International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 8, Number 4 (2015), pp. 341-354
© International Research Publication House
http://www.irphouse.com

Implementation of Energy Management System using Fuzzy Control to the Hybrid Power Generation System for DC Microgrid Applications

Mr. A. Albert Martin Ruban*[1], M.E., (Ph.D)., G. Mathew Rajasekaran[2], M.E., Mrs. N. Rajeswari[3], M.E., Mr. J. Arokia Raj[4], M.E.,

[1]*Associate Professor, Department of Electrical and Electronics Engineering, Kings College of Engineering, Punalkulam, Pudukkottai-613303.*

[2,5]*PG student, M.E-Power Electronics and Drives, Kings College of Engineering,*
[3,4,]*Assistant Professor, Kings College of Engineering,*

Abstract

This paper mainly deals with the Energy Management System for the Smart micro grid applications. This system consists of the power sources which obtains its power from the PV panel, wind turbine, and steam power generation system. The storage system employs the batteries. The Energy Management System (EMS) incorporates the fuzzy control, meant for the battery management and generation energy management. This system also incorporates the RS485 and ZigBee networks communication protocol to know the generation status of the power sources. The EMS commands the generating sources depends upon the SoC (State of Charge) of the battery and load demand.

Keywords: Energy Management System, SoC, Smart Microgrids

I Introduction:

The development of the renewable energy sources had overcome the various disadvantages of conventional power sources. The Smart microgrids technologies infrastructure load developed in many nations such as Maldives, USA, and Chicago. Electrical Power Research Institute(EPRI) has conducted many research projects in the implementation of the smart grids and microgrid systems and infrastructures. The implementation of the smart microgrid system is essential for the increasing demand in of the load. The Smart microgrid syste in Chicago was entitled as “A perfect Smart microgrid system” installed and its architectural description was discussed[1]. It was first installed in the main campus of Illinos Institute of Technology in Chicago, the cost estimation of such system was $520,000. The north and south substations of the campus fed with 15 KV feeders. The overall capacity of the generation system is 6 Megawatts, employs the gas fired generation system. SAN FRANCISCO, built a first grid scale fleet of hybrid electrical buildings, which has the capacity of 50 megawatts [2]. The microgrid is a relatively small localized energy network, which includes loads, network control system and set of the distributed energy networks, and storage device. Fig.1. Shows the general block architectural view of the proposed system. The existing microgrid system consists of the power sources and storage battery. In Cannada BC Hydro Boston Bar microgrid supplies power without the storage unit, it supplies power to 3000 customers. Fig.1. Shows the block diagram of the proposed system.

The block diagram of the proposed system consists of the PV-Wind turbine-Steam power generation system. The power sources are connected to the grid through the MPPT converters such as the DC-DC converters. The grid system consists of the DC loads, which are directly connected to the grid. The Energy Management System incorporates the fuzzy control algorithm mainly responsible for the optimization and distributed energy generation, and battery management. During the normal condition the MPPT trackers are associated with the PV and Wind turbine that delivers power to the load. During the power failure condition the steam power generation system delivers power to the load. The overall operation of the entire system was monitored by the EMS, and it commands the generation system when to operate as per the load demand and SoC status of the battery. This EMS incorporates the fuzzy control algorithm. This control algorithm gives first priority to the load satisfaction, battery management, and selling the power to the EB system, which employs the AC grid. The RS485 and ZigBee network communication protocol employed to collect the information consists of the generating status of the power sources employed in the system. Based on these information the EMS commands the generation sources to commit for the particular load demand, and SoC value of the battery.

II Generating Systems

A. PV system

The PV system consists of the solar cells. Fig.2 shows the equivalent circuit diagram of the solar cells. The commonly used solar panels are classified into the monocrystalline, polycrystalline, and Thin film solar panels. Among these classification the polycrystalline panels are employed for the residential and industrial applications. This types of panel gives constant output towards the partial shading effects. The modeling equations of the PV cells are discussed [3].

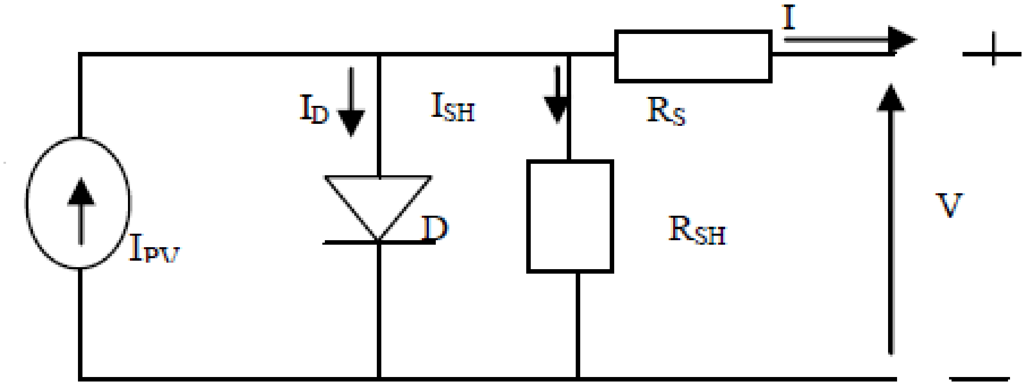

Fig.2. Equivalent circuit diagram of the solar cells

B. Wind turbine

The Wind turbine employs the Doubly Fed Induction Generator (DFIG), comparing to the Squirrel Cage Induction Generator (SCIG), the DFIG has distinct features. The power electronic converters employed in the DFIG are cheaper than the SCIG based wind energy conversion systems. Fig.3 shows the block diagram of the DFIG based wind energy conversion system using for the AC gird. The Power electronics based control of the grid connected wind energy conversion system are discussed [4], [5].

