Smart Grid with Data Integration and Protection Using ZigBee

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Abstract: ***Smart grid the next generation electric power system is effective way of digital transmission of electricity. It is a digital technology that allows two way communications between utility and customers. We provide a system model that will monitor critical asset parameters such as current, voltage and temperature. A smart grid sensor is a small, low cost lightweight node that serves as a detection station in a sensor network. These sensors enable the remote monitoring of equipment such as transformers and power lines. They are improving the performance and extending the life of grid components to ensure a safe and reliable operation of the electricity network. Use of ZigBee based communication protocol make system more reliable. A lot of research is now going on the various issues and challenges on the real monitoring of power line parameters using smart grid based sensors. The used of smart grid for real time monitoring of power line parameters is the now become interest of research. This paper discussed network architecture and different design aspects for implementation of smart grid based monitoring network using smart sensors.***

Keywords: Smart Grid Technologies, ZigBee

1. Introduction

Today's electrical infrastructure has remained unchanged for about a hundred years. The components of the grid are near to the end of their lives. While the electrical grid has been ageing, the demand for electricity has gradually increased. According to the U.S. Department of Energy report, the demand and consumption for electricity in the U.S. have increased by 2.5 % annually over the last twenty years [1]. Today's electric power distribution network is very complex and ill-suited to the needs of the twenty-first century. Among the deficiencies are lacks of automated analysis, poor Visibility, mechanical switches causing slow response times, lack of situational awareness, etc. These have contributed to the blackouts happening over the past 40 years. Some additional inhibiting factors are the growing population and demand for energy, the global climate change, equipment failures energy storage problems, the capacity limitations of electricity generation, one-way communication, decrease in fossil fuels and resilience problems [4]. Also, the greenhouse gas emissions on Earth have been a significant threat that is caused by the electricity and transportation industries [5].Consequently, a new grid infrastructure is urgently needed to address these challenges. To realize these capabilities, a new concept of next generation electric power system, the smart grid, has emerged. The smart grid is a modern electric power grid infrastructure for improved efficiency, reliability and safety, with smooth integration of renewable and alternative energy sources, through automated control and modern communications technologies [1], [10]. Renewable energy generators seem as a promising technology to reduce fuel consumption and greenhouse gas emissions [6]. Importantly, smart grid enabling new network management strategies provide their effective grid integration in Distributed Generation (DG) for Demand Side Management and energy storage for DG load balancing, etc. [7], [8].Renewable energy sources (RES) are widely studied by many researchers [9] and the integration of RES, reducing system losses and increasing the reliability, efficiency and security of electricity supplies to customers are some of the advances that smart grid system will increase [11]. Different components of the system are linked together with communication paths and sensor nodes to provide interoperability between them, e.g., distribution, transmission and other substations, such as residential, commercial and Industrial sites. In the smart grid, reliable and real-time information becomes the key factor for reliable delivery of power from the generating units to the end-users. The impact of equipment failures, capacity constraints, and natural accidents and catastrophes, which cause power disturbances and outages, can be largely avoided by online power system condition monitoring, diagnostics and protection [1]. To this end, the intelligent monitoring and control enabled by modern information and communication technologies have become essential to realize the envisioned smart grid [1], [13].

2. Smart Grid

Smart Grid (SG) is defined as the power grid integrated with a large network. The SG is the combination of billions of smart objects: smart appliances, smart meters, actuators and sensors. The term grid is used for an electricity system that may support all or some of the following four operations: electricity generation, electricity transmission, electricity distribution, and electricity control.

