International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 02 - Issue 08 || August 2017 || PP. 46-54

Hardware Realization of Two Level Fuzzy Based Energy Management System Using Wireless Sensor Network

[1]A.Albert Martin Ruban, [2]K.Selvakumar,[3] N.Hemavathi, [4]N.Rajeswari
[1] Research Scholar, Manonmaniam Sundaranar University, Tirunelveli, India &Associate Professor, Kings College of Engineering, Pudukkottai, India
[2]Associate Professor, Annamalai University, Chidambaram, India
[3,4]Assistant Professor, Kings College of Engineering, Pudukkottai, India

Abstract: Conventional energy sources are diminishing and also creating environmental hazards. Hence, renewable energy sources play a crucial role since they are more synergetic and provide eco friendly energy solution. Among the renewable energy sources, solar and wind are the most promising power generation technologies owing to their accessibility in abundance. On the other hand, due to variation in geographic and seasonal climatic condition, there is an uncertainty in power generation leading to improbable power production which ought to be dealt seriously. Therefore, a two level fuzzy based Energy Management System was proposed [13]. The proposed scheme is validated using hardware. The temperature, relative humidity, wind direction and wind velocity are sensed using respective sensors and the rest of the parameters are taken based on the literature. The first level fuzzy based controller is implemented to decide the duration and the instant of triggering pulses of converter in order to produce the maximum power from these renewable sources. Then, the total power generated from the integrated system is fed along with state of charge of the battery and total demand by loads as input to the second level fuzzy logic based Energy Management System. Using the second level fuzzy logic controller, the excess power is predicted and exported to the utility grid. Thus, hardware of two level fuzzy based Energy Management System using Wireless Sensor Network is realized and the results exhibit proximity with the simulation results.
Keywords: EMS, FLC, PV, WIND, WSN

I. Introduction

Ultra capacitor based Energy Management System (EMS) using fuzzy controllers is proposed [1]. The analysis and evolution of better battery power management systems with optimal storage, charging and discharging characteristics of ultra capacitor is carried out. Nevertheless, the renewable energy sources are not considered. Model of Micro grids with steady state and their transient responses to changing inputs are presented [2]. Current models of a fuel cell, micro turbines, wind turbine and solar cell have been discussed. Finally a complete model including a Micro grid, the power sources, the electronics part, a load and a mains in MATLAB/Simulink is presented. However, the model is not validated through hardware. Regulation of the energy management for a normal day in summer via intelligent control is proposed [3]. Solar panel and wind turbine are the generators and the load is assimilated to a residential demand. This fuzzy logic based approach considers electricity prices, renewable production and load demand as the parameters. Furthermore, the command rules are developed in order to ensure a reliable grid taking into account the financial aspect to decide the load modification's level. A fuzzy control approach based Battery management using hybrid solar photovoltaic and wind power system for stand-alone applications is proposed [4]. In this work, the life cycle of the battery is improved with the desired State of Charge (SOC). The performance of fuzzy controller is compared with that of classical PI controller and is found to be superior. Energy management system for DC microgrid is implemented [5]. In this design, analysis and control of power sources are performed using Matlab/Simulink and Integration of these models is carried out using Labview. The Microgrid contains a solar panel, wind turbine, lithium ion battery and a fuel cell for continuous supply of power to the grid. For the improvement of battery life and its usage, state of charge has been introduced and its desired state is managed by fuzzy control of Labview.

To overcome the problem of power distribution, this paper provides an overview of wireless sensor network by managing the equal power distribution using zigbee sensor network [6]. The hardware demonstration of the Home Energy Management (HEM) system for managing end-use appliances is proposed [7]. The communication time delay of the HEM to perform load control is analyzed, along with its energy consumption. It provides a homeowner the ability to perform smart load controls based on utility signals, customer's preference and load priority automatically. An energy management system, which controls power generation and consumption optimally based on the mixed integer linear programming method, is developed [8].

The system aims to control unstable renewable energy, monitor the battery's state of charge and maintains the automatic operation. The system has successfully achieved the goals and has been operating for over one year without any significant failure.

A Smart Home Energy Management System (SHEMS) with hybrid sensor networks is presented [9]. Hybrid sensor networks consist of two types of sensors: the Power Information Monitoring Sensor (PIMS) and the Environment Information Monitoring Sensor (EIMS). To maximize the hybrid sensor network lifetime, a routing protocol based on cooperation between PIMS and EIMS, is proposed. The smart demand responsive energy management system under new comprehensive field tests for wireless communication using mesh network based on AODV is proposed [10]. A case study of smart grid-connected buildings having solar Photo Voltaic (PV) panels for distributed electricity generation and batteries for local energy storage is considered. The hardware design and implementation of a multiple nodes mesh network based wireless sensor network is designed which wirelessly connects appliances to the user through the wireless sensor networks. Current sensors used to sense produced current by PV and to sense current consumed by all appliances at every moment and forward this data to control unit instantaneously. In the control unit, a program is developed to receive the data and store in to a database for further processing of energy management by the control unit. Priority is assigned based on battery charge and loads consuming power. The scheme can response to the resident's command with the economically suggestion and help them shift their non-urgent appliances to the off-peak hours. But, in all these works the factors influencing power production are not studied using appropriate sensors.