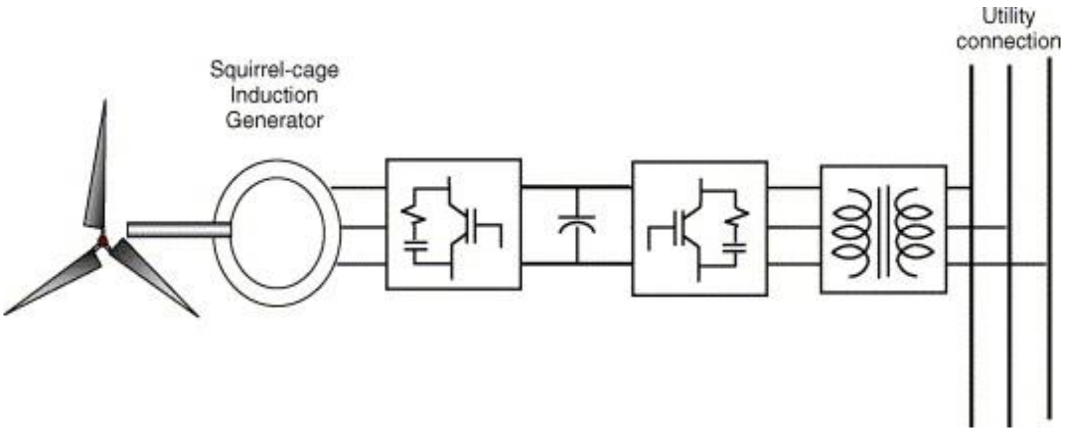

Fig.3. Block diagram of the SCIG based Wind Energy Conversion System

III Maximum Power Point Tracking (MPPT)

The Maximum Power Point Tracking of the power sources are achieved by the fuzzy logic controllers. In this system the maximum power point trackers are associated with the PV and Wind Energy Conversion System

A. Maximum Power Point Tracking of the PV system

The maximum power point tracking of the PV system employs the PV panel, DC-DC converters, intelligent processors, controllers to provide the gating signal to the converter switch, and the load. The closed loop control of the MPPT system is shown in the fig.4. The MPPT of the PV system using the fuzzy and intelligent controllers are discussed [5]

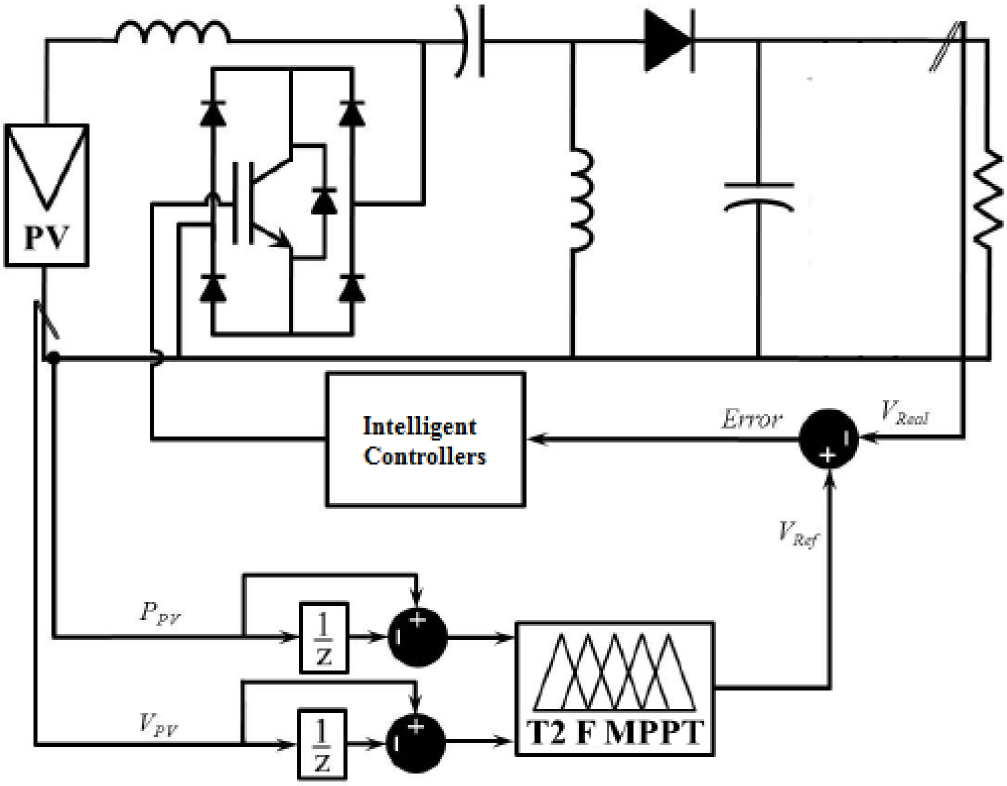

Fig.4. MPPT of the PV system

B. MPPT of Wind Energy Conversion System

The MPPT of the Wind Energy Conversion system consists of the wind turbine and the fuzzy controllers to achieve the maximum power tracking. Fig. 5 shows the characteristics of wind turbine for various values of the speeds. Fig.6 shows the MPPT block diagram of the Wind Energy Conversion System. The MPPT achievement of the Wind Energy Conversion System was discussed [6], [7]. The Wind Energy Conversion System consists of the Maximum power trackers, which can able to protect the wind turbine during hazardous conditions. The protections of the Wind Energy Conversion System are also possible using the intelligent controllers and Processors.

