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European Journal of Advances in Engineering and Technology, 2021, 8(1):34-41

Research Article ISSN: 2394 - 658X

Power Management in DC Microgrid

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ABSTRACT

DC loads have proliferated rapidly on the market today and DC micro grids with renewable energies are being built as a potential solution to meet the rising demand for electricity. As different energy sources such as solar, wind, fuel cell, and diesel generators can be incorporated into the DC grid, it is important to control the power flow between the sources. An attempt is made in this paper to study the hybrid system consisting a three energy sources, namely wind energy, photovoltaic power source and Battery. Each of the three energy sources is controlled so as to deliver uninterrupted power supply to the load. A control strategy for the management of power flows with solar and wind energy sources in DC micro grid are discussed. Given that voltage profile regulation is critical in a standalone system, a dedicated converter should be used to maintain the voltage of the DC connection. The battery circuit regulates DC charging voltage, while the full power is derived from Solar and Wind to power the attached DC bus charges. An algorithm is developed to manage power flow between three outlets. The algorithm is evaluated in MATLAB / SIMULINK environments for different charging conditions and variations in solar and wind energy.

Key words: Microgrid, Power management, Photovoltaic, Wind conversion systems, Hybrid system

INTRODUCTION

Alternating current is used as the energy source in previous days of electricity. The number of consumer goods is growing as a result of the modernization and the demand for electricity has increased [1]. The rising demand for fossil fuels is driving people into renewable sources of energy. The use of solar and wind energy for power has been made viable by recent advances in semiconductor technology [2]. Since most electronic loads need a DC supply, the ac power is converted into DC within the device itself in order to supply the load [3]. The DC voltage of the solar panel is converted to alternating current and returned to DC prior to charging. PV is a DC power generation system. Due to additional converters reducing the performance of the device tremendous amount of power is wasted. There is a simpler way to directly supply the power from the source. DC micro grid is then applied. More performance and reliability can be accomplished by using this method. When power from solar or wind systems are not sufficient, the micro grid can receive power from the batteries. The area and the grid can be supplied with voltage, frequency and energy quality by means of Microgrid controls [4].

In order to efficiently leverage available sources of renewable energy, it is important always function in MPPT mode. Different management of power flow algorithms for grid connected systems was stated. In standalone systems, it is important to maintain the voltage profile that the MPPT mode is sacrificed [5]. In this paper, the DC link voltage is controlled with the battery charge /discharge device circuit, while maximum renewable energy sources are extracted [6-7]. The developed Power Flow Management algorithm can decide the mode of operation depending on whether solar and wind power is available while taking account of the battery voltage and demand to ensure the reliable and uninterrupted power to the load. The proposed DC Microgrid consists of solar PV array, Wind energy conversion system, battery bank, power converters for interfacing with the DC bus. Fig.1 shows the block diagram of DC Micro grid considered for study [8-9].

The output of the PV array is connected to the DC grid through the DC-DC boost converter. The power from the wind turbine is generated through the PMSG. The generated power rectified to DC and fed into the DC bus through a power converter. MOSFET is used for the switching purpose. The output from the DC-DC boost converter is connected to the

DC micro grid where the loads are connected. The charging and discharging of the battery is done by bidirectional buck-boost converter which also regulates the DC link voltage [10-12].

