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Integrated Renewable Energy Sources with EMS using Fuzzy Control and WSN for Smart Grid Applications

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Abstract: This paper deals with the integrated renewable energy sources with EMS using fuzzy control for smart grid applications. This paper comprised of power supply which obtains its power from the green energy resources, which includes solar, wind, and fuel cell. The modeling of the above mentioned generating system and storage device was simulated by using MATLAB/ Simulink. The RS 485 ZigBee network, a communication protocol employed to monitor and command the EMS. The fuzzy employed to manage the battery.

Keywords: EMS, Fuzzy control, Smart grid, Solar, Wind, Fuel cell, Zigbee, Renewable Energy.

I. INTRODUCTION

The development of the renewable energy (also called green energy) system has overcome all the disadvantages of the conventional or non renewable energy sources. The current green energy systems employed in the power generation are: Solar, wind, biomass, tidal [1]. These renewable energy resources are developed in many countries. In USA, electrical grids consists of around 5,000 power projects, over 2, 00,000 miles of high tension (HV) transmission lines, and around 55,00,000 miles of low tension distribution lines [2]. EPRI (Electrical Power Research Institute) estimates the annual cost of US business power outages [2]. The renewable energy generations are in the form of DC that can be employed for the DC application. This generated power can be utilized for the AC system by using the inverter with power factor correction. The generation of green energy to the DC grid is far different from the conventional power generation [1]. The hybrid power system provides better reliability than the isolated stand alone system [3]. The hybrid system comprised of more than one generating sources [4]. The integrated power system can be used with grid connected and stand alone mode of operation [5]. The optimization and distributed energy generation can be achieved in the smart grid [6].

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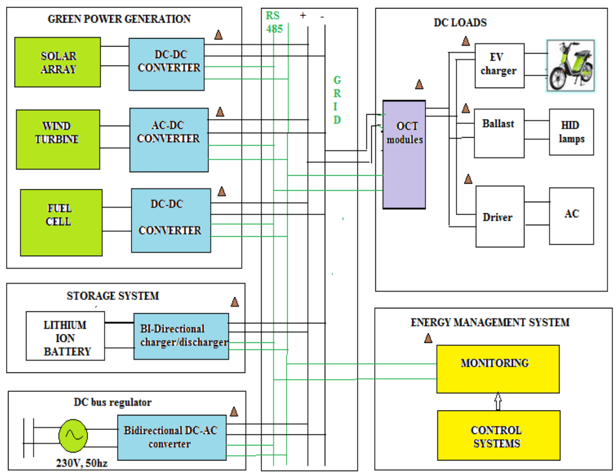
This paper is comprised of the sources, storage systems, DC bus regulators, and Energy Management Systems (EMS) with fuzzy controller. The optimization and distributed energy generation of the grid was achieved by using the Energy Management System. The storage system employed here is the Lithium ion battery. The EMS employs RS 485 ZigBee network, a communication protocol for commanding operation [7]. Fig.1 is a block diagram of proposed system comprised of five major blocks: generation block, storage block, regulator block, load blocks and management block. The generation block includes PV, wind turbine, and fuel cells (Integrated renewable energy sources). The storage block includes battery and its charge controller. The regulator block includes the EB supply. The load employed in this proposed work is DC loads, which constitutes a multi agent system, supplies the power to the stand alone DC loads [8].



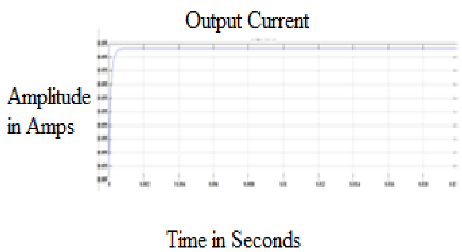


Fig.1. Block Diagram

The PV and Wind turbine deliver maximum power to the grid during normal conditions with the help of maximum power trackers.