This paper proposes a deterministic energy management system for a micro grid, including advanced PV generators with embedded storage units and a gas micro turbine [11]. The system is organized according to different functions and is implemented in two parts: a central energy management of the micro grid and a local power management at the customer side. The power planning is designed based on the prediction for PV power production and the load forecasting. The central and local management systems exchange data and orders through a communication network. According to received grid power references, additional functions are also implemented to manage the power flows locally between the various sources. Application to the case of a hybrid super capacitor battery-based PV active generator is also presented.

Smart grid concept is prevailing rapidly in electrical engineering research and is expected to provide sustainable and efficient energy services with advanced control and communications infrastructure [12]. Smart grid involves all the stakeholders of power systems, from generation to consumption, with bi-directional flow of power and information. Communication technologies are the vital part of the smart grid and enable the utility to manage the tasks like energy management in Home Area Networks (HANs), Neighbor Area Network (NANs), and Wide Area Network (WANs) etc. This paper presents a review of Zigbee communication technology for smart grid applications like Home Energy Management Systems (HEMS), Advanced Metering Infrastructure (AMI), Electric Vehicles (EVs) etc. Moreover, specifications, features and drawbacks of Zigbee have also been discussed in detail. However, these works did not concentrate on factors influencing renewable energy based power production.

II. Background of the Work

On reviewing previous research studies, it is evident that either wind energy or solar based power production are foreseen. In the same way, if both wind and solar are considered, the energy management system was designed and implemented without taking into account all the influencing parameters for power production. Hence, a two level fuzzy based Energy Management System for hybrid power production from solar PV panel and wind energy was simulated [13]. The implemented system considers temperature, relative humidity, shading, irradiation and soiling with relevance to solar PV panel output. While for wind energy, the wind direction, wind speed, elevation, temperature and relative humidity are taken into consideration.

The algorithm as shown in Figure 1 was implemented with micro controller and the efficiency of the implemented methodology was exhibited. The fuzzy based EMS considers the influencing parameters namely temperature, relative humidity, shading, irradiation and soiling for PV panel output. Similarly, the parameters namely wind direction, wind speed, elevation, temperature and relative humidity were taken to estimate wind turbine power production. The Fuzzy Rule Base was structured depending upon the input and output parameters. The output of first level fuzzy was used to maximize output power through DC-DC converters. The outputs obtained in first level fuzzy were fed as input to the second level fuzzy. The second level fuzzy considers the output of DC-DC converters in addition to State of Charge of battery and connected load as input parameters. Based on FRB, the output namely, number of units to be sold to the utility was estimated. To have better performance, in both the levels 'Centroid' based defuzzification was carried out.

The purpose of two level fuzzy was to reduce the computational complexity. It is elaborated as follows: Utilizing the Fuzzy Rule Base (FRB), 243 rules (3x3x3x3x3) is framed for both solar and wind energy system. In this executed system, the first level fuzzy is split into two and was implemented with 486 (i.e. 243+243) rules. If implemented with all the inputs for PV and wind turbine power together, then 6561 (i.e. 3x3x3x3x3x3x3x3) rules is mandatory. This clearly elucidates the efficiency of the executed system with reduced computational complexity. Similarly, the outputs of first level fuzzy along with their inputs namely SoC of battery and the connected load were fed to second level fuzzy with FRB as 225 (5x5x3x3) rules.

