ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(43), DOI: 10.17485/ijst/2016/v9i43/104392, November 2016* ISSN (Online) : 0974-5645

Design and Implementation of Remote Wireless Monitoring and Control of Smart Power System using Personal Area Network

L. Chhaya[1]*, P. Sharma[1], G. Bhagwatikar[2] and A. Kumar[1]

[1]Department of Electronics, Instrumentation and Control Engineering. University of Petroleum and Energy Studies, Dehradun – 248001, India; lipi.chhaya@gmail.com, paawan.sharma@ddn.upes.ac.in, adeshkumar@ddn.upes.ac.in
[2]Sany Group, Pune, India; gowind.india@gmail.com

Abstract

The most essential requirement of empowerment is energy. Smart grid technology is a significant leap towards reliable and consistent electricity. Integration of information and communication technologies is a vital part of smart grid progress. Smart grid communication infrastructure is a hierarchical network integrating heterogeneous set of communication standards and technologies. Microgrid plays an important role as a strategic component of smart grid as it enables the use of renewable energy resources. It can resolve the issues like unelectrified villages, electricity theft, depletion of fossil fuels, Green House Gas (GHG) emissions and greenhouse effect. Smart microgrid can operate on both island as well as grid connected mode. It also contains various hierarchical communication networks for monitoring and control of complete system. This paper describes an experimental investigation of wireless monitoring and control of smart microgrid prototype using IEEE 802.15.1 based low power Personal Area Network.

Keywords: Bluetooth, Communication, Energy Monitoring and Control, Home Automation, IEEE 802.15.1, Microgrid, Renewable energy, Smart Grid, Solar Photovoltaic, Wireless.

1. Introduction

Smart grid is the most radical technology of contemporary era. An electric 'Grid' is a network that carries electricity from power plants to customers. The grid is made 'smart' or 'intelligent' as it can monitor and control the entire distribution system. Smart Grid is an automated and broadly distributed energy generation, transmission and distribution network. It is characterized by bidirectional flow of electricity and information. It is a close loop system for monitoring and response. Supervisory Control and Data Acquisition (SCADA) system is an integral part of Smart Grid system. Integration of renewable energy resources will lead to reduced carbon footprint and emissions[1,2]. Smart Grid can be defined in various ways as per its functional, technological or beneficial facets. As per the definition given by U.S. department of energy[3], "A smart grid uses digital technology to improve consistency, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources." Smart grid technology ensures reliable, efficient, resilient and advanced energy distribution system with enormous features. It is an intelligent power grid with integration of various alternative and renewable energy resources by using automated monitoring, data acquisition, control and emerging communication technologies. Application of diverse set of communication standards requires analysis and optimization depending upon requirements. These requirements can be decided on the basis of area of coverage, application, bandwidth requirement,

* *Author for correspondence*

security aspects etc. Hierarchical communication networks can be characterized as Home Area Networks (HANs), Neighbourhood Area Networks (NANs) and Wide Area Networks (WANs) as per the applications of communication technologies at various levels of deployment of smart grid. The proposed prototype is designed for the management of energy distribution in HAN. A consumer can choose the type of source manually or it can be automatically changed on the basis of load requirement. The prototype is developed for data logging as well as control purpose.