A smart grid (SG), also called smart electrical/power grid, intelligent grid, intelligrid, future grid, intergrid, or intragrid, is an enhancement of the 20th century power grid. The traditional power grids are generally used to carry power from a few central generators to a large number of users or customers. In contrast, the SG uses two-way flows of electricity and information to create an automated and distributed advanced energy delivery network. By utilizing modern information technologies, the SG is capable of delivering power in more efficient ways and responding to wide ranging conditions and events. Broadly stated, the SG could respond to events that occur anywhere in the grid, such as power generation, transmission, distribution, and consumption, and adopt the corresponding strategies. In general, ZigBee offers better capabilities over Wi-Fi with

Respect to energy consumption in sensor based mesh network. Even though ZigBee has low data rate. When co-existing with Wi-Fi, it is proposed by many Researchers in various applications of SG where urgent and critical Data demand is notcrucial [14]. Based on these researchers, the communication back bone of the SG which links the DR Gand the control center should be wired-line. Testing company have tested ZigBee implementation in solar, wind, and also home energy management system where in general no significant interference with other transmission and power signal is detected. However, there are some researches that have addressed the Interference problem between ZigBee and Wi-Fi and have it resolved. A delay sensitive data of wind turbine are Monitored through ZigBee-Wireless Sensor (WS) for ensuring that DRG detects the in accuracyies of the system. The performance Of 15 ZigBee WSN nodes is an alyzedunder different spectrum Environments and concluded based on statistical analysis that ZigBee –WS can only be utilized in lower requirement of data rate and power application of SG [14]. It has proposed smart energy distribution and management system where ZigBee is particularly used for controlling and remotes consumer side load. ZigBee in addition to Wi-Fi, 3Gand Power Line Communication (PLC) are used for maintaining communication between appliances. ZigBee based home automation System or smart home monitor in ghas already been implemented few years before and found flexible, effective, feasible, and secured. ZigBee for demand response can meet the real-time data import service requirement in build in automation. ZigBee based embedded technology has achieve deficient Monitoring and transmission system where different parameters in industrial application are measured namely; vibration, temperature, electricity, and gas sensing. Similar demand response under home energy management system is implemented and evaluated practically in Spain where one of the communication modesis ZigBee. We are motivated by this trend of using ZigBee technology to consider it .The goal of unique vision of smart transmission grid is to promote technology innovations to deliver reliable, flexible, continuous, inexpensive and sustainable electric power to consumers. It also provides some of the important features such as:

i. Greater flexibility in monitor, operation and expansion.
ii. Development in embedded intelligence.
iii. Sustainability and reliability of the grids.
iv. Improve customer benefits.
v. Provides quality of service.

3. Zigbee

ZigBee was developed by the ZigBee Alliance, a world-wide industry working group that developed standardized application software on top of the IEEE wireless standard. So it is an open standard. The power measurement application encompasses many services and appliances within the home and workplace, all of which need to be able to communicate with one another. Therefore, open standards architecture is essential. Open standards provide true interoperability between systems. Open standards also help to future-proof investment made by both utilities and consumers. Using an open protocol typically reduces costs implementing: there are no interoperability problems to solve, and manufacture costs tend to be lower .ZigBee also provides strong security capabilities to prevent mischief, and is extremely tolerant interference from other radio devices, including Wi-Fi and Bluetooth. ZigBee- enabled meters form a complete mesh network so they can communicate with each other and route data reliably and the ZigBee network can be easily expanded as new homes are built or new services need to be added. Zigbee modules feature a UART interface, which allows any microcontroller or microprocessor to immediately use the services of the Zigbee protocol. All a Zigbee hardware designer has to do in this case is ensure that the host's serial port logic levels are compatible with the XBee's 2.8- to 3.4-V logic levels. The logic level conversion can be performed using either a standard RS-232 IC or logic level translators such as the 74LVTH125 when the host is directly connected to the XBee UART. The X- Bee RF Modules interface to a host device through alogic-level asynchronous Serial port. Through its serial port, the module can communicate with any logic and voltage Compatible UART; or through a level translator to any serial device. Data is presented to the X-Bee module through its DIN pin, and it must be in the asynchronous serial format, which consists of a start bit, 8 data bits, and a stop bit. Because the input data goes directly into the input of a UART within the X-Bee module, no bit inversions are necessary within the asynchronous serial data stream. All of the required timing and parity checking is automatically taken care of by the X-Bee's UART.

