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The Novel Multichip smart grid power sensing module

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Abstract

Smart grid technology is one of the recent developments in the area of electric power systems that aid the use of non-conventional sources of energy in parallel with the conventional sources of energy. Monitoring and control of smart grids is essential for its efficient and effective functioning. In this paper, we propose architecture for monitoring power in smart grid applications using wireless sensor network (WSN) technology. A prototype power sensing module is designed and developed to calculate the power for any kind of loads. Using WSN technology, the monitored power is communicated to the sink at periodic intervals. Multi hop wireless mesh network is set up using IRIS motes to enhance the communication between the power sensing nodes and the sink. The data collected is a rich source of repository for data analysis and modeling. A number of smart actions and applications, such as power theft detection, energy efficient building design, smart automation systems and smart metering can evolve out of the proposed model. A novel Power theft detection algorithm is proposed and simulated in this paper. The system is also scaled using GSM technology to extend the range of communication. Load monitoring can aid distributed architecture in smart grids with automated technology to switch between the non-conventional source of energy and the grid.

Keywords:multichip, smart grid, power sensing module.

1. Introduction

Improvements in power electronics technologies and utilization of renewable energy sources for power generation have given rise to the use of distributed generation and create concept of smart grids and micro grids to overcome rapid increase in the demands for electricity and depletion of conventional energy sources. Monitoring of power system parameters like voltage, current and power at distribution level is crucial for efficient functioning of smart grid.The power exchange between the smart grid and the utility grid happens by switching. This switching needs complete synchronism between the smart grid and the utility grid. An economic & reliable communication backbone along with accurate monitoring system is essential. Monitoring of the power system essentially has two main modules: communication module which is the backbone and the sensor module for sensing the different parameters like voltage, current and power. The basic communication architecture is simple and the actual network topologies can be very diverse and depend mostly on the field-level network. With respect to the communication requirements, several options are possible [1]-[4]. Wired communication with dedicated data networks connecting the field devices is one possibility. Dedicated wired data networks can be designed to fulfill the requirements, but the installation costs do not permit an intensive use [5].A less expensive option is wireless networks. Technologies for wireless local area networks or Personal Area Networks like IEEE 802.15.4 can, in principle, be used as a replacement for wired links [6, 7]. An alternate wireless technology is cellular networks as used in telecommunications, like global system for mobile communications (GSM) or general packet radio service (GPRS), or worldwide interoperability for microwave access (WiMAX). They have high coverage and low installation costs for the end devices if the infrastructure already exists [5].

The downside is the general dependency on the network provider if public telecommunication networks are used– regarding both costs for the communication channels and quality of service (QoS). A power line communication system is another popular method for communication [7]–[11]. They use the existing power cabling and need only moderate additional network elements but require a more complex technology in order to overcome the rather poor communication channel characteristics. This type of communication needs higher technical effort and cannot be used in case of a disaster where the power lines are disconnected. Recently, WSNs have been recognized as a promising technology that can enhance various aspects of today's electric power systems, including generation, delivery and utilization, making them a vital component of the next generation electric power systems, smart grids [12]. Wireless sensor networks in conjugation with SCADA have been implemented in wind power plants. The wireless sensor network can provide abundant, real-time data for wind driven generators' reliable running, guaranteeing the steady running of wind power plant [13].

ZigBee based WSN are proven to be more reliable in packet delivery due to mesh based multihop networking. The security of 802.15.4 is also proven better than many exiting protocols in the literature. Generally wireless sensor networks have the main constraints of battery power and scalability but these constraints are well addressed in new ZigBee based sensor networks with more sleep mode options and dynamic multihop algorithms. The proposed application is for smartgrids, so with little auxiliary charging circuit sensor networks can be made less energy independent.

In India context of application of WSNs to power systems, new ideas and implementation plans are coming up where various parameters in the system, etc., are being dealt with [14]. The harsh environments of the power systems need properly designed wireless modules along with efficient sensing elements. Generally sensing mechanism for measuring the voltages and currents in a power systems is to use potential transformers (PTs) and current transformers (CTs). This technology for sensing has proved itself over a long period of time in industry and in the field. The commonly available current sensors for higher ratings of current are magnetic core based CTs. In case of lower ratings, different transducers like the Hall-Effect current transducers are also available [15]. The usual method of measuring the voltages is by using the potential transformers. This paper focuses on proposing architecture for power monitoring system for smart grid applications using WSN technology. The mode of communication used is 802.15.4 protocol with a multi-hop network.

Multi-hop wireless communication extends the range of monitoring with the flexibility of easy installation of the monitoring system. A power sensing module is designed and developed to measure the active power consumption of any kind of load. In this paper, we also discuss an algorithm to detect power theft which is one of the novel applications using the proposed architecture of the WSN based power monitoring system. Rest of the paper discusses the system architecture for WSN based power monitoring, design of the sensing module, experimental results, discussion and finally the conclusion.