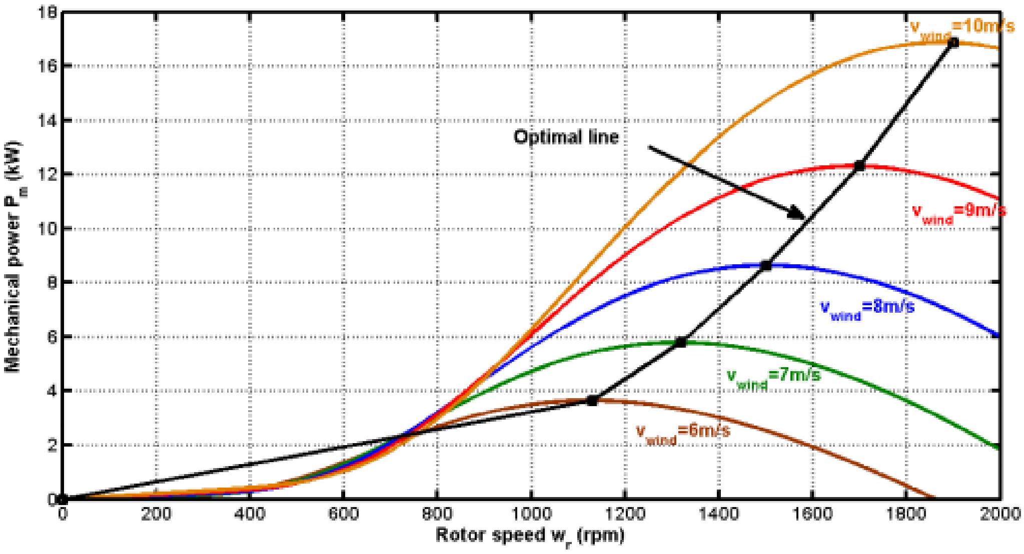

Fig.5. Characteristics of the Wind turbine

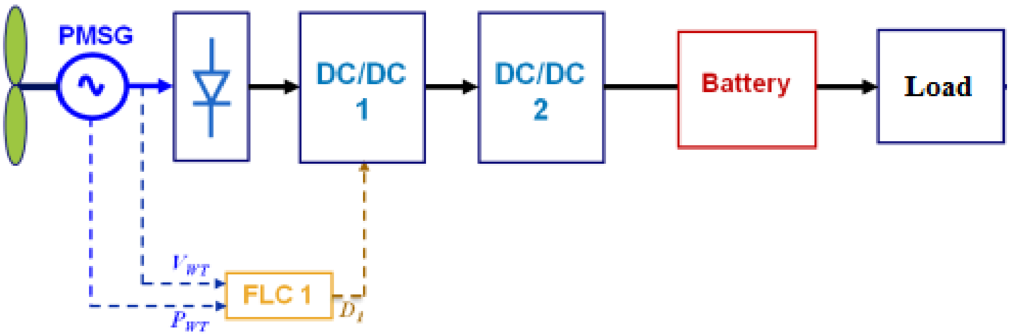

Fig.6. Block diagram of MPPT for Wind Energy Conversion System

C. Steam Power Generation System

The operation of the Steam power generation system was discussed [8].

D. Battery

The battery employed in this system consists of the storage battery, and the bidirectional DC-DC converter. It has two modes of operation. The SoC of the battery was estimated as follows.

$$SoC = \frac{I_c}{Q} \tag{1}$$

The equation shows the SoC estimation of the battery where the SoC is the State of Charge, Q is the battery capacity, and I_c is the battery current.

IV Intelligent 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 [7]. The intelligent management system is essential for this decentralized system for the purpose of optimization, and battery management. The intelligent management system also essential for the optimized load flow. The intelligent management system also employs cost prizing 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 of the installation of the intelligent 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 management system has been proven, that it provides the better solution for the battery management and optimization. The intelligent management system also responsible for balanced power generation.

The intelligent management system employed fuzzy control, for the purpose of optimization and distributed energy generation. 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 difference between the actual load and the total generating power of the system (PV, wind, and fuel cell) for the battery management. The SOC of the battery is directly proportional to the life time of the battery. The fuzzy employed in this maintains the SOC of the battery.

Fuzzy control

The fuzzy logic based concepts are discussed [9], [10]. Fig. 1 shows the block diagram of the proposed energy management system with management control. The fuzzy logic system has two inputs and one output. The fuzzy logic controller decides the charging and discharging operation of the battery, which depends on the SOC. The inputs and outputs of the fuzzy was expressed as follows.

$$\mathrm{P_e} = \mathrm{Total\,Generated\,Power} - \mathrm{Load\,power} \quad (2)$$

$$\mathrm{SOC_e} = \mathrm{SOC_{command}} - \mathrm{SOC_{now}} \quad (3)$$

The input membership functions P_e and SOC_e are shown in the fig. 7 and 8 respectively. The output membership function of I_C, the charging current of the battery is shown in the fig. 11. The fuzzy employs the mamdani type of simulation. The fig.10. shows the surface diagram of the fuzzy rules.