The fuel cell and the EB supply are used as a standby system which delivers power during power failure conditions. The fuel cell delivers the base power during power failure condition.
The overall operation of the system was supervised and maintained by the centralized EMS command by using the communication protocol called RS 485 ZigBee network protocol. The battery management was done by fuzzy, which manages the SoC of the battery. The EMS commands the sources when to operate depends upon the stand alone DC load demand and operating status of the sources.

II. MODELING AND GENERATING SYSTEMS

The generating system includes PV, wind turbine, and fuel cells, and storage system. The simulation of these systems was simulated by using MATLAB / Simulink.

A. Modeling of Solar cells

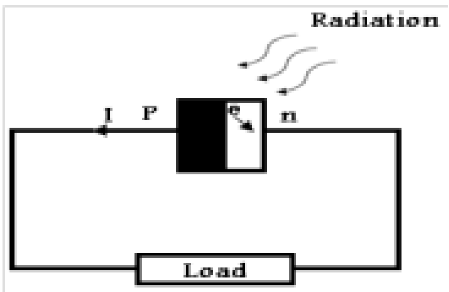


Fig. 2. Photo current generating principle.

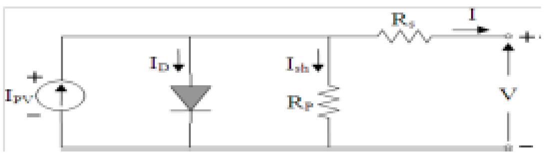


Fig. 3 Solar cell equivalent circuit

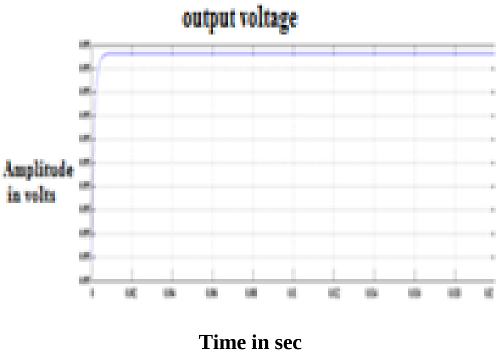


Fig. 4 Output voltage of solar cell

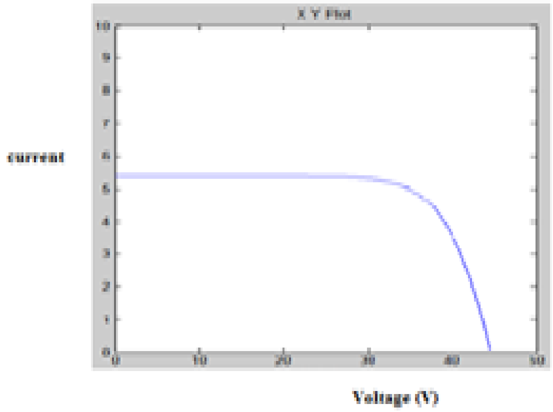


Fig. 5 Output current of solar cell

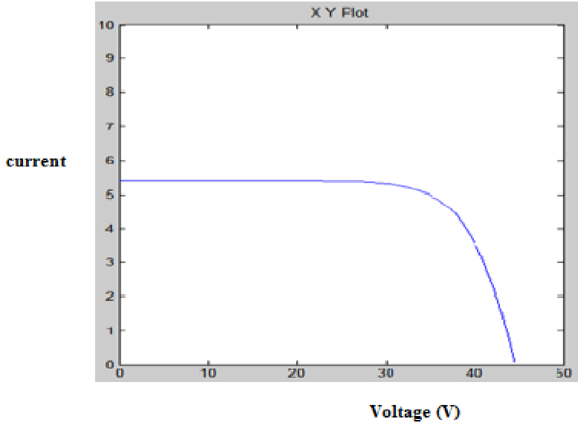


Fig. 6 Voltage-Current characteristics of a solar cell

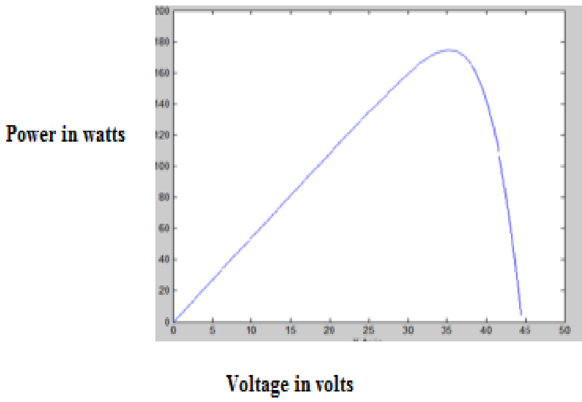


Fig. 7 Power-Voltage characteristics of a solar cell

B. Modeling of Wind turbine

The wind turbine is fed with the asynchronous generator and uncontrolled rectifiers, to integrate with the DC grid. The modeling of the wind turbine is done based on the verifications expressed by the equations (1) to (3). [11].

$$T_{turbine} = T_{em_{max}} = \frac{P_m}{\Omega_t} \quad \text{--- (1)}$$

The power electronics has rapidly changed the applications of the wind mill in many grid connected applications; it is due to the development of the semiconductor devices and microprocessors.

