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# Implementation of Energy Management System to PV-Diesel Hybrid Power Generation System for DC Microgrid Applications

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***Abstract:*** **The main objective of this proposed system is to provide Uninterruptible Power Supply to the load. This proposed system mainly deals with the Energy Management of the DC microgrid System. The Power sources employed in the proposed system composed of PV, and Diesel power generation system. The storage system consists of the batteries, and has the EB system acts as a standby system, which delivers power only during the power failure conditions. The RS 485 and ZigBee communication protocol, employed in the communication purposes. The Energy Management System (EMS) incorporates the fuzzy control manages the State of Charge (SoC) of the battery.**

***Keywords:*** **Uninterruptible Power Supply, Energy Management System, Communication Protocols, DC microgrid System.**

## I. INTRODUCTION

The development of the renewable energy system has overcome the disadvantages of the conventional power generation system. The architecture of the microgrid system consists of the interconnected loads, power sources, distributed energy sources, and consists of the standalone and the grid connected load systems. The microgrid system enhances the load reliability, reduce emissions, and improve the power quality of the system [1]. The implementation of the microgrid components composed of modelling and integrating the energy sources parallel to the grid. The smart microgrid components composed of some challenges are commonly called as the IT challenges for the Energy distribution operators [2]. The efficiency and viability of the energy management was improved by using the automated system, that depends on capturing the fine grained data composed of the voltage and current consumer by the systems, accepted the load demand commands. The process of the microgrid system briefly discussed [3]. The main characteristics of the smart microgrid systems are grouping of interconnected loads and distributed energy sources, can operate in islanded mode and grid connected mode, if desired, it acts as a single controllable entity as load. The brief classification of the microgrid are discussed [3]. The microgrid systems are exists in USA, Chicago, and in Maldives.

The block diagram of the proposed system composed of the power sources which obtains its power from the PV panels, and Diesel power generation system. Theses power sources are connected to the gird by using the suitable converters such as DC-DC converters, Bidirectional DC-DC converters, and Bidirectional AC-DC converters. During the normal condition the Maximum Power Point Trackers (MPPT) are associated with the PV systems, that delivers power to the load systems. During the power failure condition, the battery delivers its power to the load or the power can be obtained by committing the diesel generators, employed in this system. This proposed system employs the PV power as its primary source, and the battery or the diesel generators are employed as the secondary source. The RS 485 and ZigBee, a

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communication protocol, employed for the purpose of communication. This communication consists of the information that composed of the generating status of the power sources that are connected parallel to the grid, and the SoC of the battery. Based on these informations, the EMS commands the energy sources, when to operate as per the load demand and the SoC of the battery. The EMS incorporates the fuzzy control, the fuzzy based EMS system are so called as the Intelligent Management System. Such intelligent system are required for the DC micrgrid nonlinear system for the purpose of optimization and distributed energy generation.

## II. MODELLING OF GENERATING SYSTEMS

### A. Modelling of Solar cell:

The photocurrent generating principle is shown in the fig. 2. The equivalent circuit diagram of the solar cell is shown in the fig. 3. The solar cell converts the light energy to electricity [4]

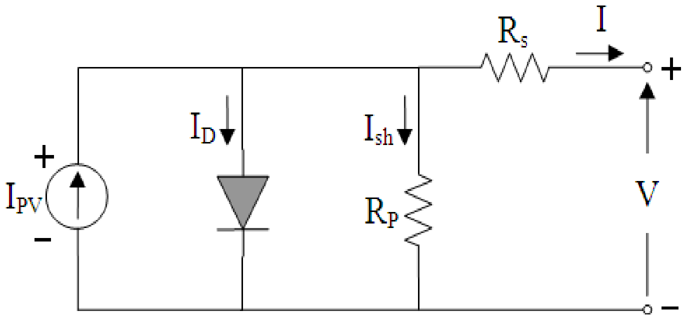


**Fig.2: Equivalent circuit diagram of PV cell**

The expressions of the PV cells comprised of the PV output current I, diode saturation current $I_0$ expressed [9] by eqn. (1) to (3)

$$I = I_{Pv,cell} - I_0 \left[\exp\left(\frac{V + R_s I}{V_t a}\right) - I\right] \qquad (1)$$

The saturating diode current of the batter is expressed by the following equations (2)

$$I_0 = \frac{I_{sc,in} + K_i \Delta T}{\exp\left(\frac{V_{oc.n} + K_V \Delta T}{a V_t}\right)} \qquad (2)$$

The power in the PV panel is expressed by (3) [5].

$$\boldsymbol{P = V\left\{I_{sc} - I_0\left[exp\left(\frac{V}{A * V_t}\right) - 1\right]\right\}} \qquad \mathbf{(3)}$$

The fig. 3, fig. 4, shows the I-V and P-V characteristics of the solar cell.