III. PROPOSED SYSTEM

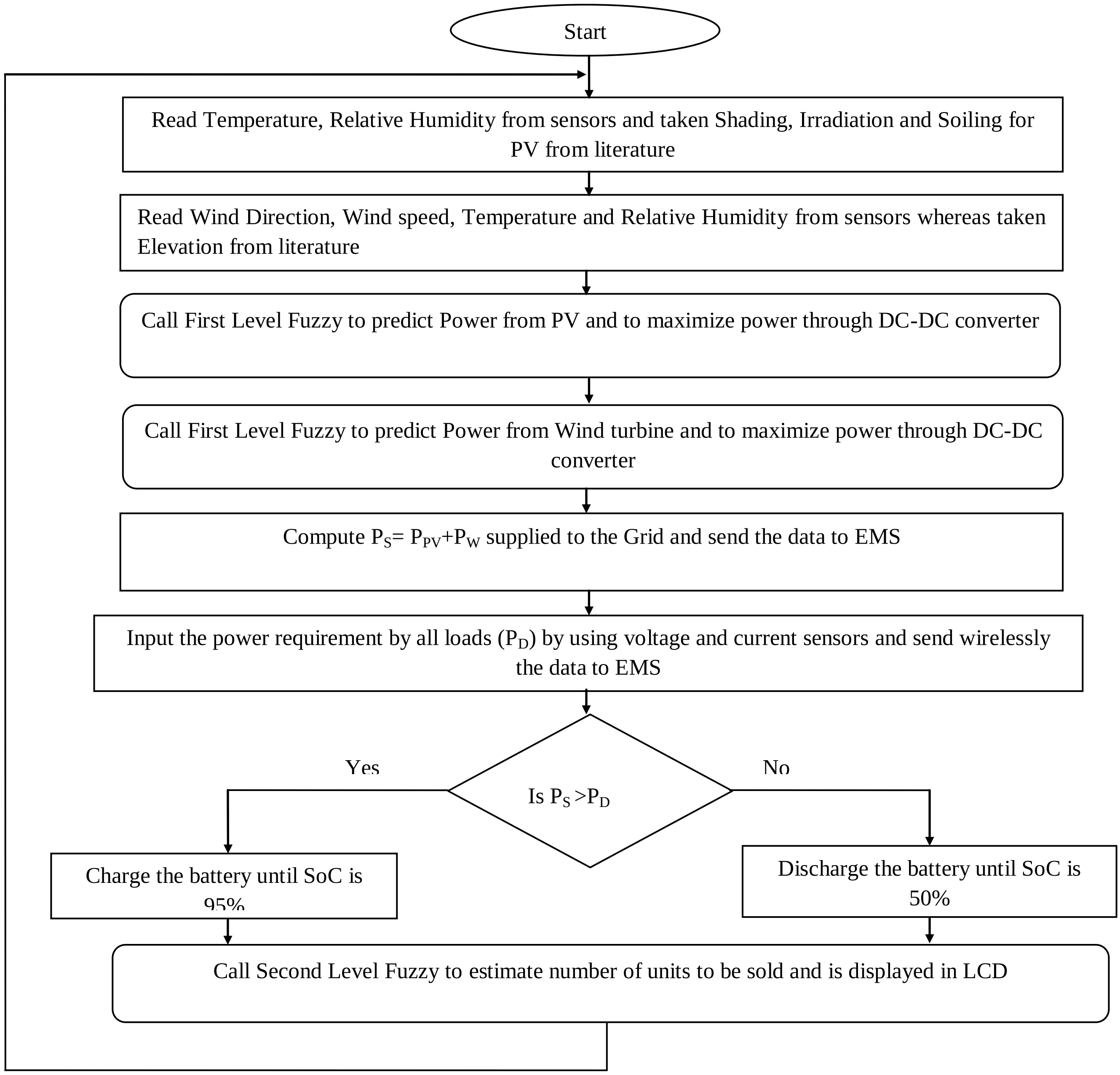
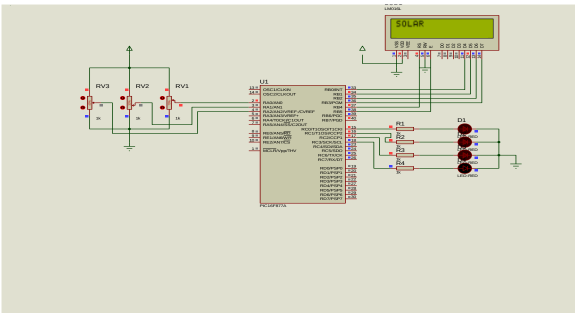


Figure 1 Flow Chart

To validate the performance of two level fuzzy based Energy Management System, the prototype is implemented with PV panel and wind turbine. The PV panel has the capacity of 50 Watts whereas the wind turbine has 9 Watts. The sensors namely temperature, humidity, wind velocity and wind direction sensors are used to predict the power from solar and wind power generator. While the remaining parameters namely shading, irradiation and soiling with relevance to solar PV panel output and elevation related to wind power generation were taken from the literaure. The power produced by these sources was stepped up using DC-DC (boost) converter. The firing pulse of the switching device (MOSFET) was varied to obtain maximum power. This is achieved by using first level Fuzzy Logic Controller. The power demand required by the connected loads was sensed using voltage and current sensor. The power demand by the loads was communicated wirelessly through zigbee to the EMS. The EMS has second level fuzzy that considers the total power generated from PV and Wind, SoC of Battery and total power demand by the connected loads as their input. Based on the input, the number of units sold to the utility is displayed in LCD. Fig 1 shows the flow chart of the implemented system.

IV. Implementation



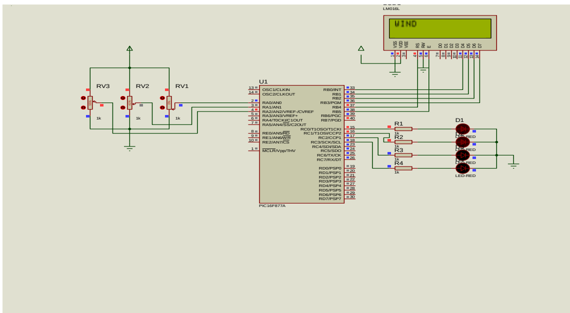


Figure 2 Simulation of solar panel power production   Figure 3 Simulation of wind turbine power production

Initially the system is designed using Proteus software. The Proteus Design Suite is an Electronic Design Automation (EDA) tool including schematic capture, simulation and PCB Layout modules. The micro controller simulation in Proteus works by applying either a hex file or a debug file to the microcontroller. It is then co-simulated along with any analog and digital electronics connected to it. This enables it to be used in a broad spectrum of prototyping controlling of any device (i.e. actuator) and user interface design. It also finds wide used, since no hardware is required and is convenient to use as training or teaching tool. The PCB Layout module automatically gives connectivity information in the form of a net list from the schematic capture module. This information is applied together with the user specified design rules and various design automation tools for error free board design.