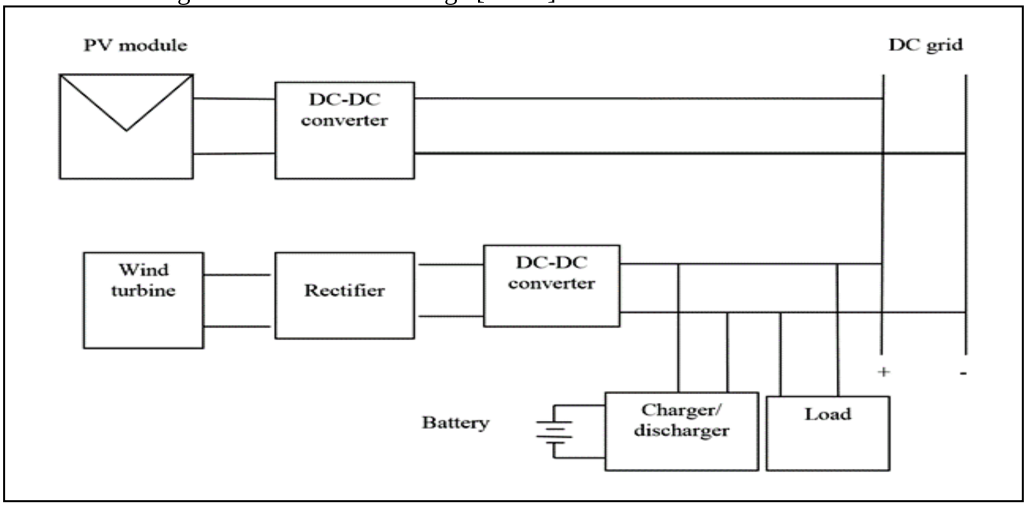


Fig. 1 Block diagram of the DC microgrid with Solar and wind energy sources

MODELLING OF SOLAR PV

PV system is based on solar energy, where PV cell is the most basic generation part in PV. As shown in Fig. 2, the PV cell is formed from a diode and a current source was connected antiparallel with a series resistance [3]. The relation of the current and voltage in the single-diode cell can be written as follows:

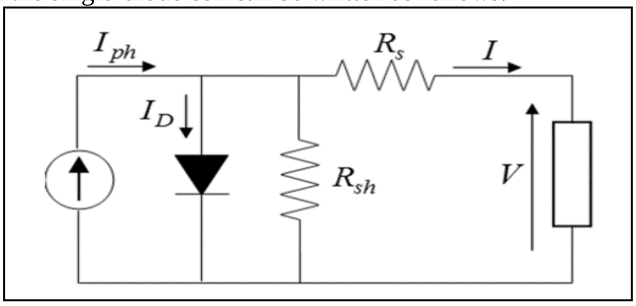


Fig. 2 Equivalent circuit of PV cell

$$Ipv = Iph - I_0((\exp(q(Vpv + Rsmod\ Ipv))/AKT \quad (1)$$

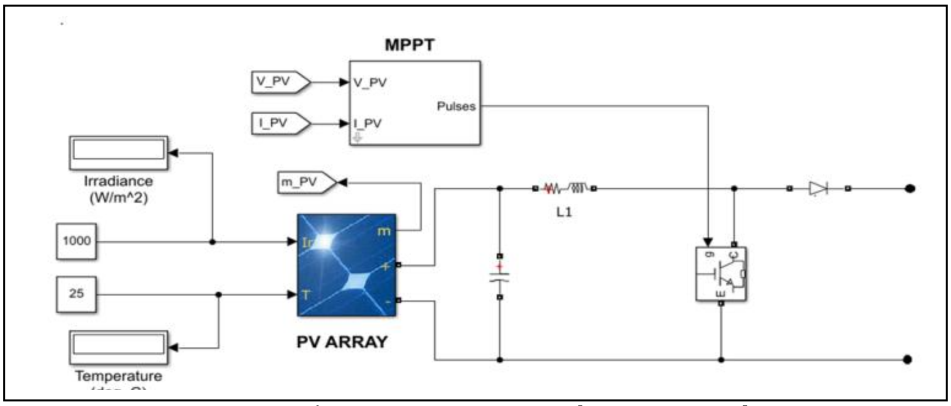


Fig. 3 Boost converter with MPPT control

DC/DC BOOST CONVERTER AND MPPT

A boost converter is a step-up DC/DC converter which increases the solar voltage to a desired output voltage as required by load. The configuration is shown in Fig. 3, which consists of a DC input voltage Vin, inductor L, switch S, diode D1, capacitor C for filter. When the switch S is ON the boost inductor stores the energy fed from the input voltage source and during this time the load current is maintain by the charged capacitor so that the load current should be continuous. When the switch S is OFF the input voltage and the stored inductor voltage will appear across the load hence the load voltage is increased. Hence, the load voltage is depending upon weather switch S in ON or OFF and this is depending upon the duty ratio D. The solar panel efficiency is increased by the use MPPT technique. The MPPT is a device that extracts maximum power from the solar cell and changes the duty ratio of DC/DC converter in order to match the load impedance to the source.