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The gated switches employed MOS transistors, and the number of controlled transistors are presented in the controller circuit [12].

The wind turbine can be employed for the variable speed and constant speed operation by using DFIG and PMSG respectively [12], [13]. The fig. 8 shows the characteristics of wind turbine variations with respect to the mechanical speed.

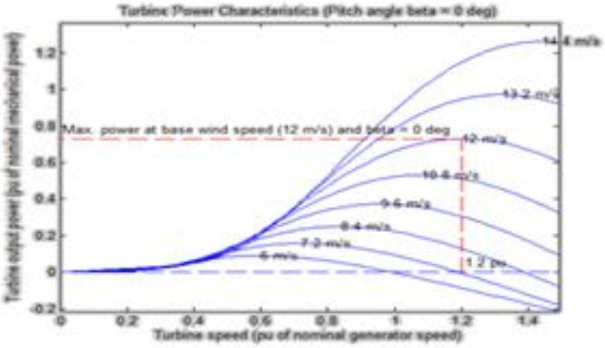

Fig. 8 Characteristics of wind turbine

C. Modeling of fuel cell

The fuel cell has different types [14]. The modeling, analysis, simulation of fuel cell, and fuel cell flow control of the fuel cell involve Humidifier and Hydrogen flow control. The simulation of fuel cell involves the steady state simulation and dynamic simulation [15][16]. Fig. 9 shows the stack voltage - current and stacks power – current characteristics of the fuel cell.

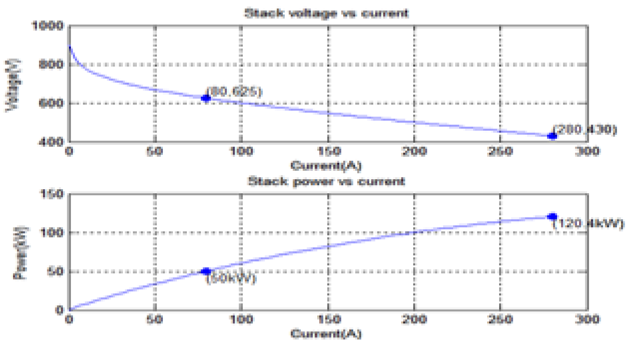

Fig. 9 Characteristics of fuel cell

III. INTELLIGENT ENERGY MANAGEMENT SYSTEM

Conventionally, the decentralized power supply systems are employed for the power generation. This decentralized system optimizes the use of components employed in the power system [17]. The intelligent management system is very important for the decentralized power system to optimize the entire power system, and battery management. The energy management system is very important to optimize the load flow analysis. The intelligent management system also employs cost pricing of the power, which is consumed by the load. The switching operation of the power system, especially in the converter employed for the particular converting operation, will also be regulated by this intelligent control system.