The power generated from solar and wind is demonstrated in figures. The power produced from these generators is maximized. Further, the maximized power along with the battery SoC is compared with the power demand by the connected loads. Accordingly, the number of units to be sold is estimated. The fuzzy logic based Energy Management System is implemented using Proteus software and based on the idea, the hardware set up is further implemented. Fig 2 & 3 shows the simulation of solar and wind power production respectively through proteus software.

The block diagram of the hardware implementation was depicted in Fig 4 which consists of sensors, micro controller and Zigbee. The various sensors for measuring parameters such as temperature, relative humidity, wind velocity, barometric pressure and current are used. For measuring temperature, the LM35 precision integrated circuit temperature sensors are employed whose output voltage is linearly proportional to the Celsius temperature.

These are advantageous over linear temperature sensors calibrated in ß Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. Relative humidity is obtained using HSM-20G module which provides DC voltage as output for the corresponding relative humidity. The Measurement Accuracy lies between ± 5% RH with the Operating Current (Maximum) of 2mA. BMP180 high-precision, low-power digital barometer breakout board is used for measuring pressure. The measuring range varies from 300 to 1100 hPa with accuracy of 0.02 hPa. The Winson WCS2720 is used for current sensing which consists of a precise, low-temperature drift linear hall sensor IC with temperature compensation circuit and a current path with 0.4 mΩ typical internal conductor resistance. Applied current flowing through this conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage.