2. Related Work

We can use both wired and wireless technologies in MGs. Popular wired technologies are serial communication RS 232/422/485, power line communication, bus technology and Ethernet. On the other hand, popular wireless technologies are Wi-Fi, WiMax, ZigBee, cellular, radio frequency and microwave [3]. Wired technologies are more reliable and have higher data bandwidth however they add to already complex grid network and have costlier installation process. Wireless technologies are comparatively cheaper and suitable for remote location. They can also easily accommodate any future expansion needs. The cost of implementing a wired technology will be significantly high with every increasing number of meters, sensors and actuators. Hence, wireless technology is best suited for the purpose of MG applications even though they have lower data transmission rates [4]. The delay of the communication system is very crucial in MG applications and must be kept within acceptable limits. The processing time of ZigBee is about 400 – 600 µs, for transmitting three different data. ZigBee has two communication capabilities, i.e., reduce function device (RFD) and full function device (FFD). A RFD can communicate with end nodes like sensors, meters or actuators but it cannot communicate with other RFDs. Hence it acts as an end node. FFD can communicate with other FFDs as well as the sensors, meters or actuators. Hence it acts as a router [5].

3. Implementation

A. Block Diagram

The sensors, actuators and meters in the network can directly communicate with the local controller using analog to digital converters, serial communication or general purpose input output ports. The local controller can process this data and transmit it to the central controller through FFD. Alternatively, the sensors, actuators and meters can directly communicate with RFD which will transmit the data to the central controller. This is shown in Fig. 1(b). However, there will be no local data processing capability in second option.

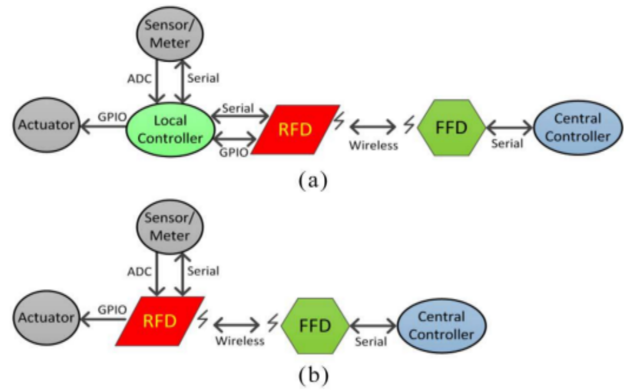

Fig. 1. (b) CB status and voltage/frequency data transfer to central controller throughRFD.

The connection between the end nodes like sensors, meters and actuators to the local controller is wired wherein local controller communicates to the central controller through a ZigBee FFD wireless node. The RFDs are known as reduced functionality devices and can only connect to end nodes, whereas the fully functional devices can also connect to other FFDs.

B. Communication Flow Chart

Due to huge number of end nodes involved, the micro grid communication system will have large number of data transmission. As ZigBee has limited rate of data transmission, a careful management of data flow is must such that the network bandwidth can handle the data traffic [6]. Real time data transfer is required only for the CB status. Other parameters like voltage magnitude, frequency and angle can be sent after a short interval of ΔT. This will reduce the data transmission through channel. To further reduce the data transmission, we can define acceptable limits for data variation such that the data will be transmitted only if it exceeds the defined limit ΔL. For example, data variation limit for frequency will be 49.5 to 50.5 Hz and for voltage, it will be 210 to 250 volts. Based on the interval and data variation value, the flow chart is shown in Fig. 2. Thus we can efficiently use ZigBee devices which have less data transmission bandwidth but are but are cheaper for mass use. The system is designed to have a dual handshake protocol for better reliability. Fig. 4 shows the communication sequence of data transfer between RFDs and FFDs. The coordinator of FFD sends a request for data transmission to RFD/FFD. Then, the RFD / FFD confirm the request by sending an ACK signal and the requested data. Once the complete data is received, the coordinator will send an ACK signal to the respective RFD/FFD. So both the nodes will have an acknowledgement of data increasing reliability of the system. Hence by using the time interval, data variation limit and dual handshake, we can achieve both low transmission rate as well as reliability of the data.

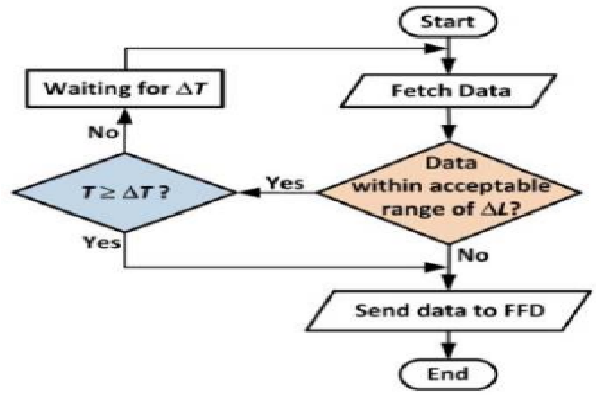

Fig. 2. Flow chart of the communication system.