WIND ENERGY SYSTEM

The wind energy system consists of a wing which captures the kinetic energy of the wind and turbine produces the mechanical power and that is coupled directly with a permanent magnet synchronous generator which generates ac power and is supplied to the DC bus via a diode rectifier, this is the retained structure for this modelling and simulation work. The mechanical power of a wind turbine is expressed as follows [4-5]:

$$P_{mech} = \frac{1}{2}\rho ArCpV^3 \qquad (2)$$

The power coefficient is:

$$Cp = 2Pwind/\ (\lambda S\ (Vwind)^3) \qquad (3)$$

$$Twind = Tmech = 0.5\frac{Cp\lambda\rho RS\ (V)2}{\lambda} \qquad (4)$$

PMSG model the permanent magnet synchronous machine model used is modeled by the following equations:

$$\begin{bmatrix} Vd \\ Vq \end{bmatrix} = \begin{bmatrix} Rc & -\omega Lc \\ \omega Lc & Rc \end{bmatrix}\begin{bmatrix} id \\ iq \end{bmatrix} + Lc\frac{d}{dt}\begin{bmatrix} id \\ iq \end{bmatrix} + \begin{bmatrix} ed \\ eq \end{bmatrix} \qquad (5)$$

The electromagnetic torque is given by:

$$Tem = P/\omega\ (iqeq] = P\psi iq \qquad (6)$$

The mechanical equation for the PMSG is expressed as:

$$J\ d\omega r/dt = Tem - Tl - f\omega r \qquad (7)$$

BATTERY SYSTEM

Battery plays an important role in maintaining unintruppeted power supply to the load. The objective of the battery control system is to regulate the battery current in order to obtain the required power. Charging and discharging current limits and maximum SOC limitations are also included in the model fig.4.. The BESS (Battery energy storage system) is connected to the DC grid via a bi-directional Buck-Boost DC/DC converter, as shown in Figure 4. The BESS will operate in charging, discharging or floating modes depending on the energy requirements and these modes are managed according to the DC bus voltage at the BESS point of coupling. Consequently, the BESS is required to provide necessary DC voltage level under different operating modes of the microgrid. When charging, switch S2 is activated and the converter works as a boost circuit; otherwise, when discharging, switch S1 is activated and the converter works as a buck circuit. When the voltage at the DC link is lower than the voltage reference, switch S1 is activated. Alternatively, when the voltage at the DC link is higher than the voltage reference, switch S2 is activated. The DC-link power balance can be expressed by the following differential equation:

$$V_{dc}\ I_{dc} = P_{pv} + P_w + P_{bat} - P_{Load} \qquad (8)$$

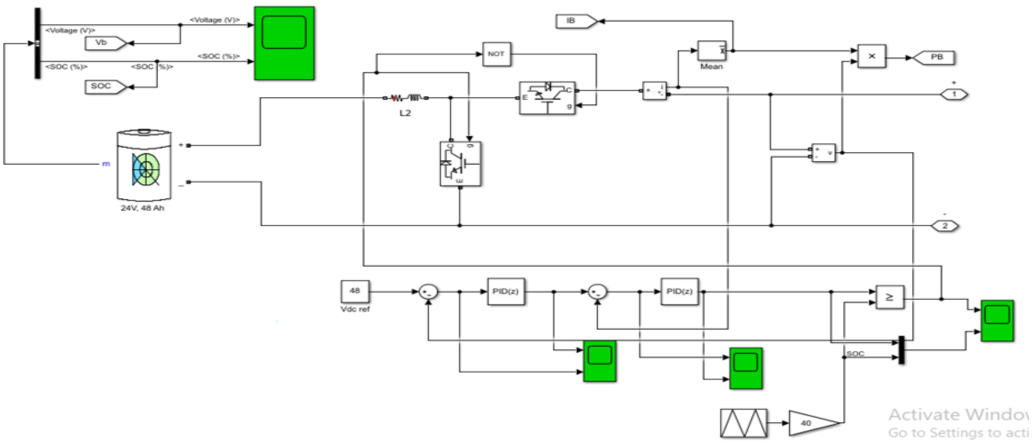


Fig. 4 Battery with bidirectional converter

The proposed flowchart of the power management system is described in Fig. 5. Accordingly MATLAB code had written, to decide the charging and discharging condition of the battery.