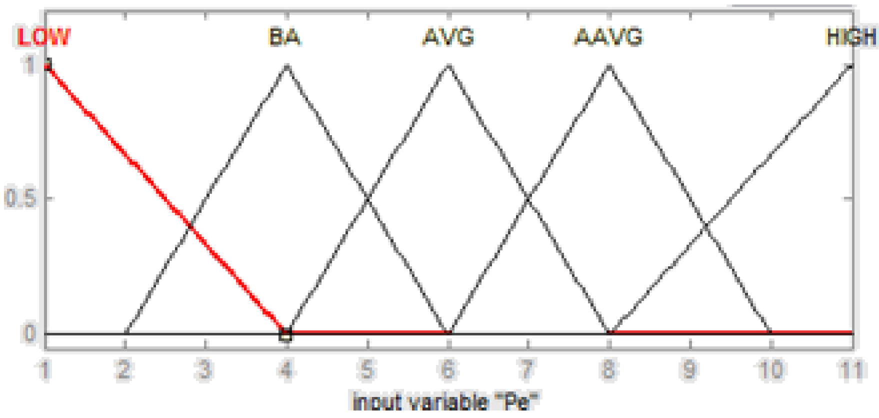

Fig.7. Input membership functions of $P_{e.}$

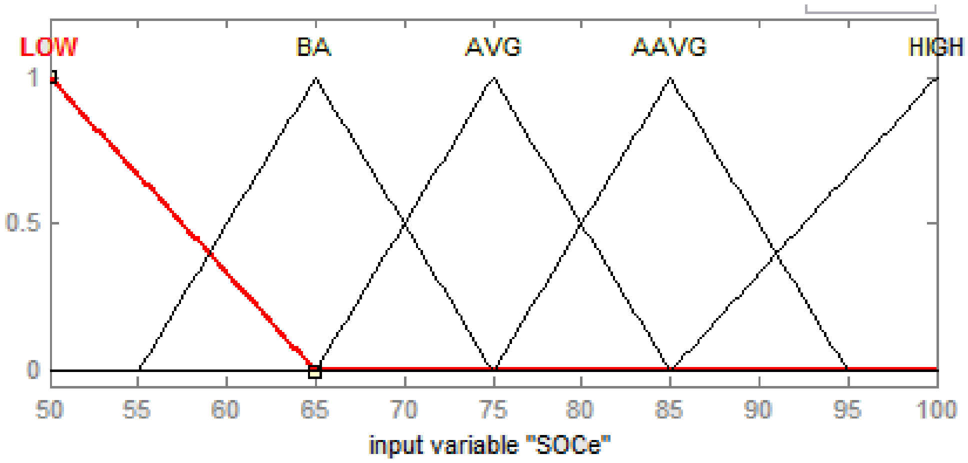

Fig.8. Input membership functions of $SOC_{e.}$

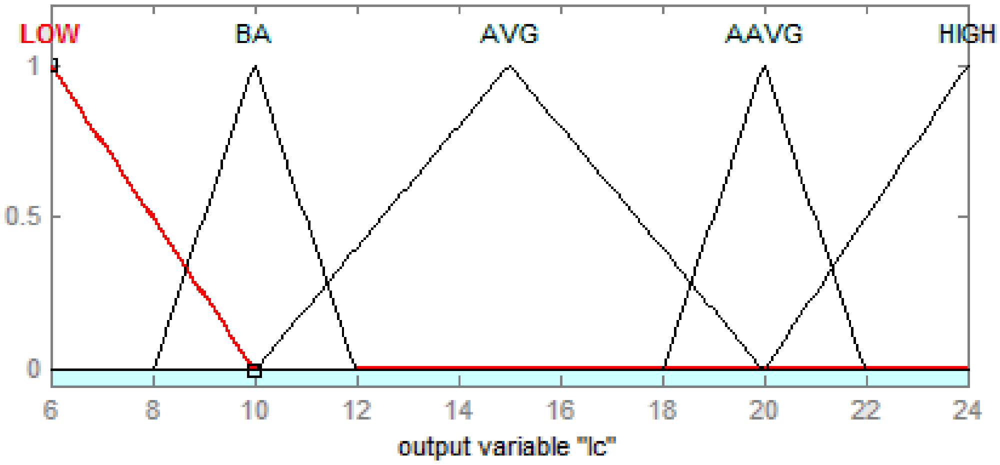

Fig.9. Output membership functions of I_c

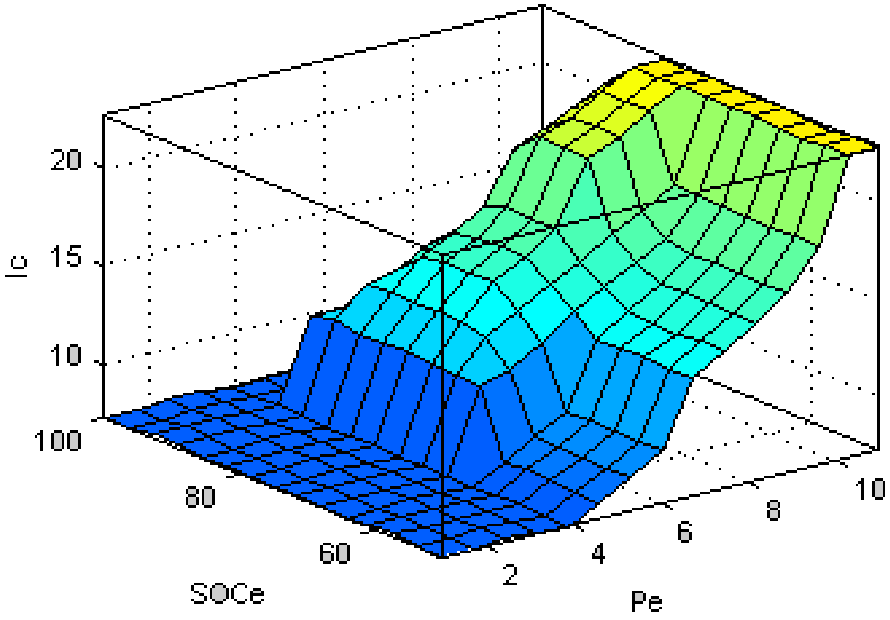

Fig.10. Surface diagram of fuzzy rules..

The control rules of the fuzzy composed of five major grades of membership functions: Low (L), Below Average (BA), Average (AVG), Above Average (AA), and High (H). When P_e is said to be low, which implies the rate 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 are 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 Ic. When the SOC_e is high, it denotes that the charging state of the battery reaches its limit, then the battery is ready to discharge its charges. The values of the SOC_e for the respective grades of the membership functions are shown in the fig. 10. The Ic, 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 Ic is high which indicates the battery charging at the rated current. The fuzzy logic comprises of the number of rules, the lowest value of the SOC of the battery is the 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 value of the SOC reaches more than 90%. The fuzzy rules are tabulated as follows:

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.

TABLE 3 Fuzzy concept rules

SOCe	Pe					
	Ic	**Low**	**BA**	**A**	**AA**	**H**
	Low	Low	Low	BA	A	H
	BA	Low	Low	BA	A	H
	A	Low	Low	A	AA	H
	AA	Low	Low	A	AA	H
	H	Low	Low	Low	Low	Low

V Simulation and Results

A.