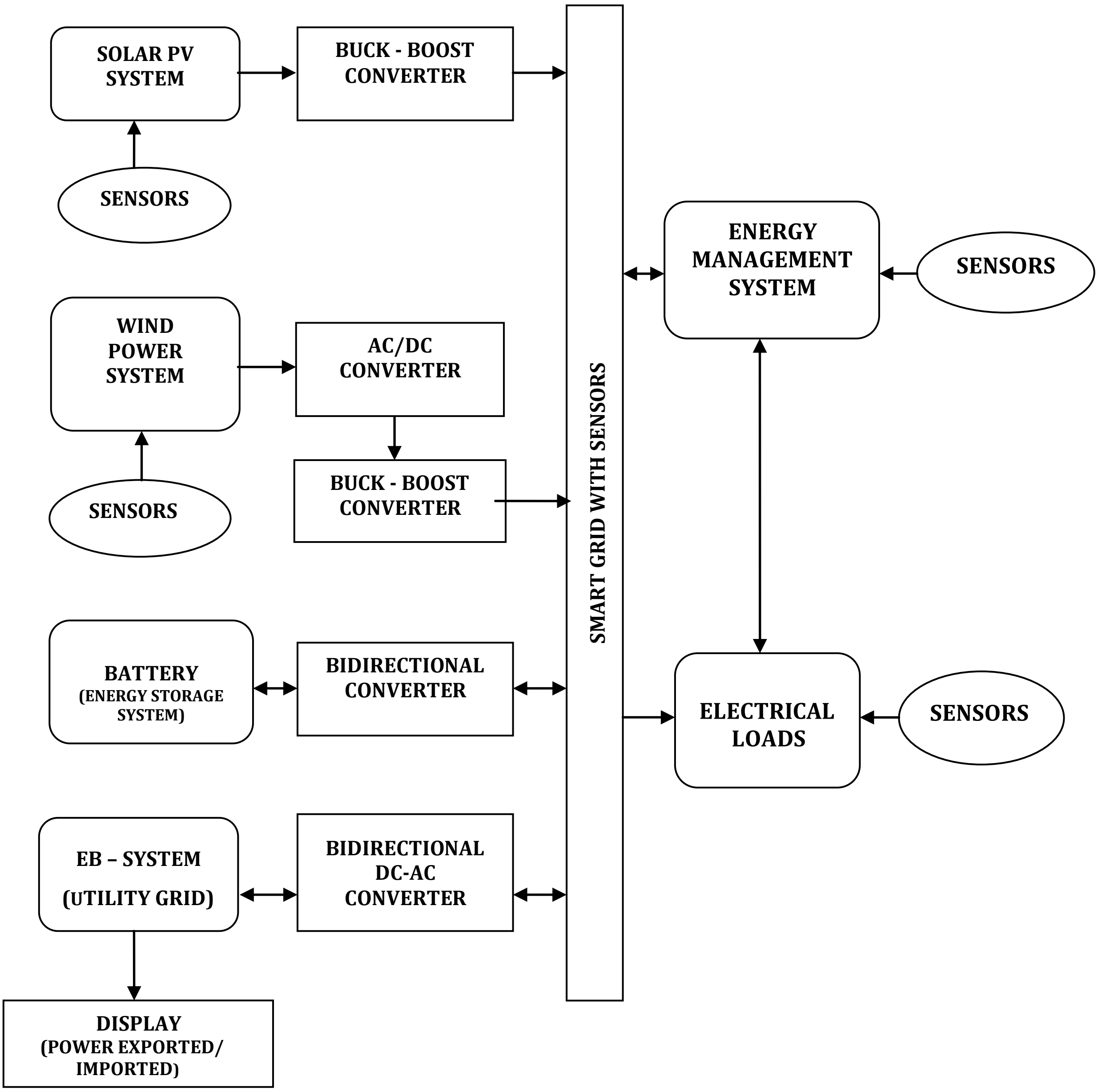


Figure 4 Block Diagram of the Energy Management System

The XBee RF Modules were engineered to operate within the Zigbee protocol and support the unique needs of low-cost, low-power wireless sensor networks. The modules operate within the ISM 2.4 GHz frequency band. It is specified that Zigbee will work with the range of indoor 30m and outdoor 90m with RF line of sight. The data rate is 250kbits/s with the receiver sensitivity of -96dBm.

V. OPERATION OF ENERGY MANAGEMENT SYSTEM

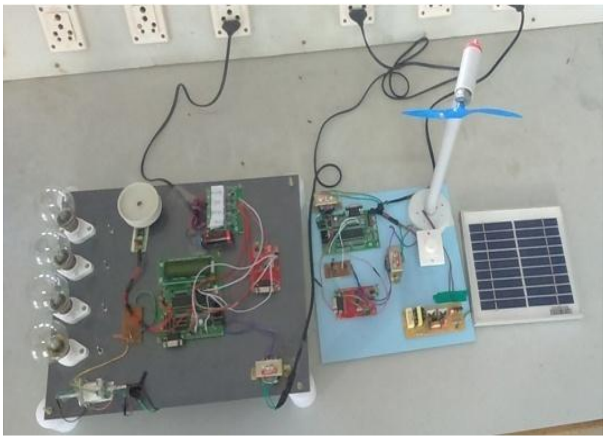


Figure 5(a)

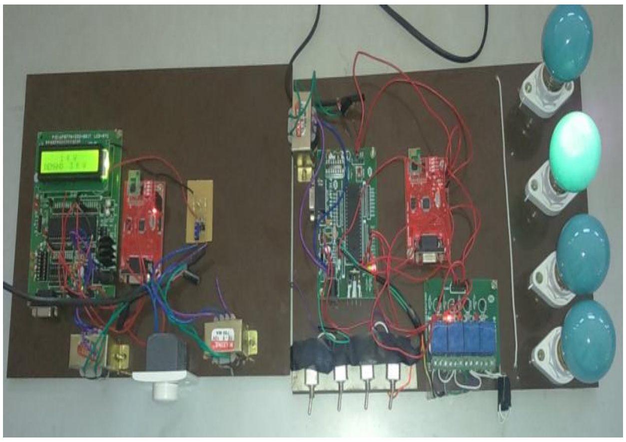


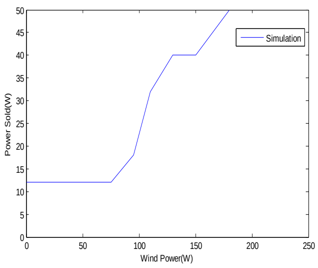
Figure 5(b)

Figure 5 Implemented system

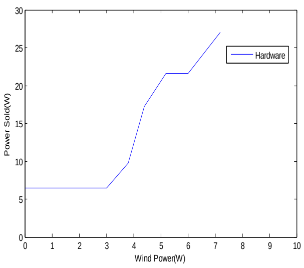
The sensors were used to measure the respective parameters namely temperature, relative humidity, wind direction and wind velocity. The remaining parameters are assumed based on the literature. The first level fuzzy logic system was implemented in the PIC micro controller which gives the decision for the Pulse Width Generator. Based on the output of Pulse Width Generator, the solar power and wind power is improved using DC-DC converter. The power demand from the connected loads was measured using voltage and current sensors whose output was transmitted wirelessly through Zigbee to the Energy Management System. The micro controller computes the power requirement by the total connected loads. The State of Charge (SoC) of the battery was maintained between 50% and 95%. If SoC was less than 50%, then battery was charged and if SoC exceeds 95% it iwas discharged so as to enhance the battery lifetime. The total power generated from solar and wind power generators, total power demand and state of charge of the battery was given as input to the second level fuzzy implemented in the EMS to estimate the number of units sold to the utility. Also, it is displayed in the LCD display. The implemented system was shown in figure 5.

VI. RESULTS AND DISCUSSION

The experiment was carried out using hardware. The parameters were measured using sensors and are communicated wirelessly through Zigbee. The fuzzy based energy management system was implemented in PIC micro controller. Based on the sensed influencing parameters for both solar and wind based power production, the triggering pulses were generated to obtain maximum power from DC-DC converters. The second level fuzzy was also implemented in PIC controller. The second level fuzzy compares the available power along with the SoC of battery with that of connected load and displays the number of units sold to the utility through LCD.