2. Concept of IEEE 802.15.1 based Smart Power System for Home Area Network

Smart home system comprises of renewable energy sources, consumer appliances, and communication network with smart sensors. Smart Grid technology is beneficial for consumer in many aspects such as monitoring and control of energy usage, time of the day billing cycle, remote control of appliances, and completely secured home automation. Plug in hybrid electric vehicle can also be used with battery storage facility in home microgrid system. Consumer electronics appliances communicate their energy consumption statistics to central or main home monitor and regulator or smart meter. Central regulator or smart meter sends it to the central electricity grid for monitoring, control, fault detection and billing purposes. Consumer has a choice to operate on a specific energy source for optimization of billing cycle and energy usage. Moreover, intermittent behaviour of renewable energy resource demands for other alternatives of power system. The Home Area Networks (HANs) ranges for the coverage area of few meters. IEEE 802.15.1 (Bluetooth), IEEE 802.15.4 (Zigbee), IEEE 802.11 (WLAN/Wi-Fi), IEEE 802.16 (WiMAX) etc. technologies and standards can be used for Home area networks[4-8]. The proposed system uses Bluetooth protocol. Bluetooth is a short distance wireless communication technology based on IEEE 802.15.1 standard [8-10]. It uses short wavelength wireless transmission in the unlicensed Industrial, Scientific and Medical (ISM) band from 2400 MHz to 2480 MHz. It uses frequency hopping spread spectrum (FHSS) technology with around 1600 hops per second. Its key features are extensive availability, low power consumption and rapid data exchange. Bluetooth was initially developed in 1994 by Ericsson and then a group of firms formed a special interest group to retain and improve this technology. There are two network topologies used in Bluetooth which are termed as Piconet and Scatternet. Piconet is a Personal Area Network in which one wireless client acts as a master and additional wireless clients serve as slaves. Maximum eight devices can communicate with each other in one Piconet. Scatternet is a group of Piconets. Bluetooth is used for communications between smart consumer appliances, energy management system and smart meters. It has peak data throughput of 1 Mbps, 79 radio frequency channels, and channel bandwidth of 1 MHz. It has a nominal range of around 10 to 100 meters[11-13].

3. Comprehensive Design of Proposed Prototype

The developed prototype is designed for smart power system. It consists of load operating on grid, solar photovoltaic system or battery. The behavior of proposed system is wirelessly monitored and controlled by user. Figure 1 shows the block diagram of developed prototype.

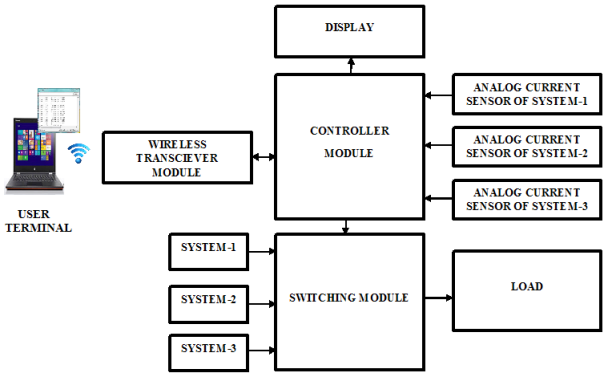

Figure 1. Block diagram of developed prototype.

The designed prototype is developed for data acquisition and control purpose. It uses IEEE 802.15.1 standard for short distance wireless communication. The prototype is controlled by ATMEGA28P microcontroller. In the proposed energy management prototype, three energy sources are considered. Depending upon the threshold current value, the load will be switched between grid, solar PV or battery. The sensors use Hall

Effect principle. Sensitivity of ACS 712-30A sensors used in the prototype is 66 mV/A. Microcontroller controls the switching operation through relay module. HC-05 is a Bluetooth serial port protocol module which communicates with user terminal. Serial port Bluetooth module is highly competent Bluetooth V2.0 + EDR (Enhanced Data Rate) of 3 Mbps. It works in 2.4 GHz ISM (Industrial, Scientific and Medical) band which is an unlicensed band. Figure 2 and Figure 3 show the circuit diagram as well as snapshot of actual readings of prototype respectively.