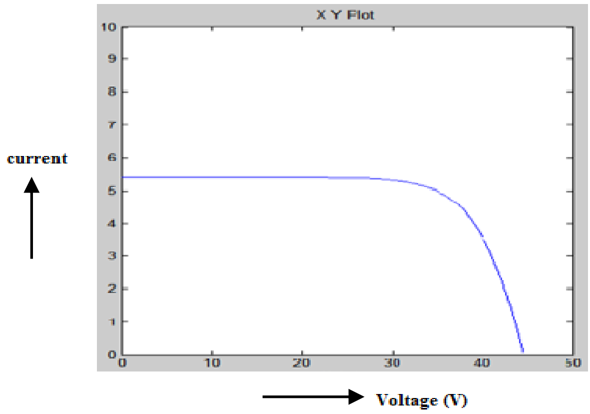


**Fig.3: I-V characteristics of solar cell**

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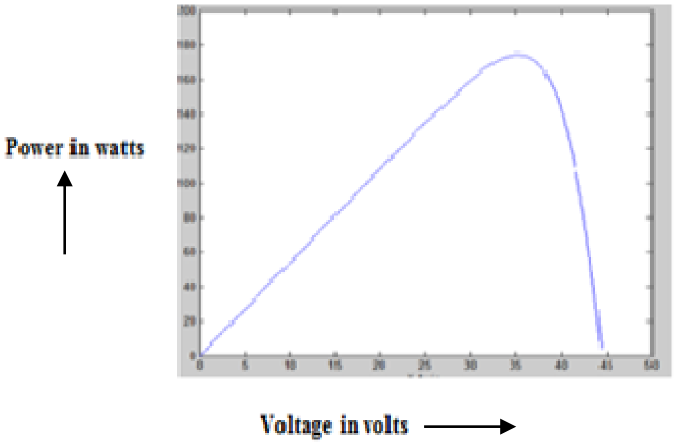


**Fig.4: P-V characteristics of solar cell**

### B. Diesel Power Generators:

The diesel generator employed in this system is the synchronous generator. The regulator and actuator transfer function are expressed as

$$H_r = \frac{K_r(1 + T_{rs}S)}{1 + T_{r1}S + T_{r2}S} \quad (4)$$

$$H_a = \frac{(1 + T_aS)}{S(1 + T_{a2}S)(1 + T_{a3}S)} \quad (5)$$

Where

| | |
|---|---|
| K | Regulator gain |
| Tr1, Tr2, Tr3 | Regulator time constants |
| Ta1, Ta2, Ta3 | Actuator time constants |

## III. MPPT OF 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. The MPPT of the PV system using fuzzy logic controllers are discussed [6].

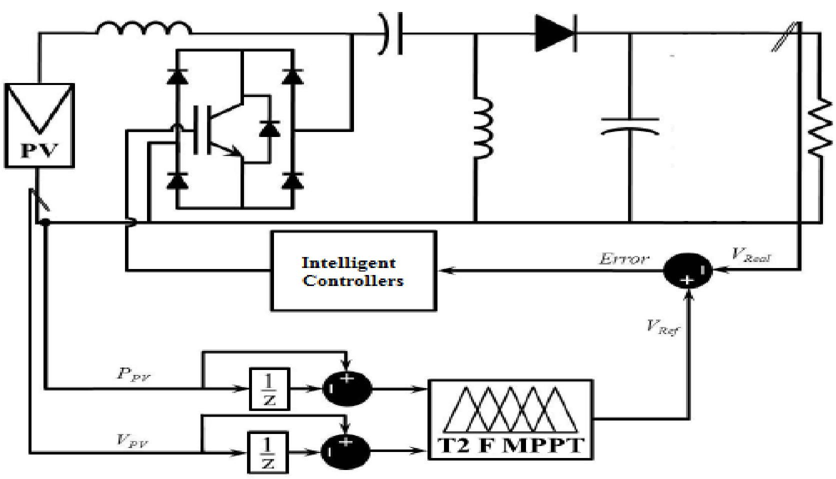


**Fig.5: MPPT of PV system**

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## IV. 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 [7], [8]. 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.

$$P_e = \text{Total Generated Power} - \text{Load power} \quad (6)$$

$$SoC_e = SoC_{command} - SoC_{now} \quad (7)$$

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.9. shows the surface diagram of the fuzzy rules.