B. Simulation of PV systems

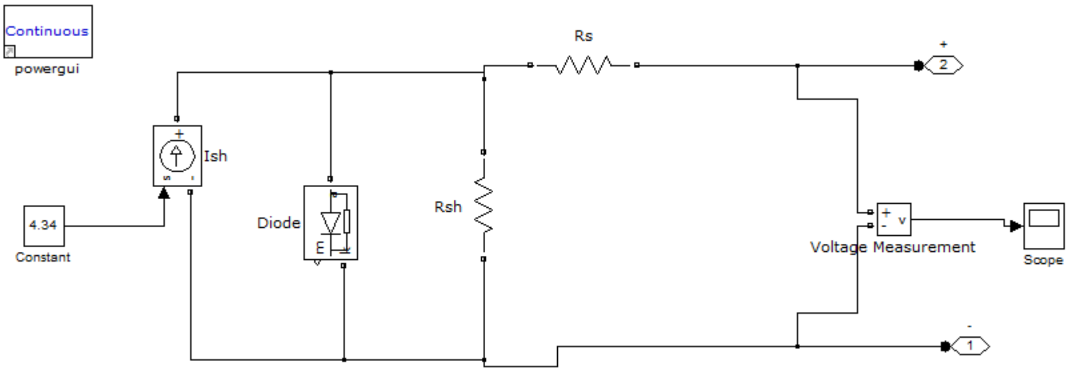

Fig.11. Equivalent Circuit of PV cell

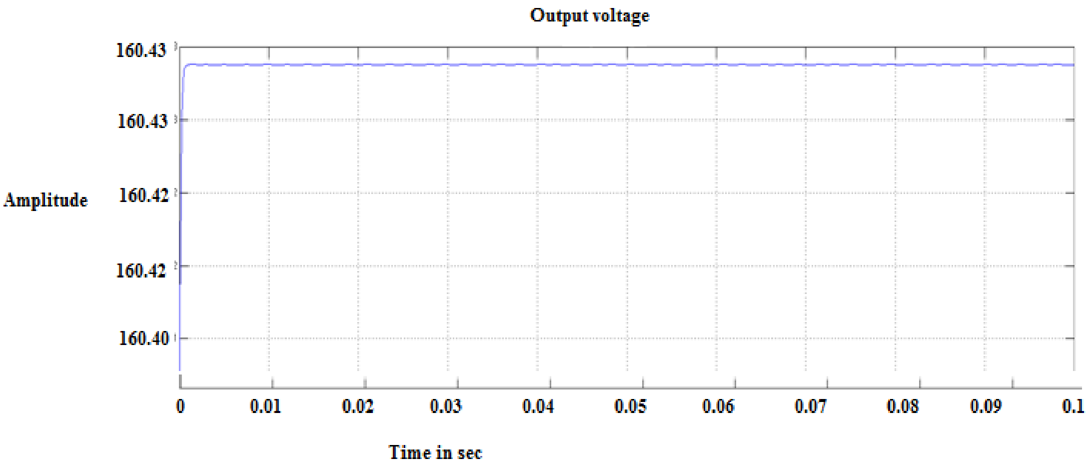

Fig.12. Simulation Waveform of PV cell

C. Simulation of PV system with MPPT

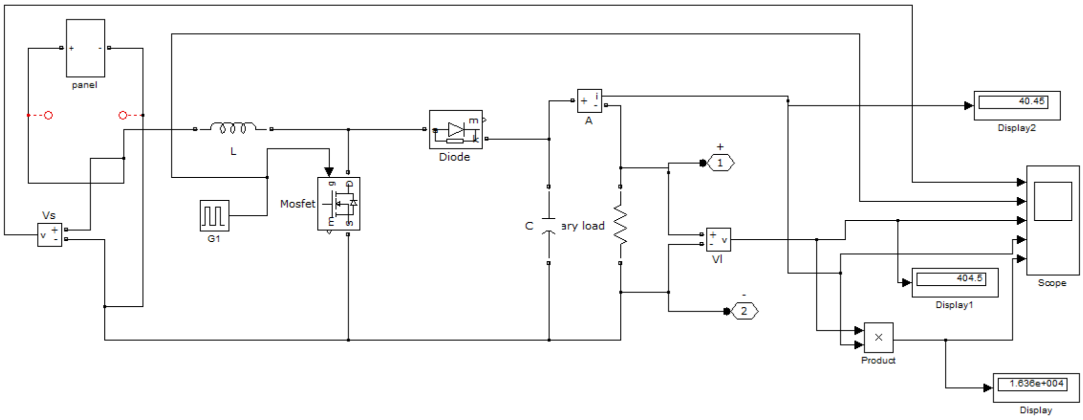

Fig.13. PV system with MPPT

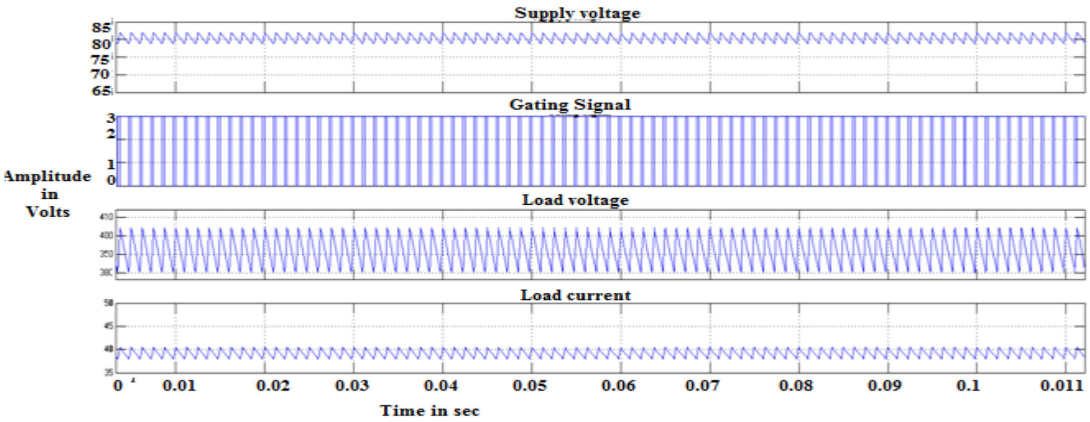

Fig.14. Simulation waveform with MPPT of the PV system

D. Simulation of Wind Energy Conversion system

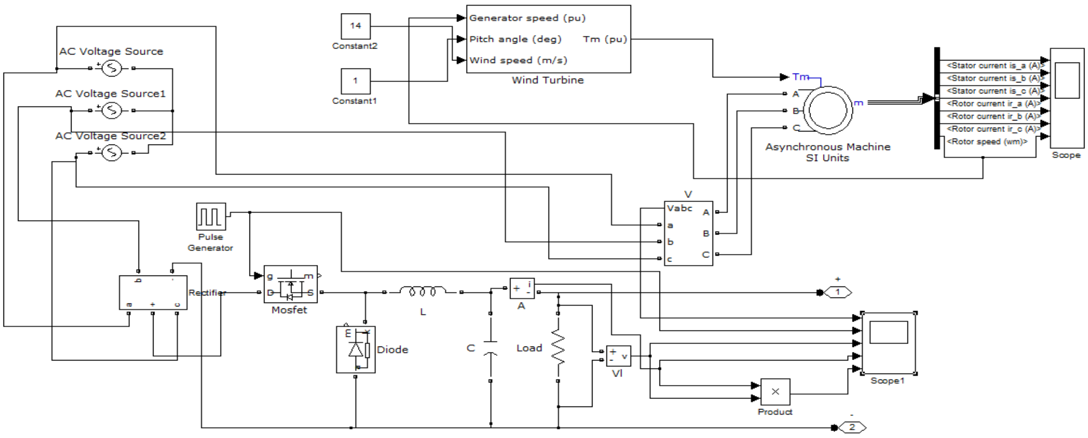

Fig.15. Simulation diagram of Wind Energy Conversion System

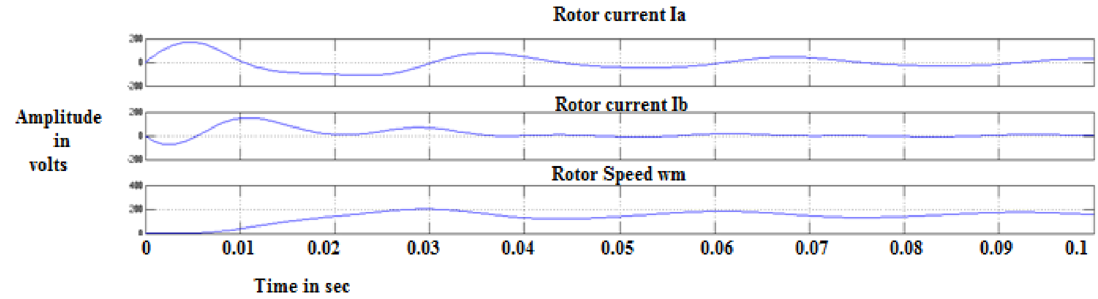

Fig.16. Speed response of rotor of Wind Generator

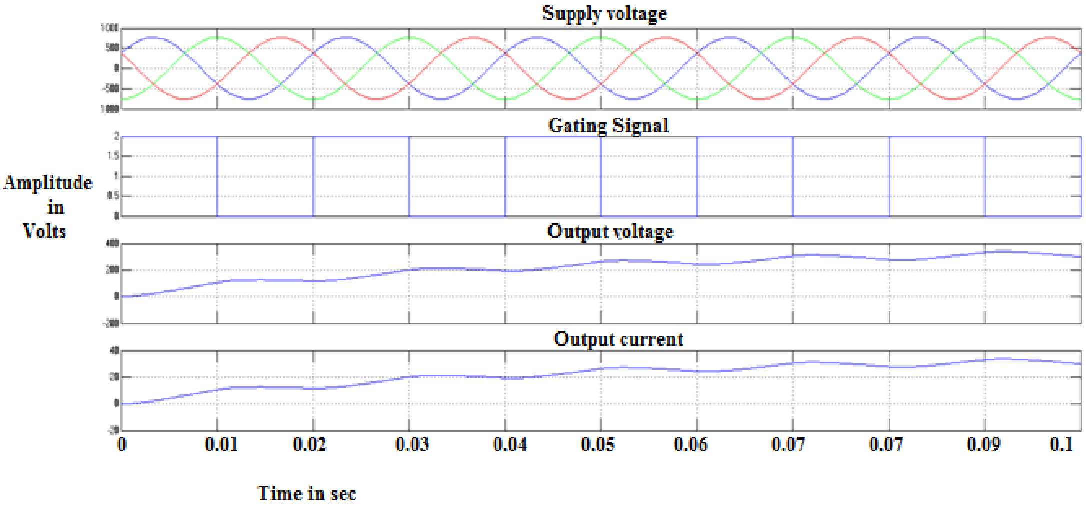

Fig.17. Simulation waveform of Wind Energy Conversion System

E. Simulation of Steam Generation System

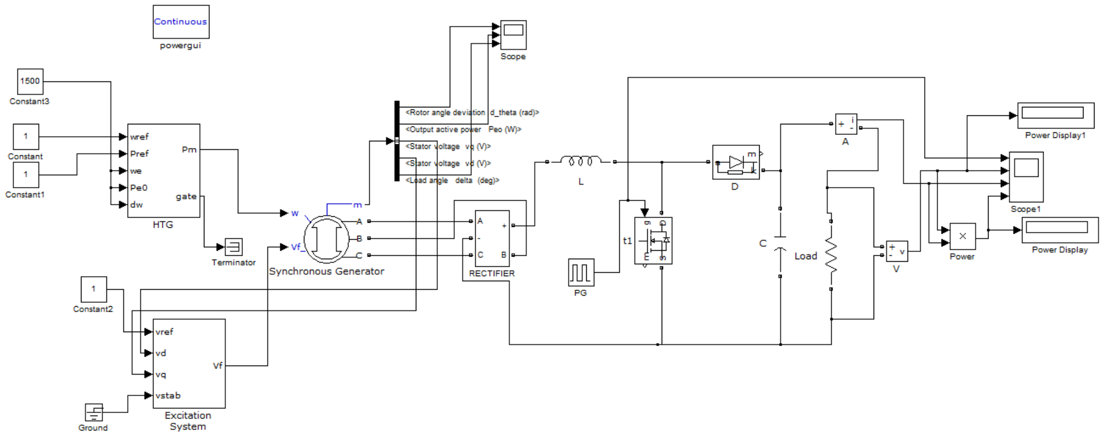

Fig.18. Simulation diagram of Steam Power Generation System