RESULTS AND DISCUSSION

The DC Microgrid consists of - 720 W PV array, 500 W wind generator, 24V,48Ah battery,1000W d c load. The PV array is connected to the 48 V DC bus using a boost converter. The permanent magnet induction generator is

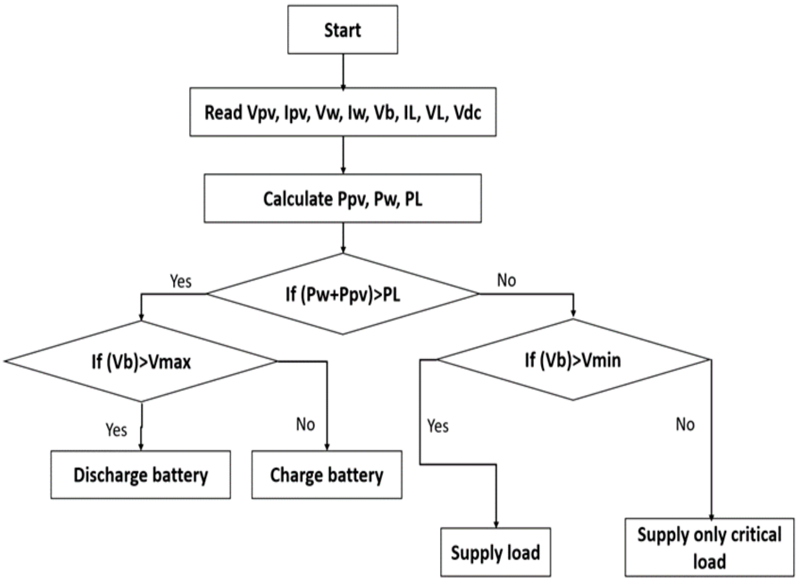


Fig. 5 Flowchart of the management of power flow algorithm

connected to the DC bus through a rectifier. A 24 V, 48Ah battery is connected through a charger/discharger circuit to the DC link. Bus voltage is maintained by the PI controller. The whole system has been implemented in MATLAB/Simulink and tested for various load conditions and also for changes in input power (Fig 6 and 7).

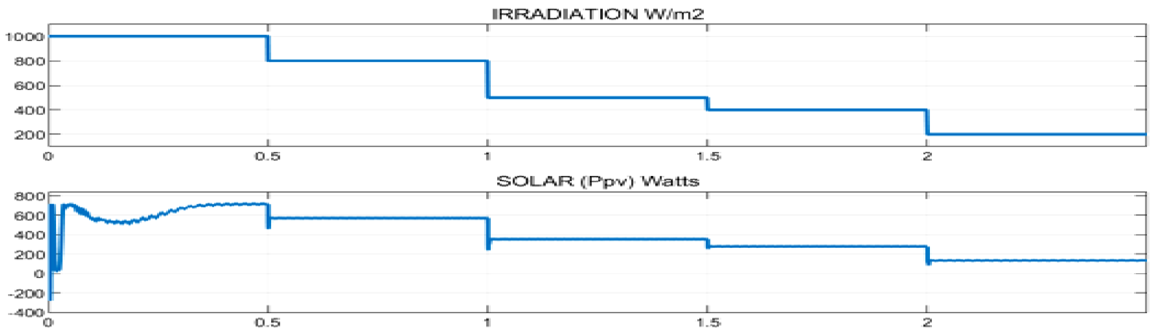


Fig. 6 Output power from solar PV for different irradiation levels

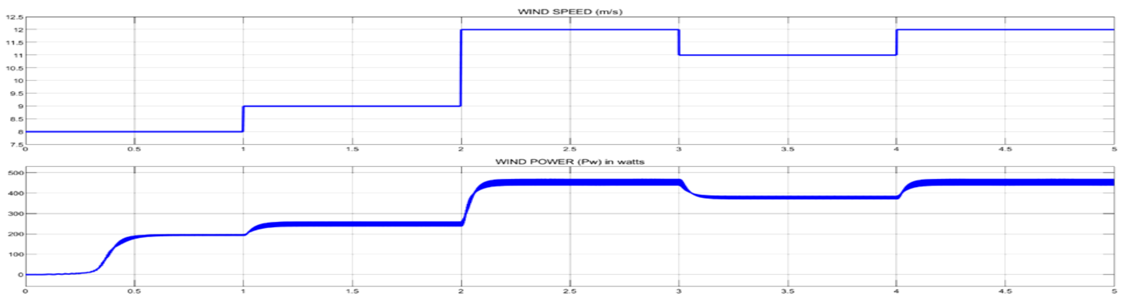


Fig. 7 Output power from Wind system for different wind speeds

VARIATION IN LOAD

CASE 1: (Ppv+ Pw) >Pl, and Vb<Vmax

Power from the solar panel (P_{PV}) is supplying the power of 719W and the power from the wind turbine (P_W) provides about 416W. And load demand is about 900W. Hence load demand is less than total generation (Ppv+Pw) i.e 1133W and battery voltage (Vb) is 26.3V which is less than the maximum battery voltage (Vmax) 28V. So, the excess energy is used to charge the battery as shown in figure 9.

