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Implementation of Energy Management System to PV-Wind Hybrid Power Generation System for DC microgrid Applications

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Abstract-***This paper mainly deal with the Energy Management System of the microgrid system which was fed with the hybrid power generation system consists of PV and wind energy conversion system. The battery acts as a storage system, and the EB system acts as a stand by source, this sources was committed during the power failure condition. The Energy Management System incorporates the fuzzy logic control, which was used to achieve the optimization and distributed energy generation. The main operation of the Energy Management System is that committing the energy sources, and battery management. In the case of the battery management the fuzzy control the State of Charge (SoC) parameters of the battery.***

Key Words: *Hybrid system, fuzzy control, microgrid, Energy Management, Battery management.*

1. 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.

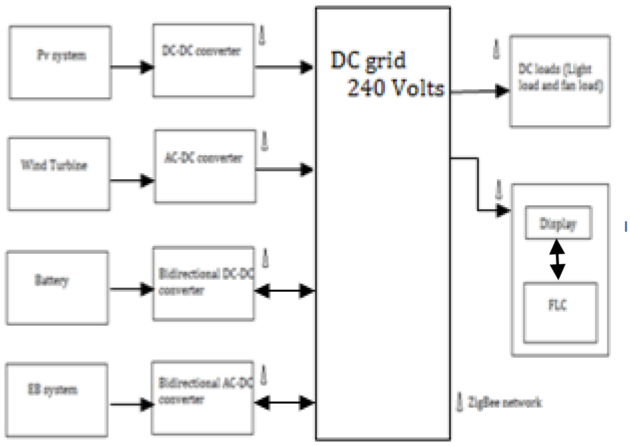

Fig.1. Block diagram of the proposed system

The block diagram of the proposed system consists of the PV, wind energy conversion system, Battery, and EB system. The PV source acts as a primary source and the wind acts as a secondary source. The battery and the EB acts as standby sources, which delivers power during the failure condition. The Maximum power trackers are associated with the PV and wind energy conversion system. During the normal condition, the PV, wind system delivers power to the load. The generated power from this hybrid generating system equally distributed to the load, storage unit, and the remaining power will be sold to the EB system. During the power failure condition the battery delivers power to the load. The SoC percentage of the battery decides the charging and discharging. The communication protocol ZigBee, and RS 485 network are employed for the purpose of communication. This RS 485 and ZigBee networks collects the informations about the generation systems, and the storage unit. The information consists of the generating status of the generation systems and the SoC of the battery. Depends on the SoC and the load demand the generating sources are committed. The DC microgrid system is the nonlinear system, an intelligent control system is essential for the system to achieve the optimization and distributed energy generation. The following sessions describes about the modeling of the generation systems PV, Wind energy conversion system and Battery, storage system.

2. Modeling of the Generation systems

The modeling of the generation system consists of the PV, Wind and battery.

2.1. Modeling of Solar cell

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].

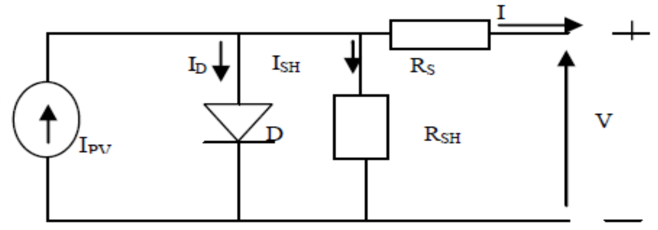

Fig.2. Equivalent circuit diagram of the solar cells

2.2. 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].

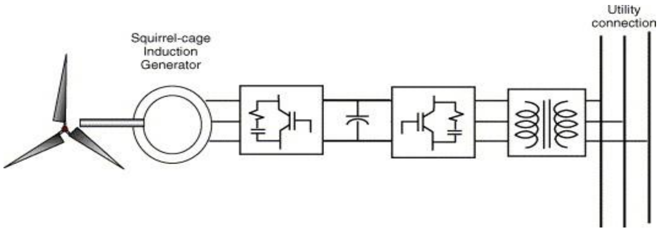

Fig.3. Block diagram of the SCIG based Wind Energy Conversion System

3. MPPT of the PV system

The MPPT of the PV system consists of the PV panel, DC-DC converters, and Load systems. The MPPT of the PV system was achieved by the switched mode converters. The block diagram of the MPPT of the PV system is shown in the fig.4.