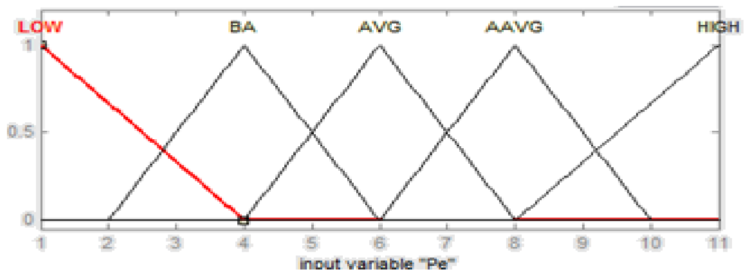


**Fig.6: Input membership functions of $P_e$.**

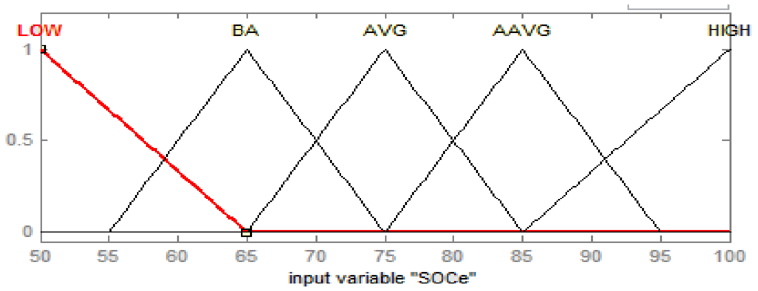


**Fig.7: Input membership functions of $SOC_e$.**

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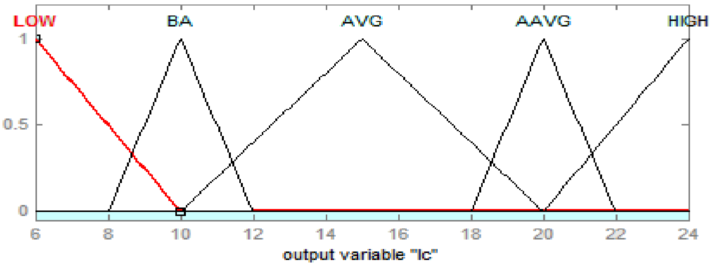


**Fig.8: Output membership functions of $I_c$**

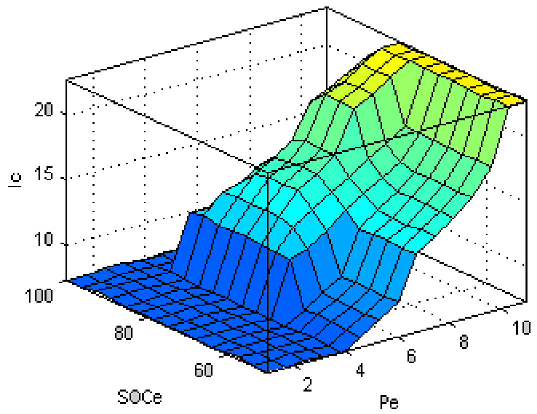


**Fig.9: Surface diagram of fuzzy rules.**

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, Diesel power generation of 1.245 kW. The battery employed in this system is the lead acid batteries. 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 |

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## V. SIMULATION AND RESULTS

### A. Simulation of PV system:

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.