4. Zigbee vs Bluetooth

Table 1: Bluetooth

• Targets medium data rate continuous duty
• 1Mbps over the air,700kbps best case data transfer
• Battery life in days only
• File transfer, streaming telecom audio
• Point to multipoint networking
• Network latency(Typical)
• New slave enumeration-20s
• Sleeping slave changing to active -3s
• Uses frequency hopping technique

Table 2: ZigBee:

• Targets low data rate ,low duty cycle
• 250Kbps over the air,60-115Kbps typical data transfer
• Long battery life(in years)
• More sophisticated networking best for mesh networking
• Network latency (typical) • New slave enumeration
• Sleeping slave changing to active
• Mesh networking allows very reliable data transfer
• Uses direct spread spectrum technique
• 2 to 65535 devices per network
• SIMPLE PROTOCOL

ZigBee is a wireless communications technology that is relatively low in power usage, data rate, complexity and cost of deployment. It is an ideal technology for smart lightning, Energy monitoring, home automation and automatic meter Reading, etc. ZigBee and ZigBee Smart Energy Profile (SEP) Have been realized as the most suitable communication standards for smart grid residential network domain by the U.S National Institute for Standards and Technology (NIST) [18]. The communication between smart meters, as well as among intelligent home appliances and in home displays, is very important. Many AMI vendors, such as Itron, Elster, and Landis Gyr, prefer smart meters, that the ZigBee protocol can Be integrated into. ZigBee integrated smart meters can communicate with the ZigBee integrated devices and control them. ZigBee SEP provides utilities to send messages to the home owners, and home owners can reach the information of their real-time energy consumption.

4.1 Advantages

ZigBee has 16 channels in the 2.4 GHz band, each with 5 MHz of bandwidth. 0 dBm (1 mW) is the maximum output power of the radios with a transmission range between 1 and 100 m with a 250 Kb/s data rate and OQPSK modulation. ZigBee is considered as a good option for metering and energy management and ideal for smart grid implementations along with its simplicity, mobility, robustness, low bandwidth requirements, low cost of deployment, its operation within an unlicensed spectrum, easy network implementation, being a standardized protocol based on the IEEE standard . ZigBee SEP also has some advantages for gas, water and electricity utilities, such as load control and reduction, demand response, real-time pricing programs, real-time system monitoring and advanced metering support.

4.2 Disadvantages

There are some constraints on ZigBee for practical implementations, such as low processing capabilities, small memory size, small delay requirements and being subject to interference with other appliances, which share the same transmission medium, license-free industrial, scientific and medical (ISM) frequency band ranging from IEEE wireless local area networks (WLANs), WiFi, Bluetooth and Microwave . Hence, these concerns about the robustness of ZigBee under noise conditions increase the possibility of corrupting the entire communications channel due to the interference in the vicinity of ZigBee. Interference detection schemes, interference avoidance schemes and energy-efficient routing protocols, should be implemented to extend the network life time and provide a reliable and energy-efficient network performance.

5. Proposed System

The Hardware implementation divided into following sections:

- Microcontroller – Arduino Mini Pro
- ZigBee – S1/S2 Series module
- Current Sensor
- Voltage Sensor
- 16x2 LCD Display
- Relay and driver IC ULN 2803

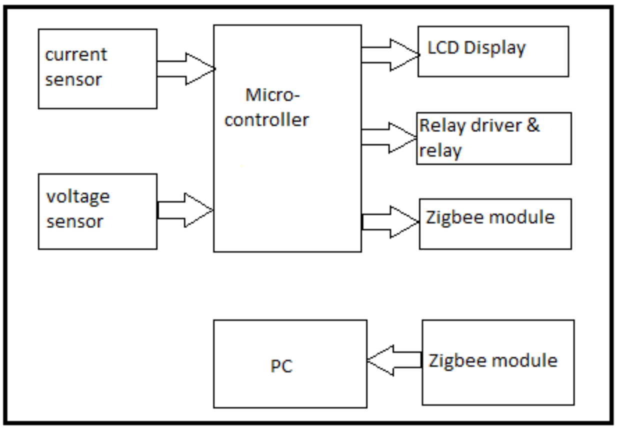

Figure 1: Complete block diagram of proposed system

The hardware description as follows:
Microcontroller – Arduino Mini Pro:
The microcontroller is a complete microprocessor system built on a single integrated circuit. Microcontrollers were developed with the purpose to build a complete microprocessor system that substantially reduces the cost of building simple products. Microcontrollers are named as they perform control functions. The microcontroller is very commonly used in variety of intelligent products. The Arduino Pro Mini is an ATmega168 based microcontroller board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 8 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. The board can be connected to the PC using USB port and the board can runs on USB power.There are two version of the Pro Mini. One runs at 3.3V and 8 MHz, the other at 5V and 16 MHz

