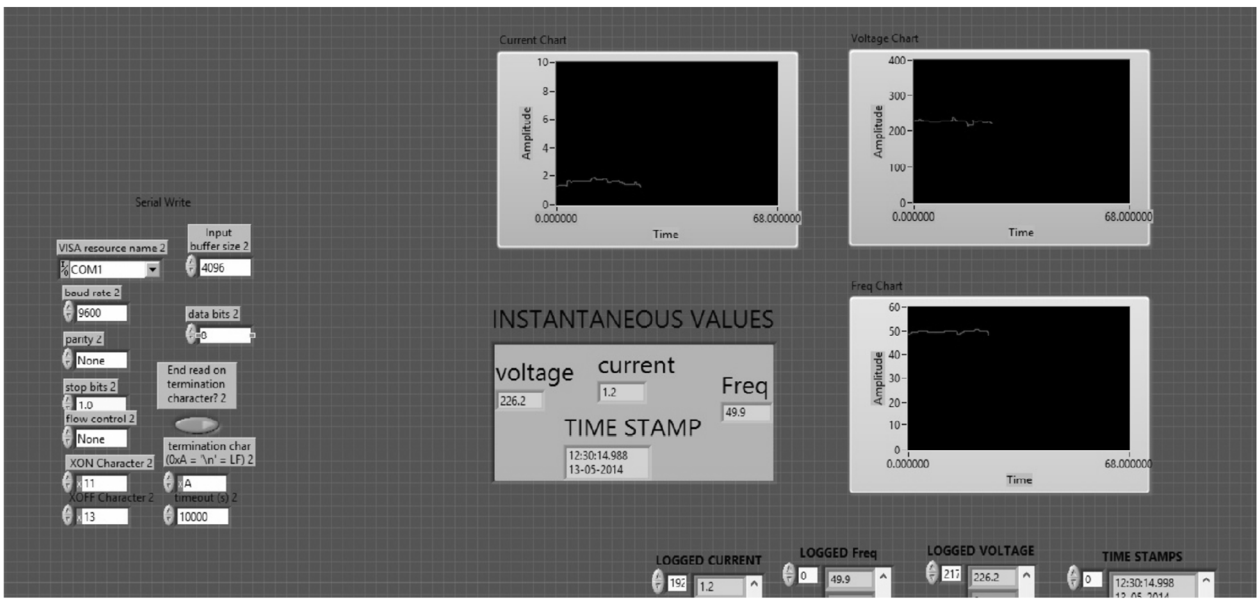

Figure 9: User interface at Central monitoring unit

5. CONCLUSIONS

In this paper, an architecture for remote monitoring system for smart grid using the wireless sensor network technology has been implemented. A prototype for wireless sensing module was designed and implemented for monitoring line parameters. The sensing nodes are calibrated and tested for the accuracy. The experimentation results show that the measured power matches the rated power in the smart grid hardware prototype. The calibrated sensing module along with the WSN node communicated the monitored parameters to the central server at periodic intervals. From the results, it is evident that the WSN may be successfully employed to smart grids for monitoring purpose.

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