The proposed prototype can work in both automatic as well as manual mode. In automatic mode, load will be served and switched on the basis of sensed threshold current value set by the user. During manual mode, the user can select any one system to serve the load. The system is working successfully in the range of around 50-60 meters. User can receive, monitor the data and control the system on serial terminal. Figure 4 shows the flow charts of wireless remote monitoring and control

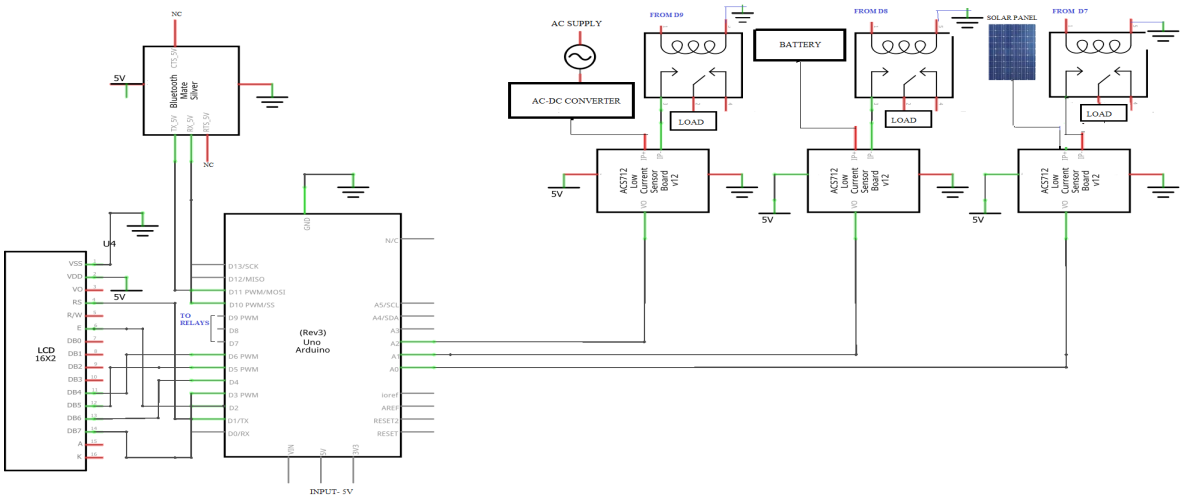

Figure 2. Circuit diagram of the system to be monitored and controlled.

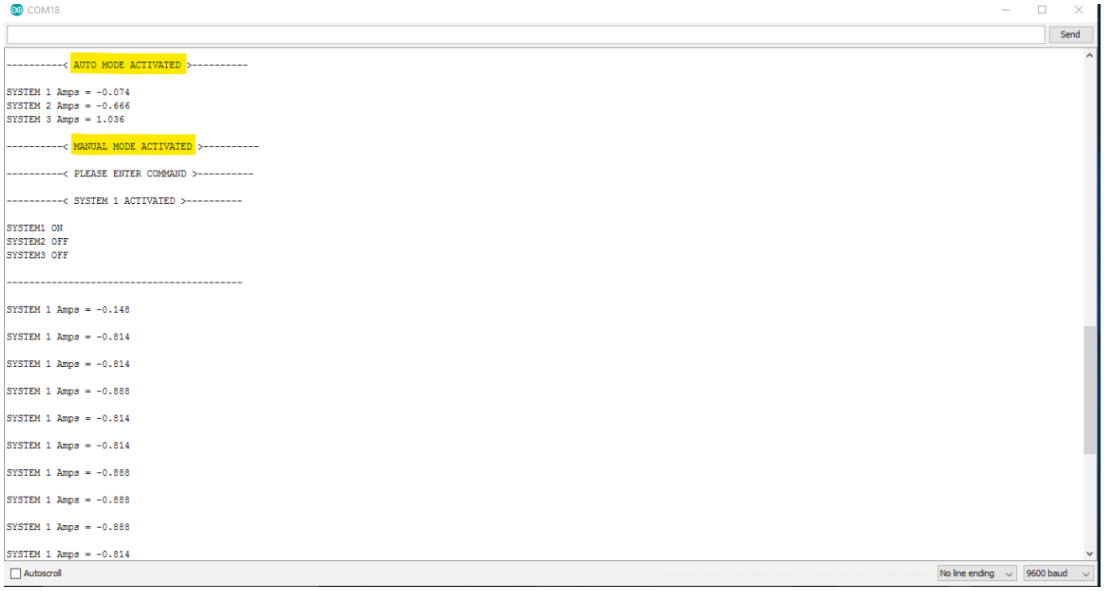

Figure 3. Snapshot of monitoring and control operation of proposed prototype.