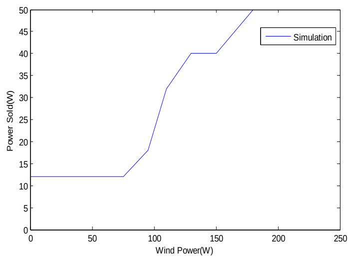


(a) Simulation output

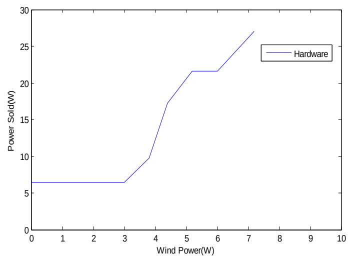


(b) Hardware output

Figure 5 Solar power generated Vs solar power sold



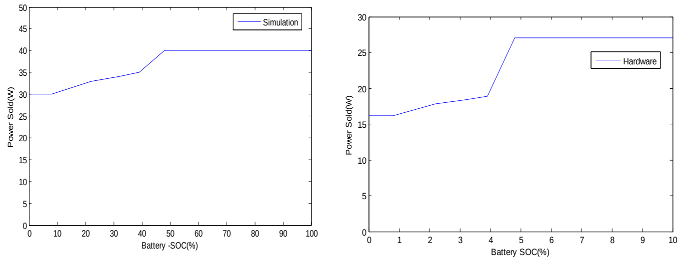
(a) Simulation output



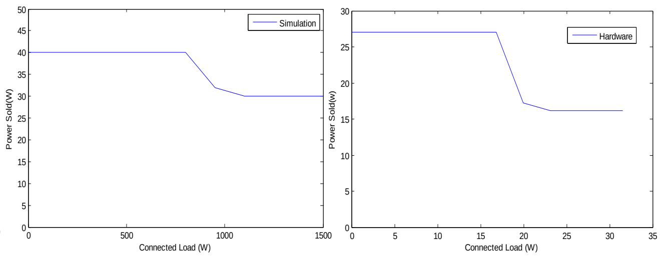
(b) Hardware output

Figure 6 Wind power generated Vs wind power sold

Figure 5 shows the relation between the solar power generated and the power sold. From this figure it was observed that the power sold to the utility increases with increases in solar power generation. Similarly from figure 6 it is evident that the power sold to the utility from the wind system was increased with the increase in wind power generation.

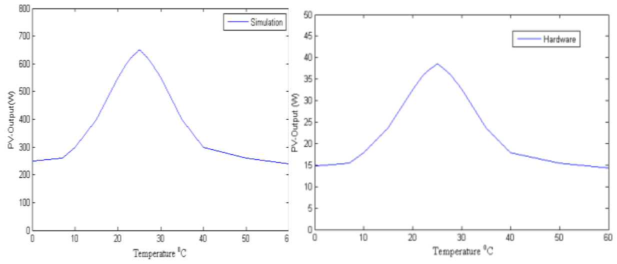


(a) Simulation output (b) Hardware output
Figure 7 Battery SoC Vs power sold

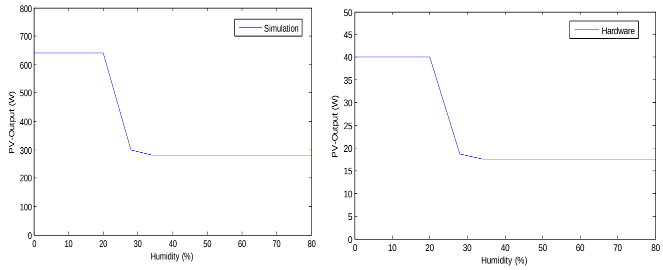


(a) Simulation output (b) Hardware output
Figure 8 Connected load Vs power sold

Figure 7 shows the relation between the battery SoC and the power sold. From this figure it was observed that the power sold to the utility increases with increases in battery SoC. Similarly from figure 8 it is evident that the power sold to the utility from the system was increased with the decrease in connected load.



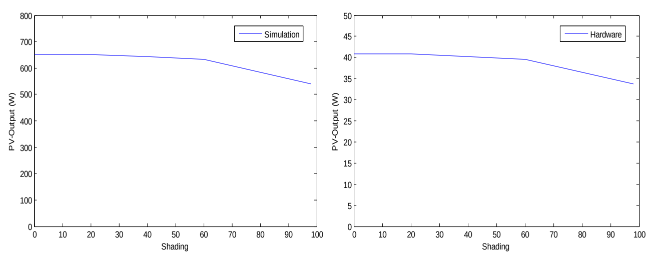
(a) Simulation output (b) Hardware output
Figure 9 Temperature Vs PV panel output



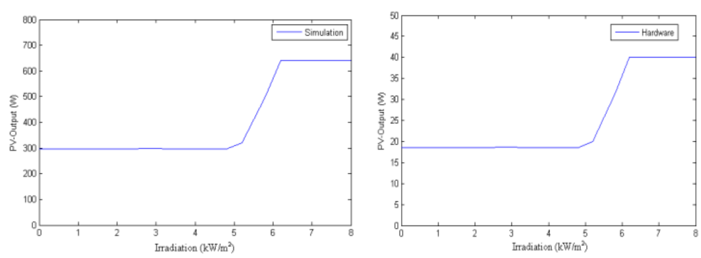
(a) Simulation output (b) Hardware output
Figure 10 Humidity Vs PV panel output

Figure 9 shows the relation between the temperature and the PV panel output. From this figure it was observed that the power sold to the utility increases with increases in temperature to a particular extent. Similarly from figure 10 it is evident that the PV panel output from the system was increased with the decrease in relative humidity.