4. Experimental Work

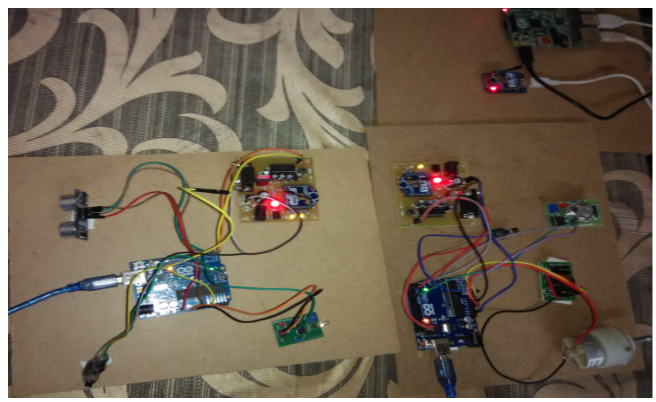

Fig 3: System Hardware Architecture1.

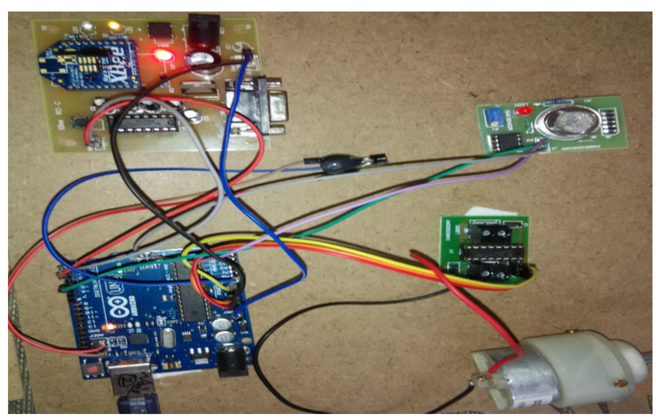

Fig 4: System Hardware Architecture2.

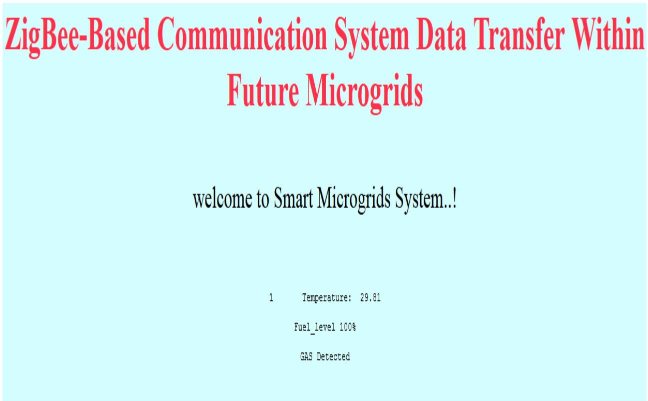

Fig 5: System Web welcomes Page.

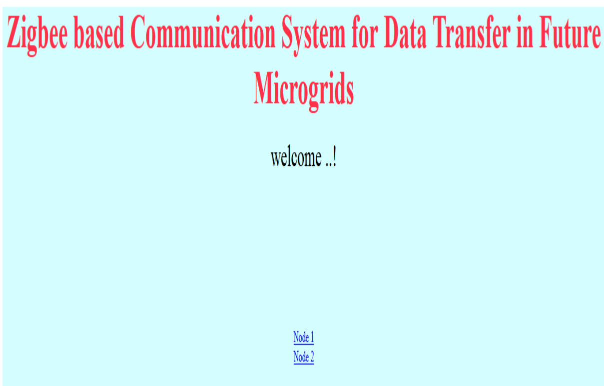

Fig 6: Web page along with Nodes1 and Node2.

5. Conclusion

In this paper, architecture for power monitoring system using the wireless sensor network technology is proposed. Multi-hop mesh network was set up for long range and reliable wireless communication. A prototype for power sensing module was designed and developed for monitoring single phase system. The sensing module is calibrated and tested for the accuracy. The experimentation performed shows that the measured power almost matches the rated power. The calibrated sensing module along with the WSN node communicated the monitored power value to base/sink at periodic intervals. With appropriate scaling this model can be extended to distribution systems also. It is clear from the experimentations that the wireless sensor networks may be successfully employed to smart grids for monitoring purpose. With proper design we also show that WSN can be employed to mitigate power theft and can be effectively used for monitoring the all costly electrical equipment as part of maintenance. For large scale deployment, cost effective power monitoring system is essential, which requires a reliable and low cost WSN mote design. This system can be extended for smart home automation, online billing and smart metering applications also. This can also be further extended for complete distribution system monitoring with the monitoring of transformers' temperature, oil levels, over-loading, etc.

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