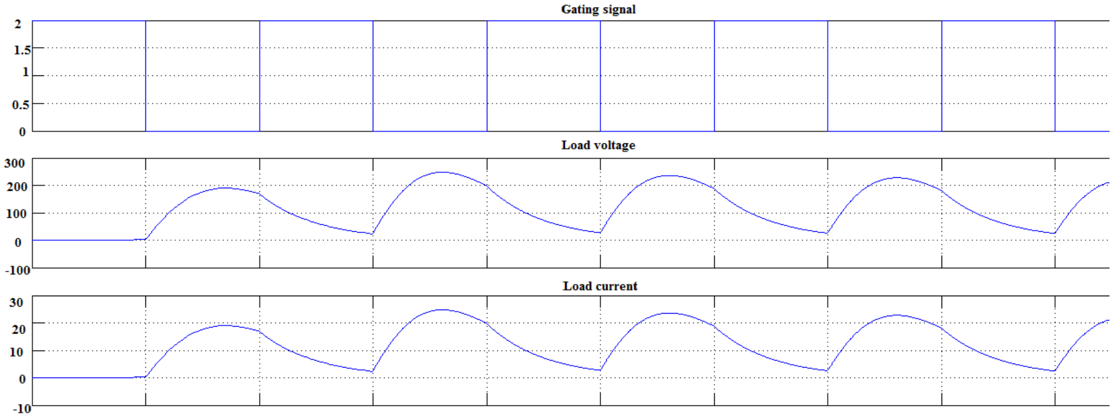

Fig.19. Simulation Waveform of Steam Power Generation System

F. Simulation of battery with Bidirectional DC-DC converter

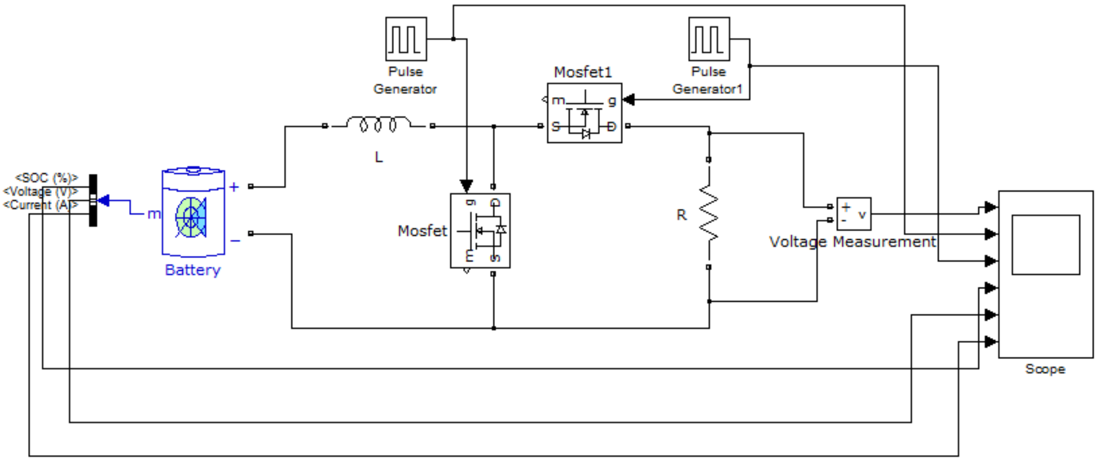

Fig.20. Simulation diagram of battery with BDC

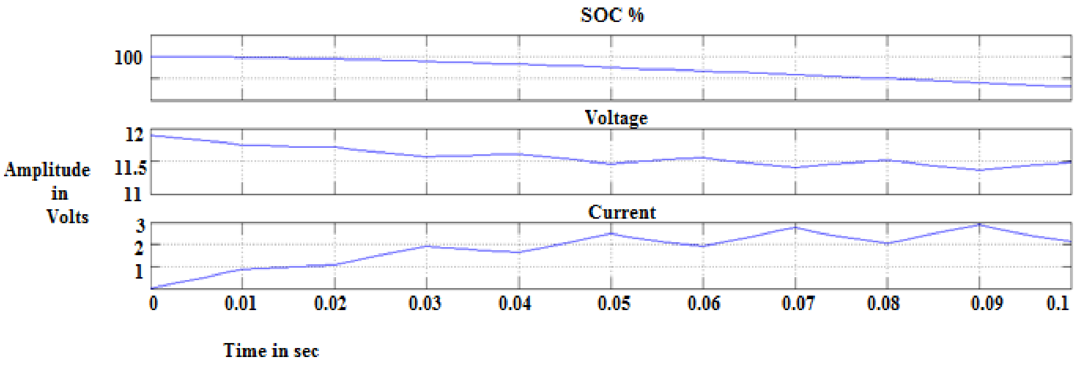

Fig.21. Simulation waveform of battery with BDC

G. Integrated Hybrid System

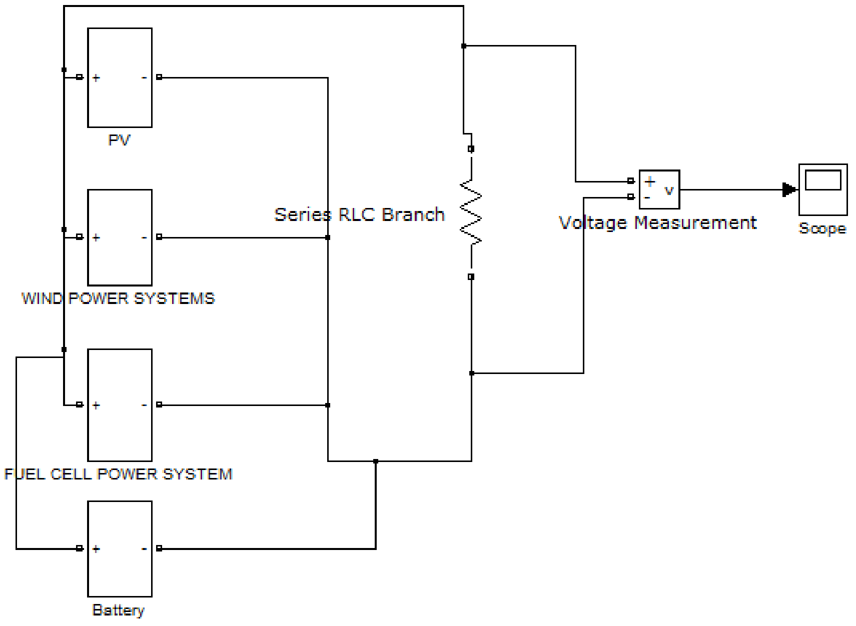

Fig.22. Simulation diagram of integrated hybrid system

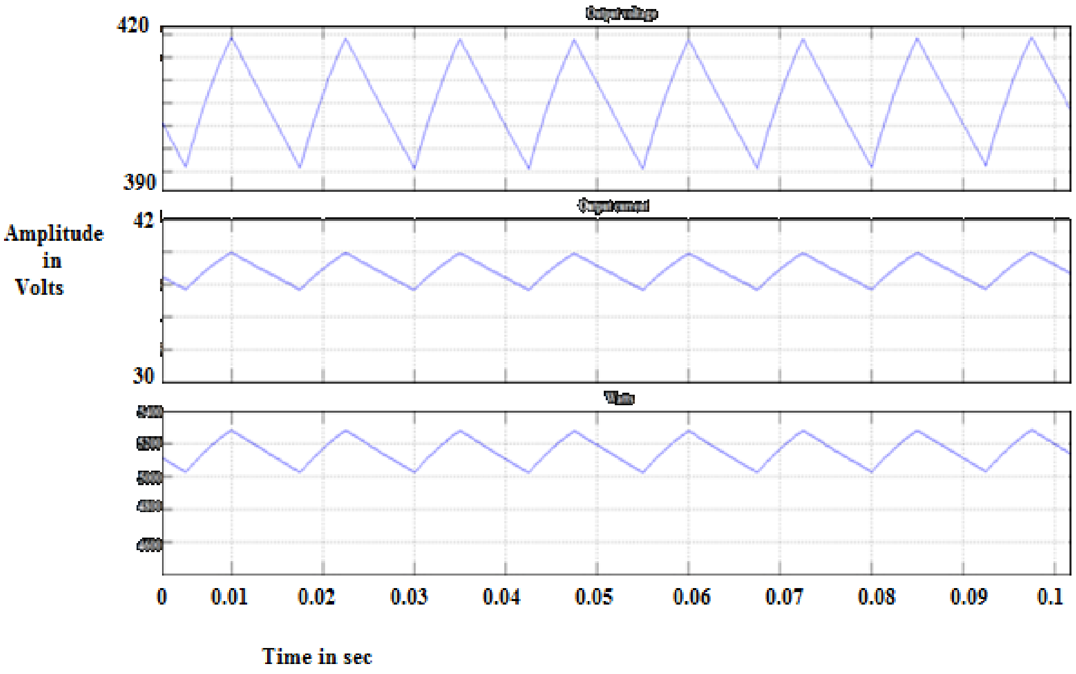

Fig.23. Simulation waveform of integrated hybrid system

V Conclusion

This system implements the fuzzy control to achieve the optimization of an energy management system for the smart gird applications. From the simulation the dynamic model of the DC smart grid system was simulated, and from this simulation of this one can able