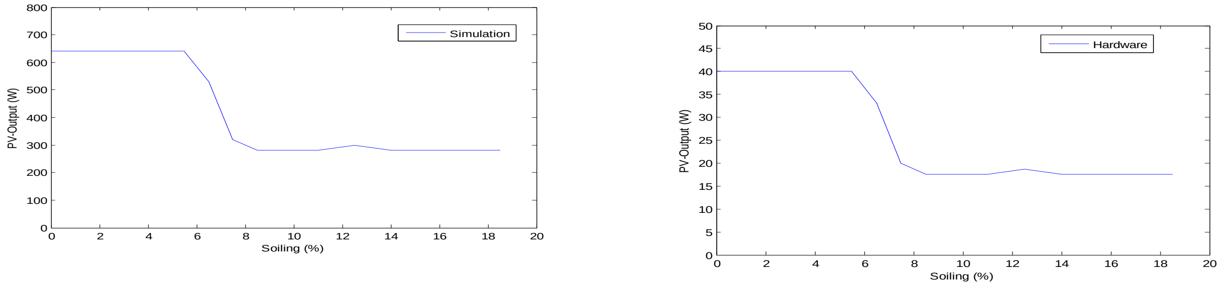
Figure 11shows the relation between the shading and the PV panel output. From this figure it was observed that the power sold to the utility increases with decrease in shading. Similarly from figure 12 it is evident that the PV panel output from the system was increased with the increase in irradiance.



(a) Simulation output (b) Hardware output
Figure 11 Shading Vs PV panel output



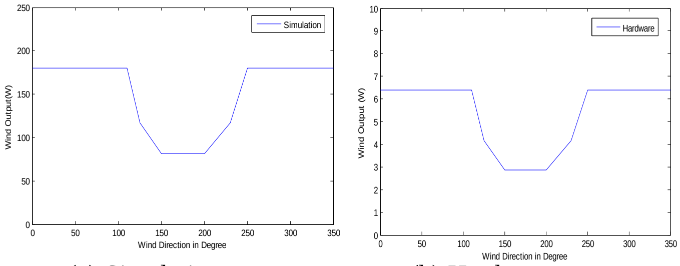
(a) Simulation output (b) Hardware output
Figure 12 Irradiance Vs PV panel output



(a) Simulation output (b) Hardware output

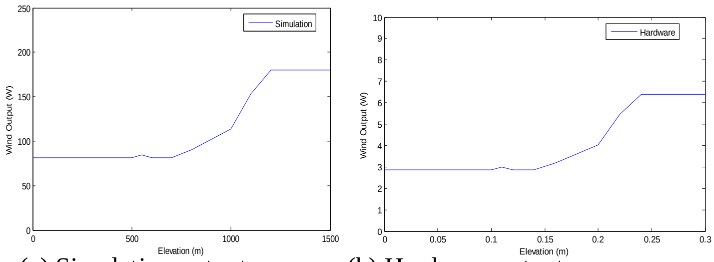
Figure 13 Soiing Vs PV panel output

Figure 13shows the relation between the soiling and the PV panel output. From this figure it was observed that the power sold to the utility increases with decrease in soiling.



(a) Simulation output (b) Hardware output

Figure 14 Wind direction Vs wind turbine output

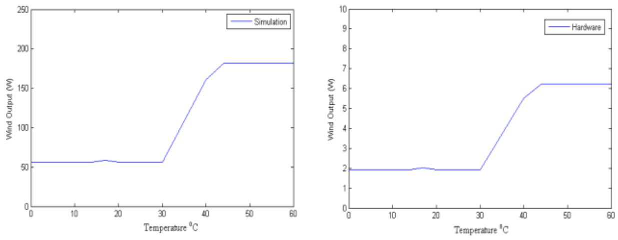


(a) Simulation output (b) Hardware output

Figure 15 Elevation Vs wind turbine output

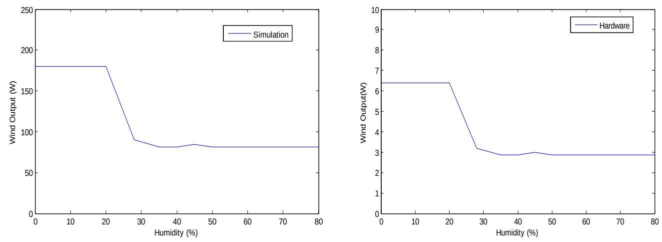
Figure 14shows the relation between the wind direction and the wind turbine output. From this figure it was observed that the wind turbine output increases with increase in wind direction to a certain extent. Similarly from figure 15 it is evident that the wind turbine output from the system was increased with the increase in elevation.