5.1 ZigBee – S1/S2 Series module:

These are very popular ISM 2.4GHz ZigBee modules. These modules take the 802.15.4 stack (the basis for ZigBee) and wrap it into a simple to use serial command set. S1 series modules work on protocol & S2 series work on ZIGBEE protocol. You cannot mix S1 with S2. ZigBee modules can give communication range of 30 meters indoor or 100 meters outdoor.

Features:
- 3.3V , 40mA
- 250kbps Max data rate
- 2mW output (+3dBm)
- 400ft (120m) range
- Built-in antenna
- Fully FCC certified
- 6 10-bit ADC input pins
- 8 digital IO pins
- 128-bit encryption
- Local or over-air configuration
- AT or API command set

5.2 ASC Current Sensor

Sensing and controlling current flow is a fundamental requirement in a wide variety of applications including, over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, etc. One of the simplest techniques of sensing current is to place a small value resistance (also known as Shunt resistor) in between the load and the ground and measure the voltage drop across it, which in fact, is proportional to the current flowing through it.

5.3 16X2 LCD display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

5.4 ULN2003 Relay driver

The ULN2003A is an array of seven NPN Darlington transistors capable of 500 mA, 50 V output. It features common-cathode fly back diodes for switching inductive loads. It can come in PDIP, SOIC, SOP or TSSOP packaging. In the same family are ULN2002A, ULN2004A, as well as ULQ2003A and ULQ2004A, designed for different logic input levels.

Features:
- 500-mA-Rated Collect or Current (Single Output)
- High-Voltage Outputs: 50 V
- Output Clamp Diodes
- Inputs Compatible With Various Types of Logic
- Relay-Driver Applications

6. Conclusion

The information technology infrastructure used to control the several assets and infrastructure layers of the Smart Grid plays an important role in the Layered Smart Grid. A criterion to a suitably choice was to look for the information technology infrastructure being less information and processing demanding. Several field tests were carried out in order to test the operability of the existing information technologies already available in the market, particularly this paper reports on the ZigBee standard. The field tests allow concluding that the ZigBee standard information technology is a more powerful one than the existing Smart Grid scientific literature proposals, showing enough stability and reliability in order to perform as the convenient choice for the information technology in order to control the Layered Smart Grid architecture.

Acknowledgment

The authors would like to thankful to my parents and teachers for their motivation and support.

References

[1] V.C. Gungor, B. Lu, G.P. Hancke, “Opportunities and Challenges Of Wireless Sensor Networks in Smart Grid," IEEE on Trans. Ind. Electron., vol. 57, no. 10, pp. 3557-3564, October 2010. I, II

[2] V.C. Gungor, G. Hancke, "Industrial Wireless Sensor Networks: Challenges, Design Principles, and Technical Approaches," IEEE Trans. on Industrial Electronics, vol. 56, no. 10, pp. 4258- 4265,October 2009. III-C

[3] B Lu, V.C. Gungor, "Online and Remote Energy Monitoring and Fault Diagnostics for Industrial Motor Systems using Wireless Sensor Networks," IEEE Trans. on Industrial Electronics, vol. 56, no. 11, November 2009. II-A1

[4] M. Erol-Kantarci, H.T. Mouftah, "Wireless multimedia sensor and actor networks for the next generation power grid" Ad Hoc Networks, vol. 9, no. 5, pp. 542-551, June 2011

[5] A.Y. Saber ,G .K. Venayagamoorthy, "Plug-in Vehicles and Renewable Energy Sources for Cost and Emission Reductions,"IEEE Trans. on Industrial Electronics, vol.58, no.4, pp.1229-1238, April 2011.