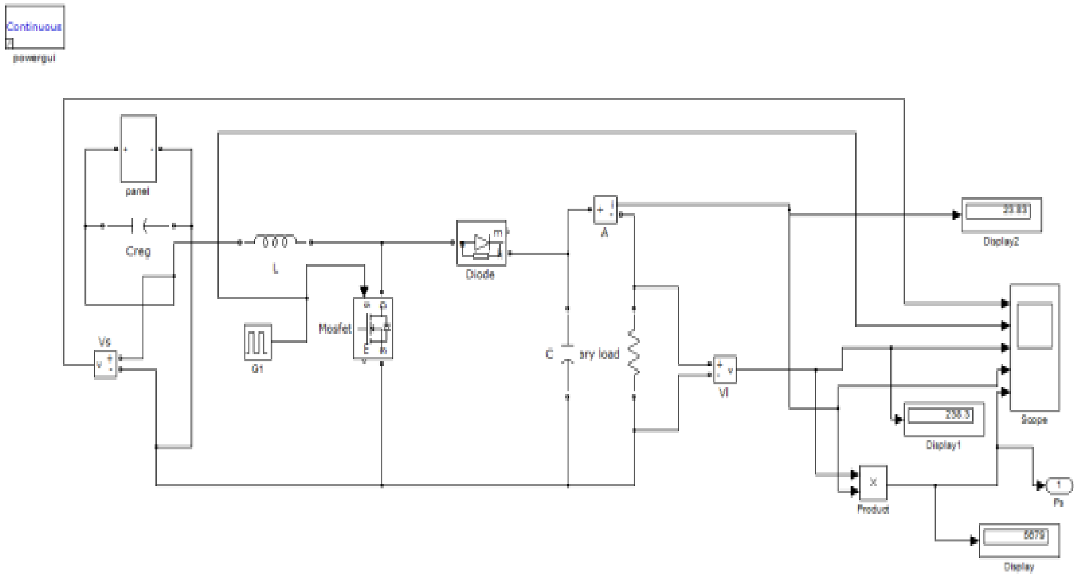


**Fig.10: Simulation diagram of PV with MPPT**

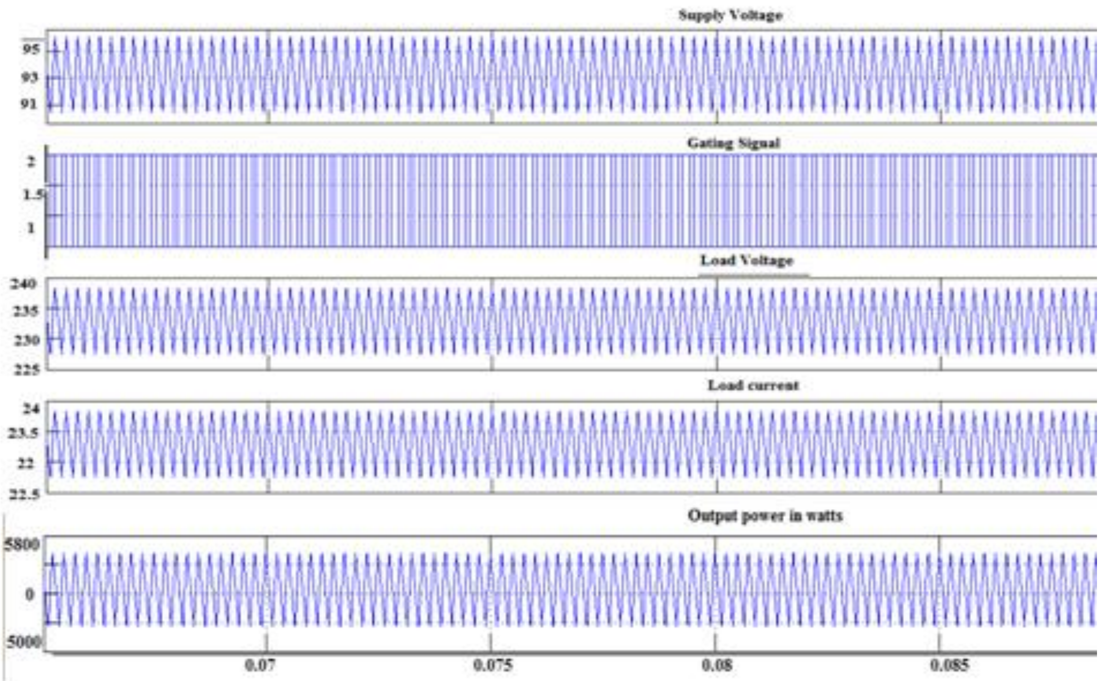


**Fig.11: Output waveform of PV system**

### B Simulation of Diesel Power Generation System:

The diesel power generation consists of the diesel generator. The generating system includes the diesel generator governor and the generator excitation system. The diesel generator employed here is the synchronous generator, which produces the output voltage of 185.2 volts. Fig. 12 and 13 shows the matlab circuit diagram of the diesel generator system and the waveform of the diesel generating system.