to understand how the fuzzy maintains the SOC parameters of the battery. In future this system can be implemented by using the supercapacitors in order to overcome the disadvantages of the batteries such as ageing, and maintainance. In case of the Energy Management System can also be implemented by the Artificial Neural Networks (ANN), which further increase the accuracy of the system.

REFERENCES

[1] Chicago illinous Institite of Technology in “the Smart grid : A Perfect Power.
[2] Advanced Microgrid Solutions “Advanced Microgrid Solutions wins contract to build fleet of Hybrid Electrical Buildings^{TM} for Souther California Edison Co.
[3] Mohd Saifuzam Jamri and Tan Chee Wei “Modeling and Control of a Photovoltaic Energy System using the State Space Average Technique.
[4] F. Blaabjerg, Z. Chen, R. Teodorescu, F. Iov “Power Electronics in Wind Turbine Systems” Aalborg University, Institute of Energy Technology
[5] Jay Verma, Yogesh Tiwari, Anup Mishra, Nirbhay Singh “Performance, Analysis and Simulation of Wind Energy Conversion System Connected With Grid” International Journal of Recent Technology and Engineering (IJRTE).
[6] Marcelo Goddy Simoes, Bimal K. Bose “Fuzzy Logic Based intelligent control for the variable cage Machine Wind Generation System” IEEE transactions of Power Electronics
[7] G. Winkler, “Intelligent Energy Management of Electrical Power system with Distributed Feeling on the basis of forecasts of Demand and Generations.
[8] System Analysis Laboratory II Simulation of the dynamic systems.
[9] Nilesh N. Karnik, Jerry M. Mendel, Fellow, IEEE, and Qilian Liang “Type 2 Fuzzy systems” IEEE transactions of Fuzzy systems.
[10] Claudio Moraga “Introduction of Fuzzy Logic” FACTA UNIVERSITATIS.