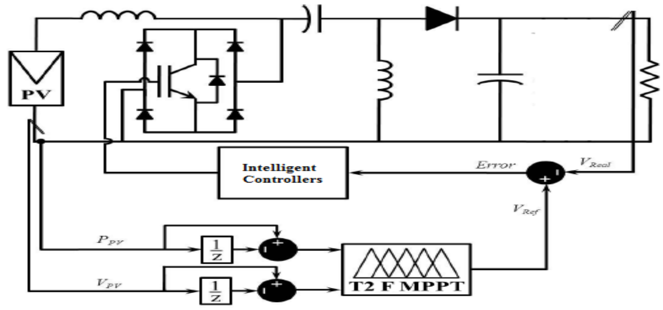

Fig.4. MPPT of PV system

4. 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.

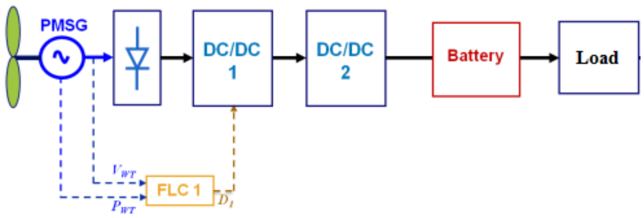

Fig.5. MPPT of Wind Energy Conversion System

5. Battery

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

$$SoC = \frac{I_c}{Q} \qquad (1)$$

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.

6. Intelligent Management System

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) 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.

$$P_e = \text{Total Generated Power} - \text{Load power}$$
$$SOC_e = SOC_{command} - SOC_{now}$$

The input membership functions P_e and SOC_e are shown in the fig. 6 and 7 respectively. The output membership function of I_C, the charging current of the battery is shown in the fig. 8. The fuzzy employs the mamdani type of simulation. The fig.10. shows the surface diagram of the fuzzy rules.

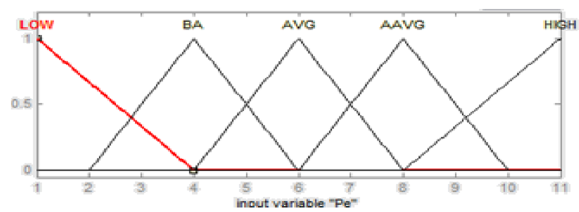

Fig.6. Input membership functions of P_e.

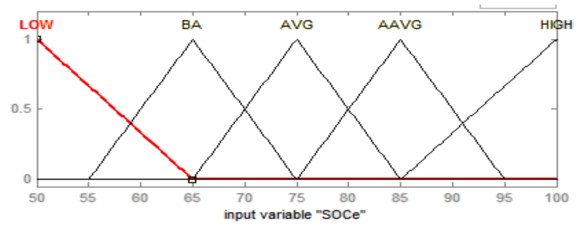

Fig.7. Input membership functions of SOC_e.

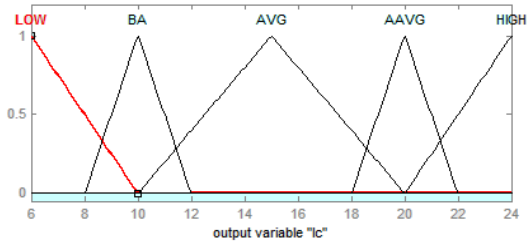

Fig.8. Output membership functions of I_c

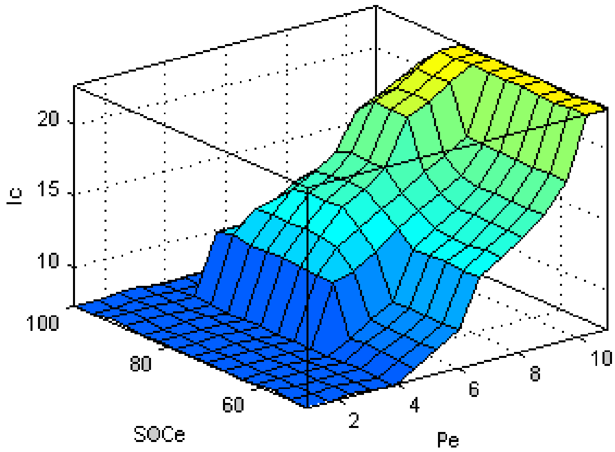

Fig.9. Surface diagram of fuzzy rules.

The control rules of the fuzzy composed of four 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-1: Fuzzy rule table

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

7. Simulation and Results

7.1. Simulation of PV system with MPPT:

The simulation of the PV system consists of the PV panel, DC-DC converters, and the Load system. The output waveform of the PV simulation shows the load voltage, load current, and load power in watts.