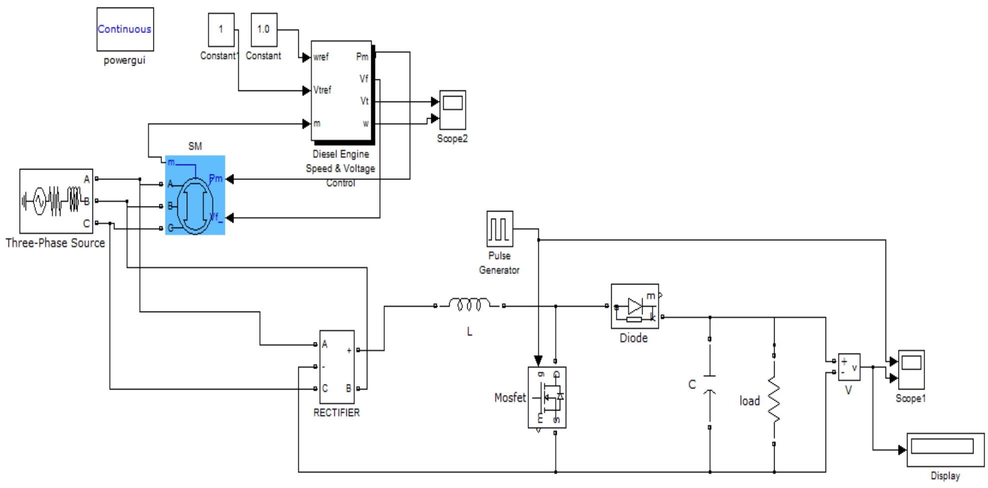


**Fig.12: Matlab circuit diagram of diesel power generation system**

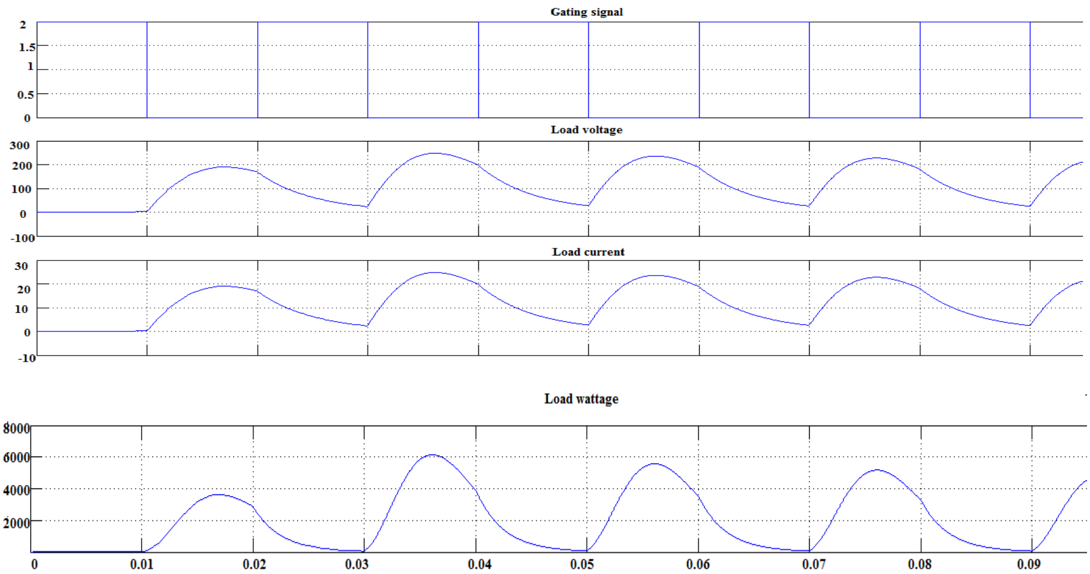


**Fig.13: Output waveforms of diesel power generation system**

## C. Batter with Bidirectional DC-DC converters (BDC):

The simulation of the battery involves the battery with BDC.