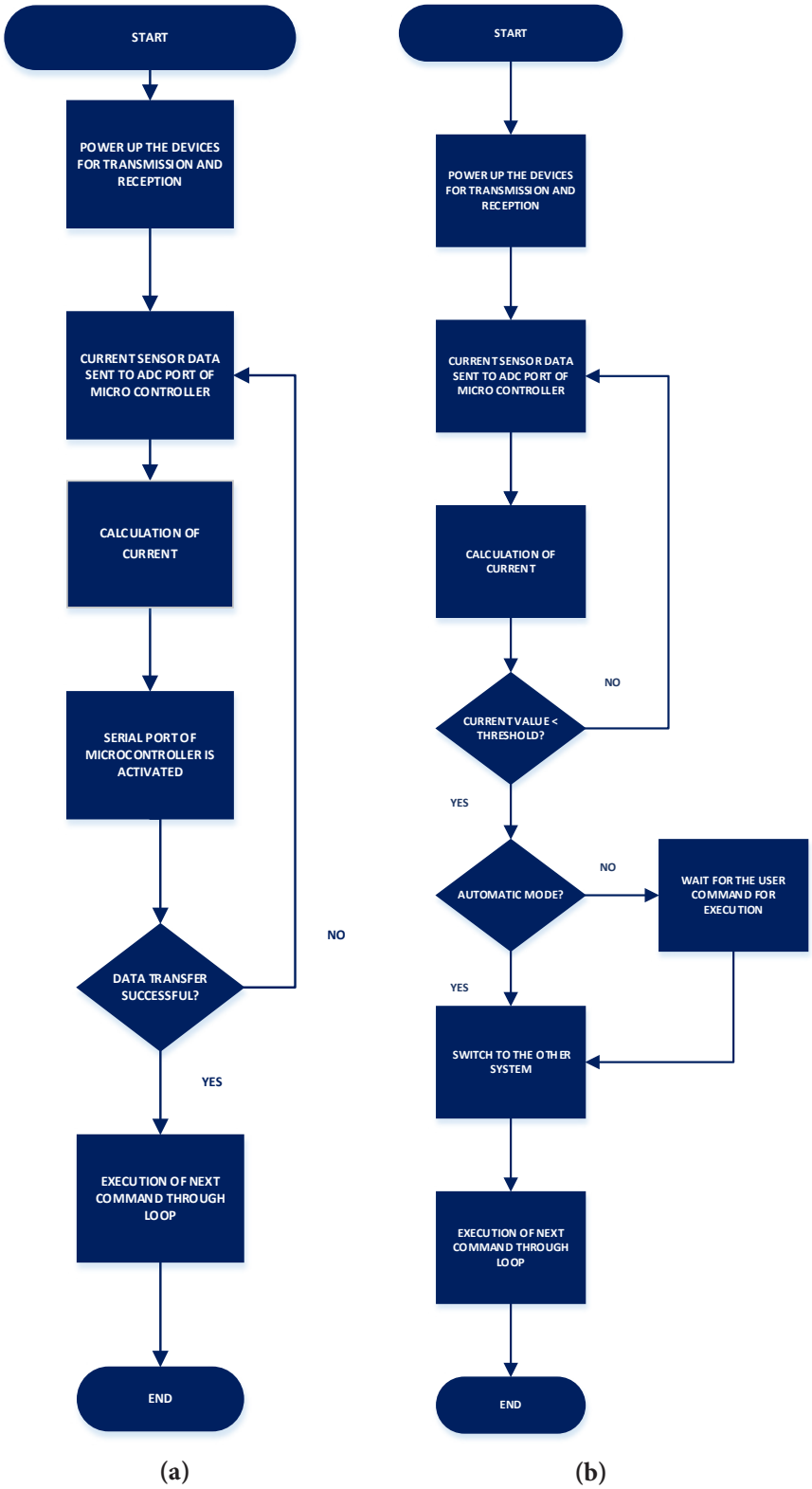

Figure 4. Flow charts for (a) energy monitoring and (b) control of prototype.

of developed energy management system. The data is received serially on user terminal and the commands are executed accordingly.