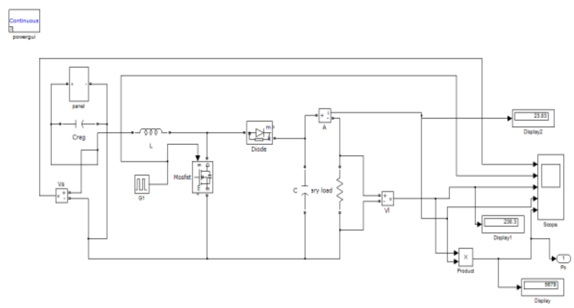

Fig.10. Simulation diagram of PV with MPPT

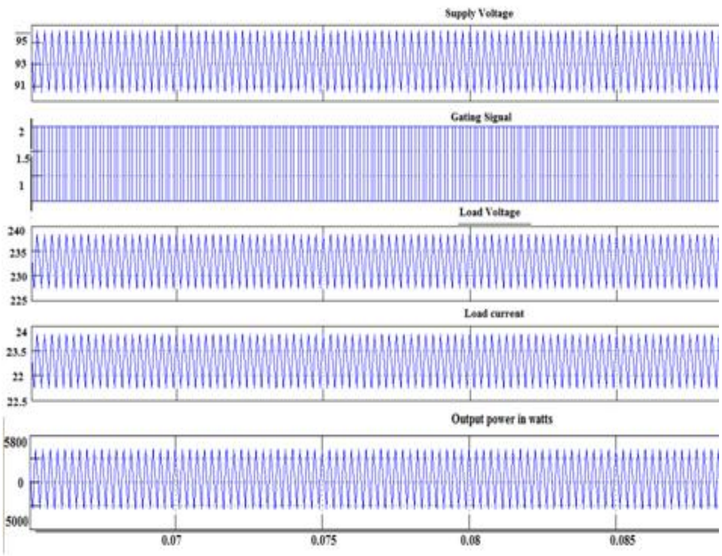

Fig.11. Output waveform of PV system

7.2. Simulation of Wind Energy Conversion System

The simulation of the wind energy conversion system consists of the wind turbine, coupled to the generator Doubly Fed Induction Generator (DFIG), uncontrolled rectifier unit, and the DC-DC boost converter. The output waveform of the wind energy conversion system shows the load voltage, load current, and the load power in watts.

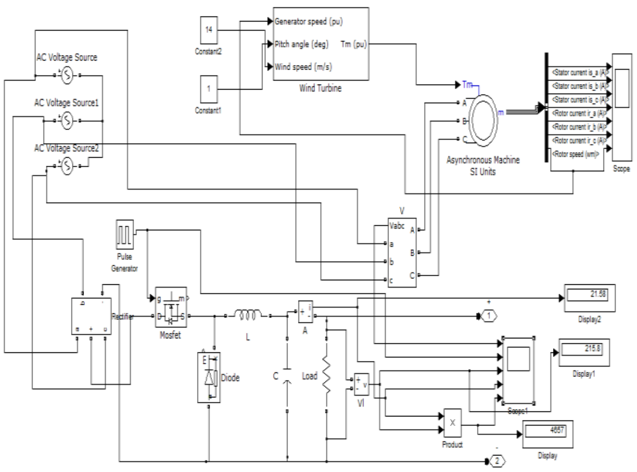

Fig.12. Simulation diagram of wind energy conversion system

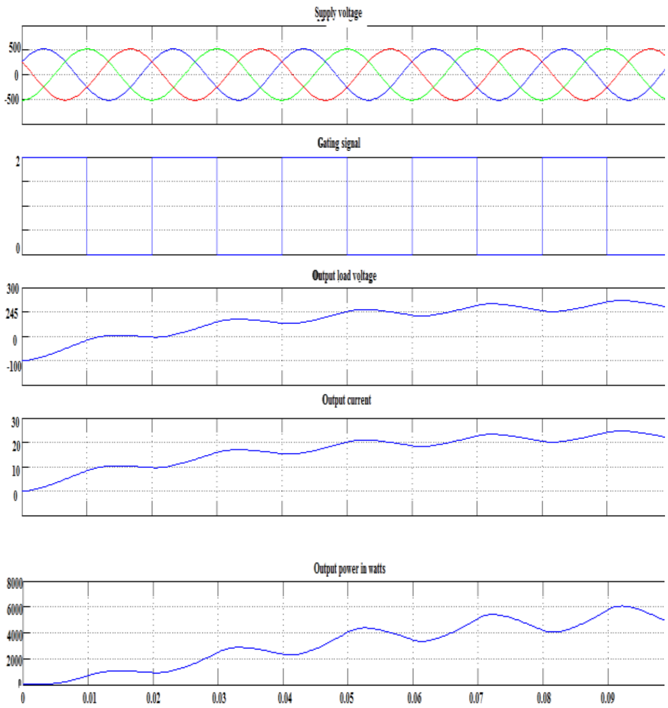

Fig.13. Output waveform of Wind energy conversion system

7.3. Simulation of battery with Bidirectional DC-DC converter

The simulation of the battery consists of the battery with the bidirectional DC-DC converter. The battery employed in this sytem is lead acid batteries which has 12 volts and 7.2 Ah.