CASE 2: (Ppv+ Pw) >Pl and Vb >Vmax

Power from the solar panel (P_{PV}) is about 719W and wind turbine (P_W) provides about 416W. And load demand is about 900W. Hence total available generation (Ppv+Pw) i.e 1133W and battery voltage (Vb) is 28.5V which is greater than the maximum battery voltage (Vmax) 28V. So, the battery also fully charged in order to avoid the overcharging of the battery disconnect the battery from the system as shown in the figure 10.

CASE 3: (Ppv+ Pw) < Pl and Vb>V min

Power from the solar panel (P_{PV}) is about 719W and wind turbine (P_W) provides about 416W. And load demand is about 1500W. Hence total available generation (Ppv+Pw) i.e 1133W is less than load demand and battery voltage (Vb) is 26.3V which is greater than the minimum battery voltage (Vmin) 18V. So, the generation is not sufficient to meet the load demand, the deficit power is supplied by the battery as shown in the figure 11.

CASE 4: (Ppv+ Pw) <Pl and Vb<V min

Power from the solar panel (P_{PV}) is about 719W and wind turbine (P_W) provides about 416W. And load demand is about 1500W. Hence total available generation (Ppv+Pw) i.e 1133W is less than load demand and battery voltage (Vb) is 17.8V which is less than the minimum battery voltage (Vmin) 18V. So only the critical loads are supplied as shown in the figure 12. In this proposed hybrid system, the constant DC link voltage is 48V as shown in figure 8.