The main objective for the installation of the intelligent energy management system is to avoid the inadequate operating time, protect the storage system. The intelligent management system provides better solution to the load, which supplies from the fluctuating power supply resources. The algorithm implemented in this intelligent energy management system has been proven, that it provides the better solution for the battery management and optimization. The intelligent energy management system is also responsible for a balanced power generation.

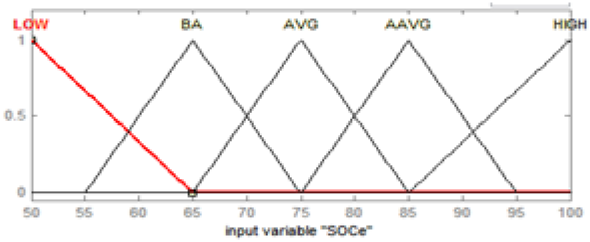

Fig.10 Input membership functions of P_e

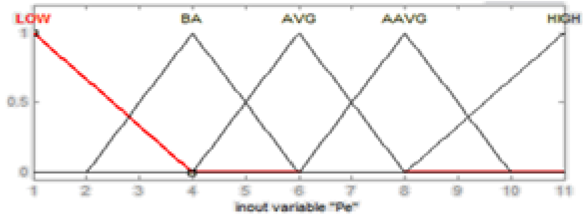

Fig. 11 Input membership functions of SoCe

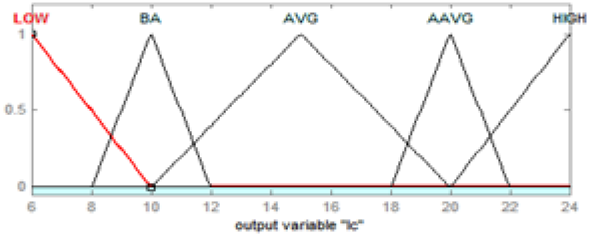

Fig. 12 Output membership functions of Ic

In this paper, the energy management system uses fuzzy logic control, for the purpose of optimization and distributed generation of energy. The DC smart grid system is the non linear system requires this centralized control system, which offers the practical way for designing the intelligent management system. This management system requires the actual power and the overall power generation of the system (PV, wind, and fuel cell) for the battery management. The State of Charge of the battery is directly proportional to the life time of the battery. The fuzzy used in this system maintains the State of Charge of the battery.

A. Fuzzy Logic control

The fuzzy logic concept was first established by Lofti. A. Zadeh in 1965, he first introduced the concept fuzzy sets. This fuzzy based system is called fuzzy, because the operation of the control system is similar to the fuzzy logic thinking. The brief description and examples are presented in [18]. It uses the logic elements 1 and 0.

The fuzzy logic system is employed in the smart grids, shown in fig.1. The fuzzy logic control generally has two inputs and one output. The fuzzy logic controller decides the charging and discharging operation of the battery, which depends on the SOC.

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The inputs and outputs of the fuzzy were expressed as follows:

P_e=Total amount of power generated-Actual load.

$SOC_e = SOC_{command} - SOC_{now}$.

The input membership functions P_e and SOC_e are shown in the fig. 10 and 11 respectively. The output membership function of I_C, the battery charging current is shown in fig.12. The fuzzy employs the mamdani type of simulation. The control rules of the fuzzy composed of five major grades of membership functions: Low (LOW), Below Average(BA), Average(AVG), Above Average(AAVG), and High(HIGH). When P_e is said to be low, which implies the rate of generation from the generating sources are low. It (P_e) has a specified low values in the fuzzy as shown in the membership functions. When the P_e is high, which implies the generating power produced by the power resources is high. When the SOC_e is low, which implies the charging state of the battery is low, and it also says that the battery requires the charging current I_c. When the SoC_e is high, it denotes that the charging state of the battery reaches its limit, and then the battery is ready to discharge its charges. The values of the SoC_e respective membership function grades are shown in fig.11. The I_c, is the charging current of the battery, when the Ic is low then it implies that the charging current is low than the required current for the purpose of charging. The I_c is high which indicates the battery charging at the rated current. The fuzzy logic comprises the number of rules, the lowest value of the SoC of the battery is 50%. The fuzzy maintains the constant SoC parameters of the battery. The entire operation of the system is controlled by the centralized controller referred as fuzzy. The SoC of the battery is maintained at 50% as its lowest value, the battery has to discharge its charges, when the power demand of the grid is high and the generations of the power resources are low. The fuzzy rules are tabulated as follows:

Table 1. Fuzzy Concept Rules

I_c	P_e					
	LOW	LOW	BA	AVG	AAVG	HIGH
	LOW	LOW	LOW	BA	AVG	HIGH
	BA	LOW	LOW	BA	AVG	HIGH
	AVG	LOW	LOW	AVG	AAVG	HIGH
SoC_e	AAVG	LOW	LOW	AVG	AAVG	HIGH
	HIGH	LOW	LOW	LOW	LOW	LOW

This system consists of the PV solar module of 5.6 kW, wind turbine of 4.6 kW, and the fuel cell of 4.6 kW. The battery employed in this system is the lithium ion battery. The initial value of the SoC of the battery is 50% and the final highest value is 100%.

The value of the load employed in this system is 5 kW. The control based fuzzy algorithm gives first priority to the selling and to maintain the SoC of the battery.

IV. SIMULATIONS AND RESULTS

A. Simulation of PV systems

The PV system comprised of the PV panels, and DC-DC converter, produces the output power of 5.6 kW. The solar cell has the output voltage of 1V. Fig.13 shows the MATLAB/ simulink diagram for the solar power system. The waveforms of the solar PV system are shown in fig.14.

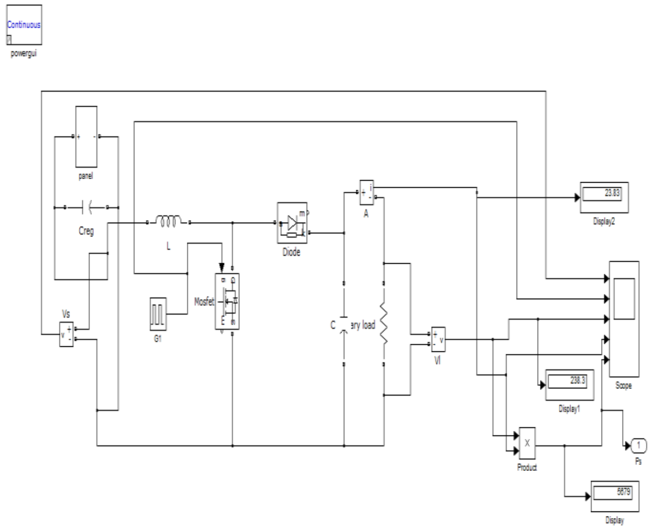

Fig.13 Simulation circuit diagram for PV system

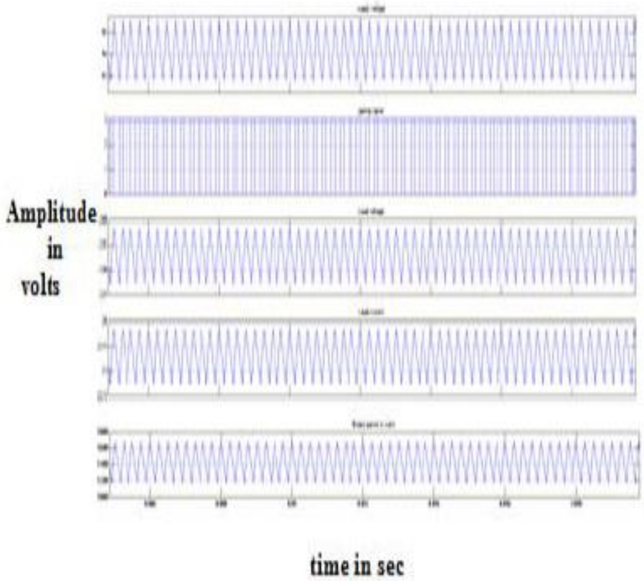

Fig. 14 Output waveform of PV system with MPPT

B. Wind Energy power generation and conversion System

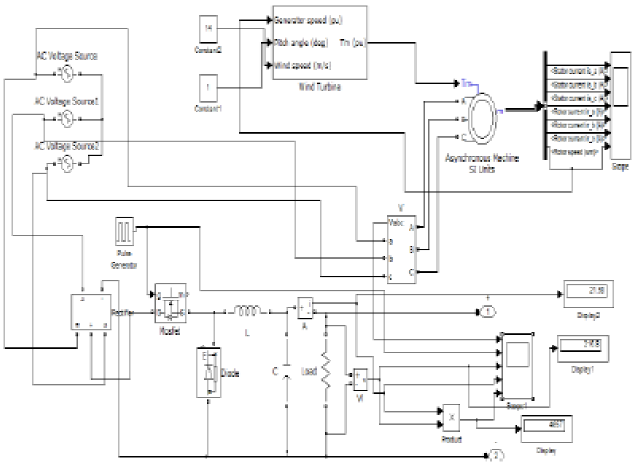

Fig. 15 Circuit diagram of Wind energy power Generation and conversion systems

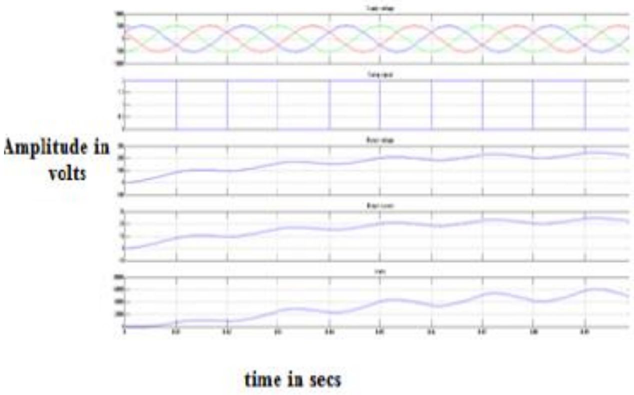

Fig. 16 Output waveform of the wind energy power generation and conversion system

C. Fuel cell

The fuel cell consists of the fuel stack connected to the DC-DC boost converter. The output watts produced in the fuel cell power generation is 4.6 kW. Fig. 17 and 18 show the circuit diagram and the waveform of the fuel cell power generation.