Figure 16shows the relation between the temperature and the wind turbine output. From this figure it was observed that the wind turbine output increases with increase in temperature. Similarly from figure 17 it is evident that the wind turbine output from the system was increased with the decrease in humidity.



(a) Simulation output (b) Hardware output

Figure 16 Temperature Vs wind turbine output



(a) Simulation output (b) Hardware output

Figure 17 Humidity Vs wind turbine output

From the results, it is evident that the number of units sold to the utility was found to increase with that of increased power production, decreased load and increased SoC.

VII. Conclusion

In India though solar and wind energy sources are surplus the utility of these resources is less due to various influencing factors such **as** temperature, relative humidity, shading, irradiation and soiling with relevance to solar PV panel output and wind direction, wind speed, elevation, temperature and relative humidity for wind power output. Hence, a research has been carried out to analyze the above factors affecting the solar

PV panel and wind turbine output. Keeping these factors into consideration the various ranges that can produce the optimal value was also analyzed. By adapting two level fuzzy system through MATLAB the produced output has been graphically represented. Thus, by implementing this two level fuzzy based systems maximum power output has been gained. And when the same is implemented practically and the efficacy of the power production can be increased to the maximum. Thereby the loss is minimized and efficacy is maximized leading to profitable power production.

References

[1]. Jarina Begum, CH.Sampath Kumar, Shaik Khamuruddin, 2014, 'Fuzzy Ruler Based Energy Management System for Hybrid Battery -Ultra Capacitor DC Micro Grid System', International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol. 2, Issue 8.

[2]. Manzar Ahmed, Uzma Amin, Suhail Aftab, Zaki Ahmed, 2015, 'Integration of Renewable Energy Resources in Microgrid', Energy and Power Engineering, Vol. 7, pp.12-29.

[3]. Lydie Roine, Kambiz Therani,Yashar Sahraei Manjili, Mo Jamshidi, 2015, 'Microgrid Energy Management System Using Fuzzy Logic Control', International Journal of Complex Systems Computing, Sensing and Control, Vol. 3, No. 1, pp. 79-92.

[4]. S. D. Saranya, S. Sathyamoorthi and R. Gandhiraj, 2015, 'A Fuzzy Logic Based Energy Management System for A Microgrid', ARPN Journal of Engineering and Applied Sciences, Vol. 10, No. 6.

[5]. S. Abdul Muqsit, A. Mallikarjuna Prasad, Energy Management System Implementation for A DC Micro Grid System Using Fuzzy Control ', International Journal of Science and Research (IJSR), pp.426-430.

[6]. Rajesh V.Sakhare, B.T.Deshmukh, 2012, 'Electric Power Management Using Zigbee Wireless Sensor Network', International Journal of Advances in Engineering & Technology, Vol. 4, Issue 1, pp. 492-500.

[7]. M.Kuzlu, M. Pipattanasomporn, S. Rahman, 2013, 'Hardware Demonstration of a Home Energy Management System for Demand Response Applications', IEEE Transactions on Smart Grid, Vol. 3, No. 4, pp.1704-1711.

[8]. Yoshihisa Ishigaki, Yoshitaka Kimura, Ikumi Matsusue, Hidekazu Miyoshi and Kentarou Yamagishi, 2014, ' Optimal Energy Management System for Isolated Micro Grids', SEI Technical Review, Number 78, pp. 73-78.

[9]. Jinsung Byun, Insung Hong, and Sehyun Park, 2012, ' Design and Implementation of a Smart Home Energy Management System with Hybrid Sensor Network in Smart Grid Environments', The Eighth International Conference on Wireless and Mobile Communications, pp.159-165.

[10]. Suman Patel and Dr.K.Nataragan, 2015, 'Wireless Sensor Based Smart Grid Management Using Photovoltaic System', International Research Journal of Engineering and Technology, Vol. 02, Issue 04, pp.1148-1157.

[11]. Hristiyan Kanchev, Di Lu, Frederic Colas, Bruno Francois, Vladimir Lazarov, 2011, 'Energy Management and Operational Planning of a Microgrid With a PV-Based Active Generator for Smart Grid Applications', IEEE Transactions on Industrial Electronics, Vol. 58, No. 10, pp.4583-4592.

[12]. R.Zafar, U.Naeem, W.Ali, A.Mahmood, 2015, 'Applications of ZigBee in Smart Grid Environment: a Review, Proceedings of the 2nd International Conference on Engineering & Emerging Technologies (ICEET), pp. 26-27.

[13]. Albert Martin Ruban, N.Hemavathi, N.Rajeswari, K.Selvakumar, 2017, Two Level Fuzzy Based Energy Management System with Integrated Solar and Wind Based Generating System in Smart Grid Environment', ISSN (Print) : 2319-8613 ISSN (Online) : 0975-4024, International Journal of Engineering and Technology (IJET), Vol. 9, No. 4, pp. 2754 – 2765, DOI number: 10.21817/ijet/2017/v9i4/170904407