[6] D. Lu, H. Kanchev, F. Colas, V. Lazarov, B. Francois, "Energy management and operational planning of a microgrid with a PV-based active generator for Smart Grid Applications," IEEE Trans. on Industrial Electronics, Digital Object Identifier: 10.1109/TIE.2011.2119451. I

[7] P. Palensky, D. Dietrich, "Demand Side Management: Demand Response, Intelligent Energy Systems, and Smart Loads," IEEE Trans. on Industrial Informatics, Inf., vol. PP, No. 99, Digital Object Identifier: 10.1109/TII.2011.2158841

[8] V. Calderaro, C. Hadjicostis, A. Piccolo, P. Siano, "Failure Identification in Smart Grids based on Petri Net Modeling," IEEE Trans. On Industrial Electronics, Digital Object Identifier:10.1109/TIE.2011.2109335. I

[9] C. Cecati, C. Citro, P. Siano, “Combined Operations of Renewable Energy Systems and Responsive Demand in a Smart Grid ,”IEEE Trans. on Sustainable Energy, in press. Digital Object Identifier: 10.1109/TSTE.2011.2161624

[10] P. Siano, C. Cecati, C. Citro, P. Siano, “Smart Operation of Wind Turbines and Diesel Generators According to Economic Criteria,” IEEE Trans. on Industrial Electronics, vol.58, no. 10, pp.—— (in press) Digital Object Identifier:10.1109/TIE.2011.2106100

[11] A. Vaccaro, G. Velotto, A. Zobaa, "A Decentralized and Cooperative Architecture for Optimal Voltage Regulation in Smart Grids," IEEE Trans. on Industrial Electronics,, Digital Object Identifier: 10.1109/TIE.2011.2143374.

[12] D. Dietrich, D. Bruckner, G. Zucker, P. Palensky, , "Communication and Computation in Buildings: A Short

Introduction and Overview," IEEE Trans. on Industrial Electronics,, vol.57,no.11, pp.3577-3584, Nov. 2010

[13] V.C. Gungor, F. C. Lambert, "A Survey on Communication Networks for Electric System Automation," Computer Networks, vol. 50, pp. 877-897, May 2006

[14] S. Paudyal, C. Canizares, K. Bhattacharya, "Optimal Operation of Distribution Feeders in Smart Grids," IEEE Trans. on Industrial Electronics, Digital Object Identifier:10.1109/TIE.2011.2112314

[15] D. M. Laverty, D. J. Morrow, R. Best, P. A. Crossley, "Telecommunications for Smart Grid: Backhaul solutions for the distribution network," IEEE Power and Energy Society General Meeting, pp. 1-6, 25-29 July 2010

[16] L. Wenpeng, D. Sharp, S. Lancashire, "Smart grid communication network capacity planning for power utilities," IEEE PES, Transmission and Distribution Conference and Exposition, pp.1-4, 19-22 April 2010

[17] Y. Peizhong, A. Iwayemi, C. Zhou, "Developing ZigBee Deployment Guideline under Wi-Fi Interference for Smart Grid Applications," IEEE Trans. on Smart Grid, vol.2, no.1, pp. 110-120, March 2011

[18] C. Gezer, C. Buratti,"A ZigBee Smart Energy Implementation for Energy Efficient Buildings," in Proc. of IEEE Vehicular Technology Conference (VTC Spring), 73rd , vol., no., pp.1-5, 15-18 May 2011

[19] R. P. Lewis, P. Igic and Z. Zhongfu, "Assessment of communication methods for smart electricity metering in the U.K.," in Proc. of IEEE PES/IAS Conference on Sustainable Alternative Energy (SAE), pp. 1-4, Sept. 2009

[20] A. Yarali, "Wireless Mesh Networking technology for commercial and industrial customers," in Proc. of Electrical and Computer Engineering, CCECE 2008

[21] K. Rajendra Prasad, Arun Alla "Smart monitoring and controlling system for power management using Zigbee Volume 5,Issue 5 October 2016