This design can also be used for solar rooftop system with some minor modifications. The DC microgrid is considered for the proposed prototype. For AC microgrid, an inverter can be used for conversion. User can decide to operate on either manual or automatic mode. The design for energy management system can be explored with other communication standards depending upon applications and necessities[12-14].

4. Conclusion

Home energy management system is an integral part of revolutionary Smart Grid technology. The proposed system uses solar PV as a renewable energy source. The system can be extended by exploration of various other sources of renewable energy such as wind, biogas, and hydropower as well as for mesh networks. The proposed design uses low power communication protocol for home applications. The advantage of using IEEE 802.15.1 is its extensive market penetration and availability. It provides simple and energy efficient solution to consumers. The developed prototype is expected to serve as an experimental demonstration tool to study smart microgrid behavior. The prototype can be implemented using different communication protocols on the basis of technical requirements such as security, data rates, coverage area and type of application. Future work includes development of energy monitoring and control system for industrial network applications.

5. References

1. Gungor VC, Lu B, Hancke GP. Opportunities and challenges of wireless sensor networks in smart grid. IEEE Transactions on Industrial Electronics. 2010 Oct; 57(10):3557–64.
2. Siano P, Cecati C, Citro C, Siano P. Smart operation of wind turbines and diesel generators according to economic criteria. IEEE Transactions on Industrial Electronics. 2011 Oct;58(10):4514–25.
3. UnitedStates Department of Energy. Smart Grid System Report, [Online].Available:http://www.doe.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/SGSR-Main_090707_lowres.pdf. July-2009.
4. Saputro N, Akkaya K, Uludag S. A survey of routing protocols for smart grid communications. Computer Networks. 2012 July; 56(11):2742–71.
5. Farooq H,Tang Jung L. Choices available for implementing smart grid communication network. International Conference on Computer and Information Sciences (ICCOINS). Kuala Lumpur. IEEE; 2014.1–5.
6. Mahmood A, Javaid N, Razzaq S. A Review of Wireless Communications for Smart Grid. Renewable and sustainable reviews. 2015 Jan; 41:248–60.
7. Erol-Kantarci M, Mouftah HT. Wireless multimedia sensor and actor networks for the next generation power grid Ad Hoc Networks. 2011 Jun; 9(5):542–51.
8. Haartsen JC.The Bluetooth radio system IEEE Personal Communications. 2000 Feb; 7(1):28–36.
9. Ferro E, Potorti F.Bluetooth and Wi-Fi wireless protocols: A survey and a comparison. IEEE Wireless Communications. 2005 Feb; 12(1):12–26.
10. Lee JS, Su YW,Shen CC. A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi 33rd Annual Conference of the IEEE Industrial Electronics SocietyIECON, Taipei. IEEE; 2007. 46–51.
11. Park Y, Cho H. Transmission of ECG data with the patch-type ECG sensor system using Bluetooth Low Energy. International Conference on ICT Convergence (ICTC), Jeju. IEEE; 2013. 289–94.
12. Baig MQ, Maqsood J, Alvi MHBT,Khan TA. A Comparative Analysis on Home Automation Techniques. 2nd International Conference Artificial Intelligence, Modelling and Simulation (AIMS), Madrid. 2014Nov.109–14.
13. Tsuda K, Suzuki H, Asahi K Watanabe A. Proposal for a seamless connection method for remotely located Bluetooth devices. 7th International Conference on Mobile Computing and Ubiquitous Networking (ICMU), Singapore. 2014.78–9.
14. Ghazal B, Kherfan M, Chahine K Elkhatib K. Multi control chandelier operations using XBee for home automation. Third International Conference on Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE).Beirut. IEEE; 2015. 107–11.