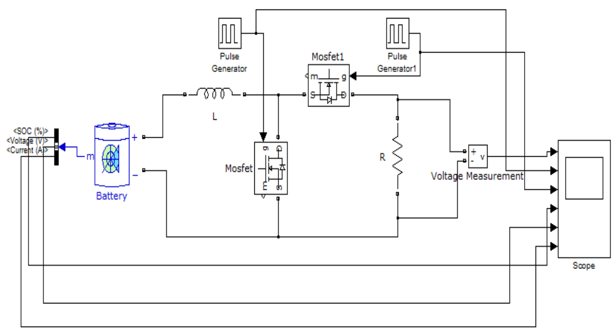

Fig.14. Simulation of battery

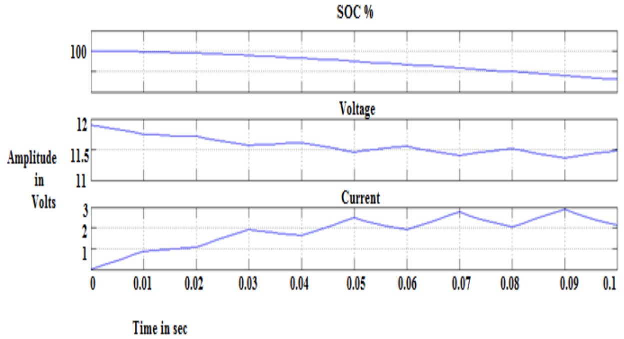

Fig.15. Output waveforms of battery

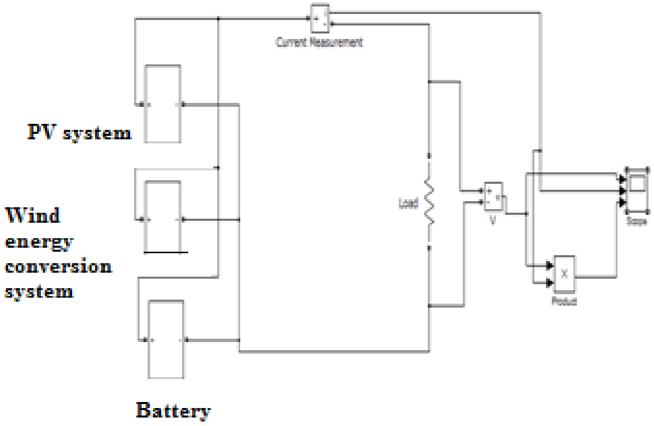

Fig.16. Simulation diagram of integrated hybrid system

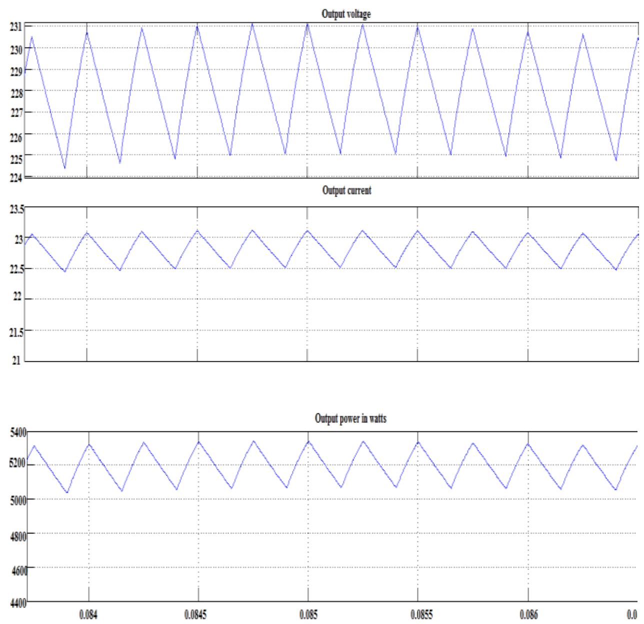

Fig.17. Simulation waveform of integrated system

The integrated system consists of the subsystem of the three sources such as PV, wind energy conversion system, and battery with Bidirectional DC-DC converter.

8. CONCLUSIONS

This paper implements the fuzzy control to achieve the optimization of an energy management system for the smart grid applications. The sources had been successfully integrates and the respective waveforms are obtained. The optimization control of the smart grid system was done through the implementation of fuzzy, which comprises of the number of rules. Such type of intelligent management system increases the accuracy of this 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 and also integrated with some other energy sources.

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