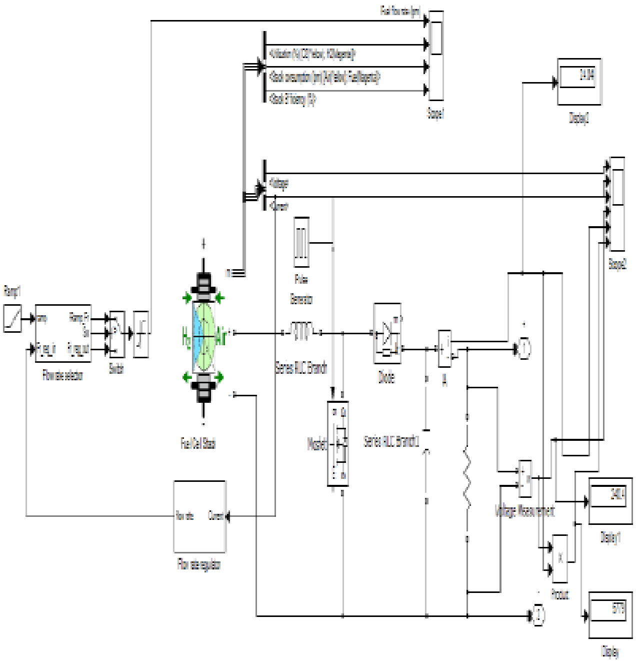

Fig. 17 Circuit diagram of the fuel cell power generations

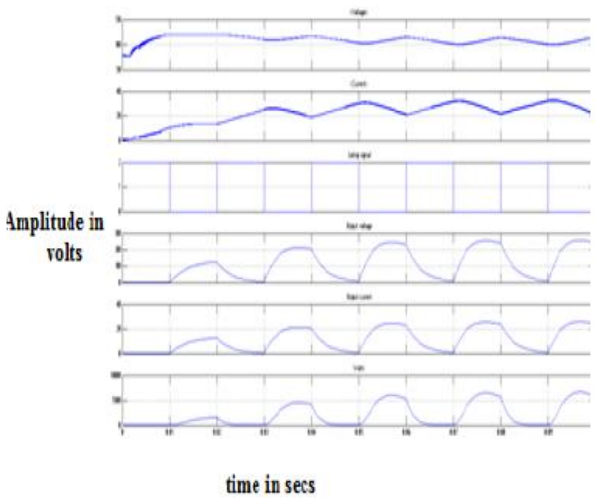

Fig. 18 Output Waveforms of fuel cell power generation

D. Integrated Power system

The integrated power system is comprised with the power sources such as solar, wind, and fuel cell. Fig.19 and 20 show the circuit diagram and output waveform of the integrated hybrid power system. The output voltage produced by this hybrid system is 240 V, and the current produced by this power system is 24 A.

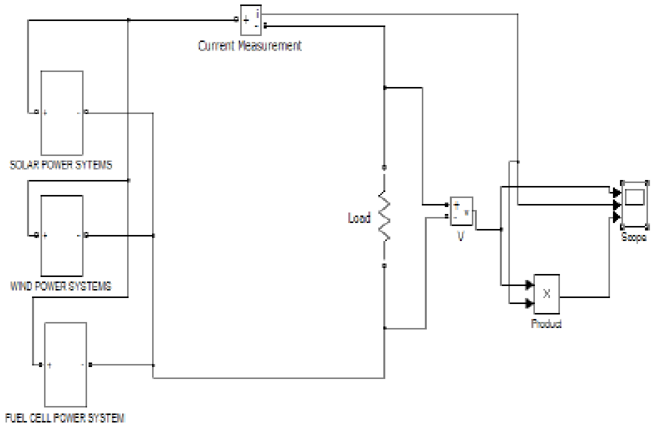

Fig.19 Simulation diagram of integrated power system

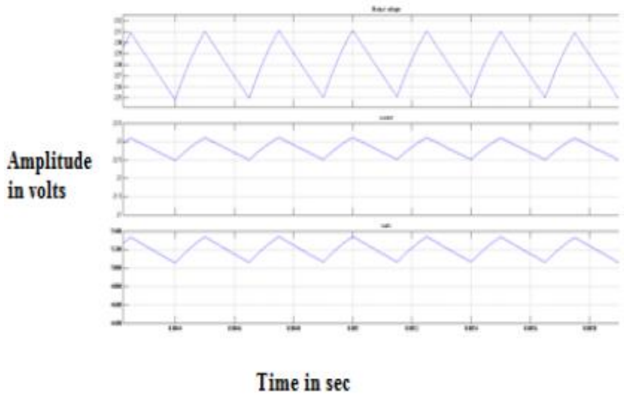

Fig.20 Output waveform of integrated power system

V. CONCLUSION

This paper implements the fuzzy logic control to achieve the optimized power of an integrated renewable energy sources with energy management system for the smart grid applications. Control signal commands are transferred through the wireless Zigbee network Protocol. The integrated hybrid power system was simulated using Matlab / Simulink. The optimization control of the smart grid system was done through the employment of fuzzy logic control, which comprises of the number of rules. Such type of intelligent management system increases the accuracy of the non linear system and it also achieves the optimization and distributed energy generation by its control algorithm. In future the Energy Management System will be implemented by using the artificial neural network.

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