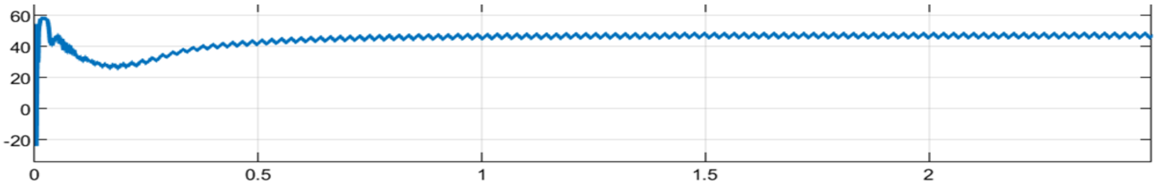


Fig. 8 DC link voltage

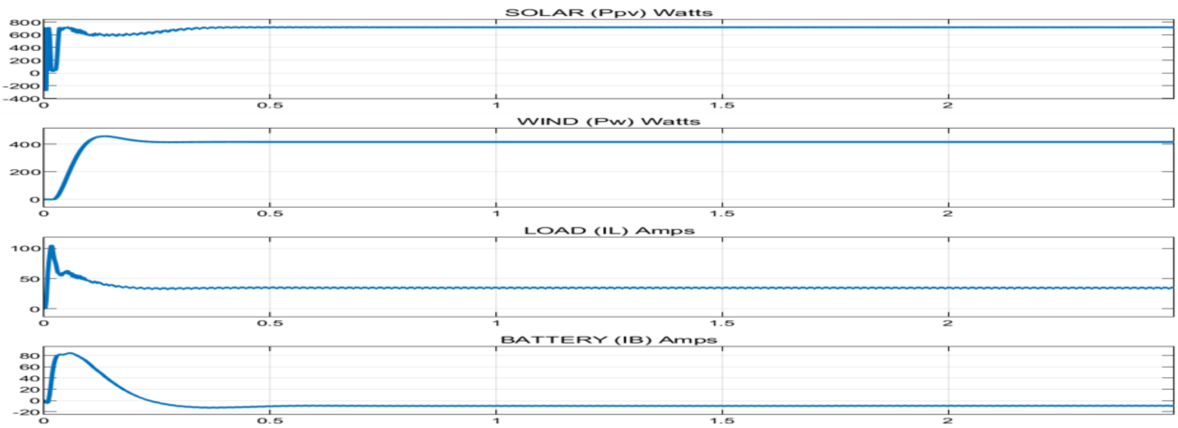


Fig. 9 Response of the system for case 1

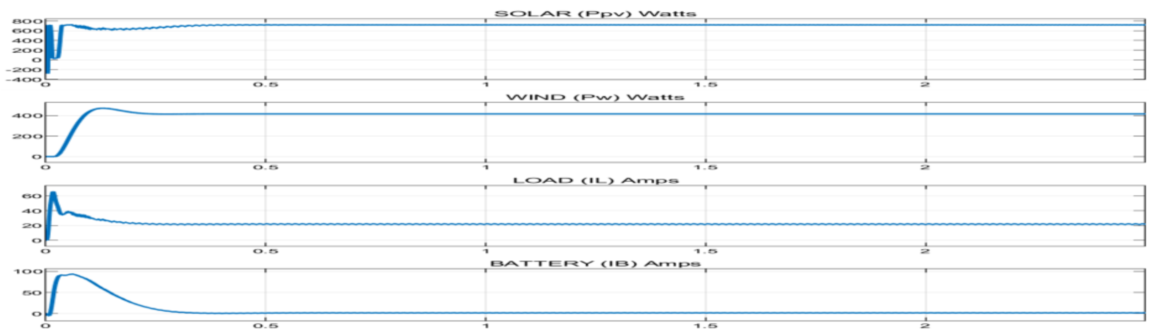


Fig. 10 Response of the system for case 2

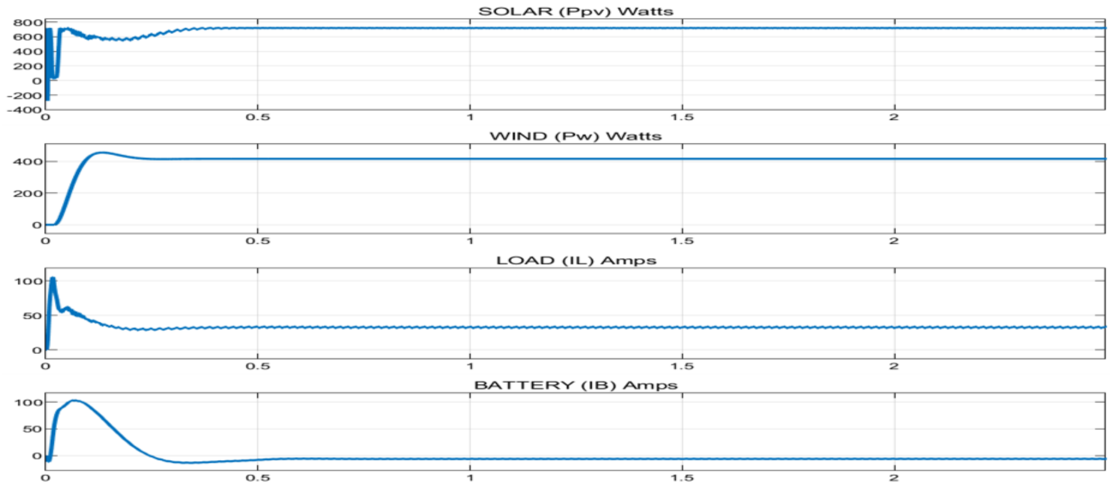


Fig. 11 Response of the system for case 3

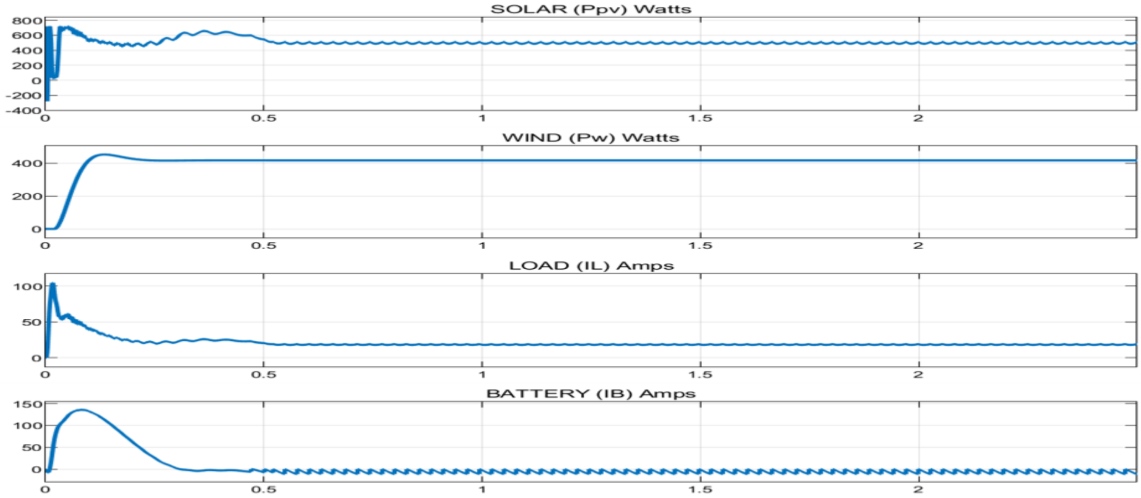
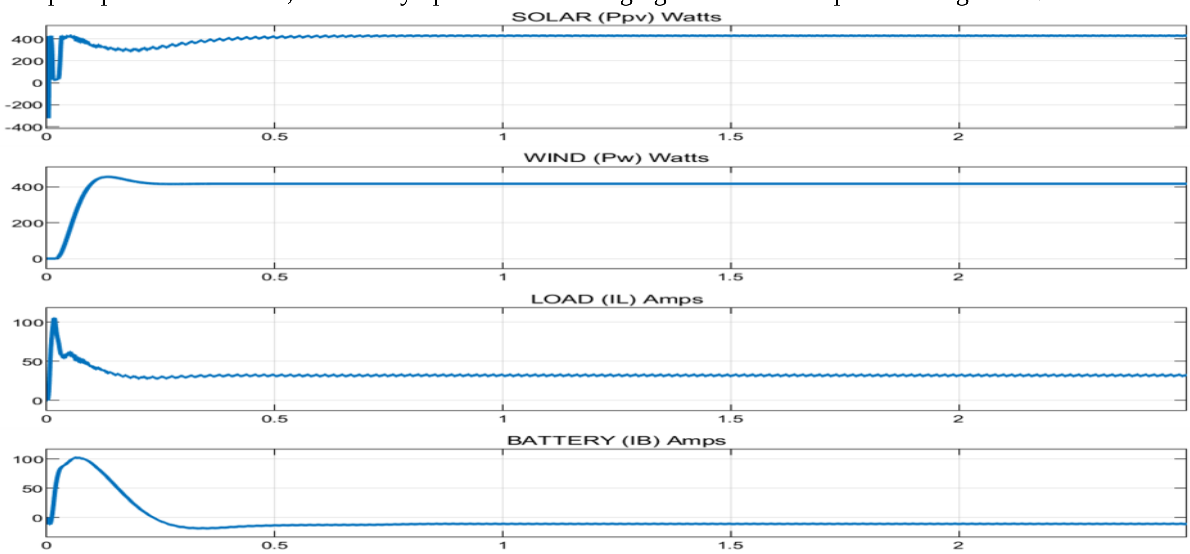


Fig. 12 Response of the system for case 4

CHANGE IN PV POWER

In order to study the response of the system for changes in input power, the power produced from the solar panel (P_{PV}) is reduced from 719W to 428W and the wind turbine producing the same power of 416W. And load demand is about 1500W Hence the total generation is (P_{PV}+P_W) 844W which is not sufficient to meet the load demand. To provide uninterrupted power to the load, the battery operates in discharging mode and is depicted in Figure 13.