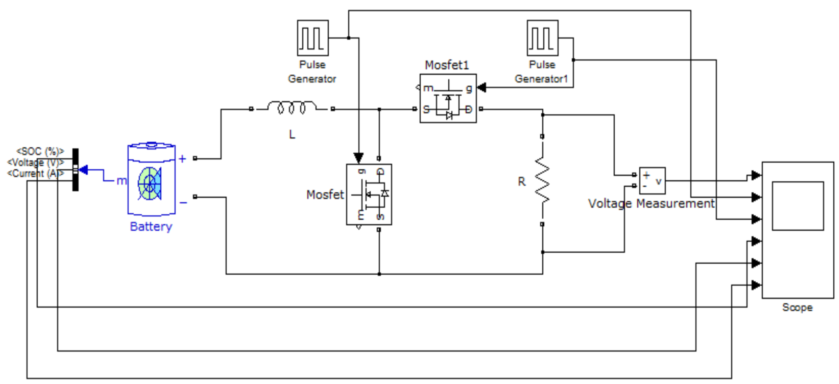


**Fig.14. Simulation of Battery**

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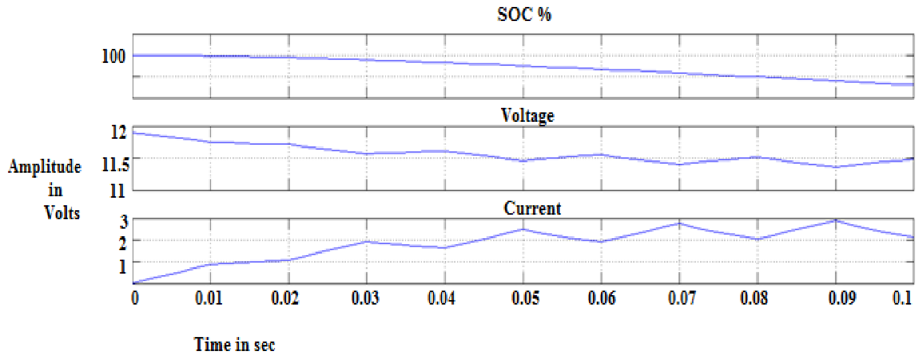


**Fig.15: Output waveform of Battery system.**

### D. Simulation of Integrated System:

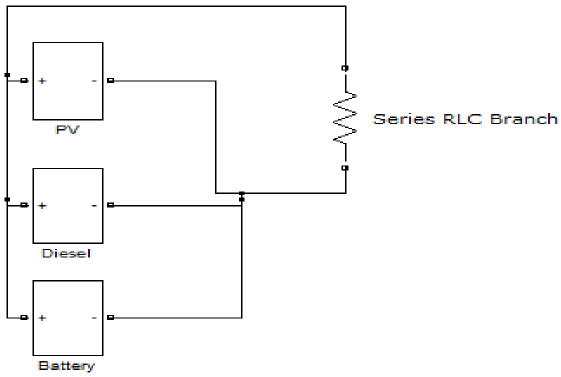


**Fig.16: Simulation of Integrated Hybrid system**

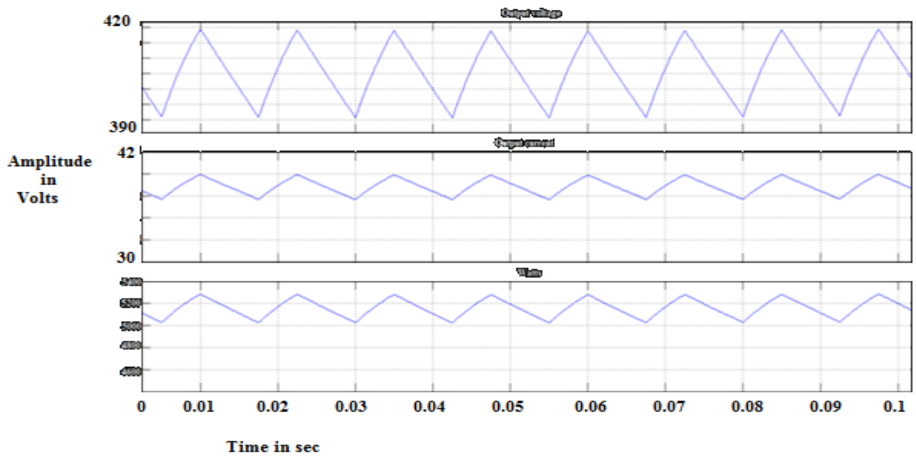


**Fig.17: Output waveform of integrated management system**

## VI. CONCLUSION

This proposed 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 micro 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. The optimization control of the DC smart micro grid was done through the employment of the fuzzy by its membership functions and the fuzzy rules. The intelligent management increases the accuracy of the non linear system and it also achieves the optimization of the energy distribution of the smart micro grid system by its control algorithm.

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