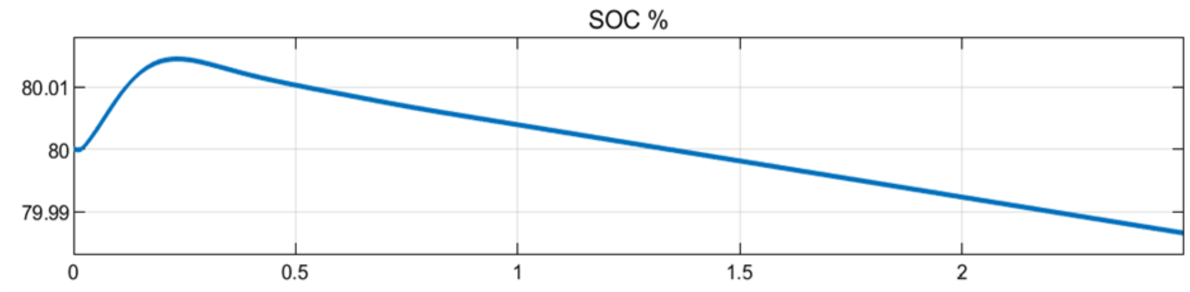


Fig. 13 Response of the system for change in solar power

CHANGE IN WIND POWER

When the power produced from the wind turbine (Pw) decreased from 416W to 228W and the solar panel producing the same power of 719W, hence the total generation becomes 947W, which is less than the load demand i.e 1500W. So, the deficit power is supplied by the battery as shown in the Figure 14.

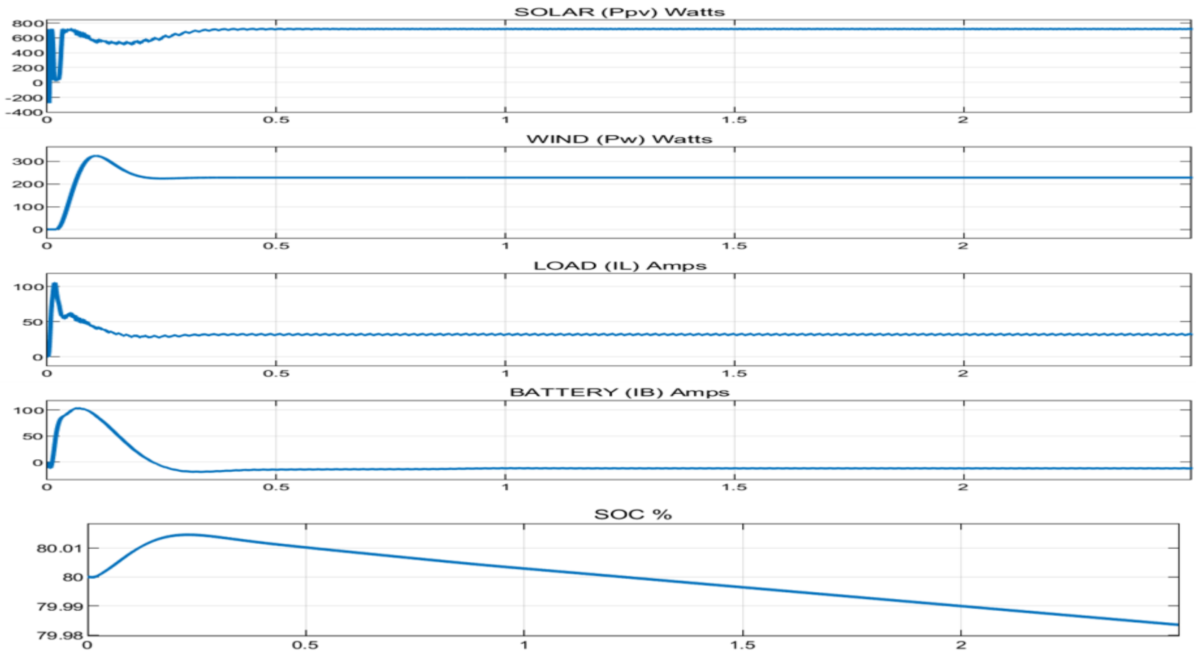


Fig. 14 Response of the system for change in wind power

CONCLUSION

In this work a multi-source energy system for hybrid wind/solar energy and battery have been presented. Dynamic modeling and simulations of the hybrid system is proposed using SIMULINK. A hybrid energy system and its supervisory-control system was developed and tested. Load demand is met from the combination of PV array, wind turbine and the battery. A Management of power flow and control algorithm for DC microgrid with solar and wind energy sources is presented. As the system involves different intermittent energy sources solar and wind and load whose demand can vary, it is necessary to develop a Management of power flow and control algorithm for the DC Microgrid. To provide ceaseless power supply to the loads and balance the power flow among the different sources at any time, a Management of power flow algorithm is developed. The feasibility of the algorithm has been tested for various load conditions and for changes in solar and wind power.

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