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ENERGY MANAGEMENT FOR HYBRID PV SYSTEM

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Abstract:- The efficiency of solar PV panel is less because of change in environmental parameters. Hence, power from solar PV is unreliable and needs backup for system reliability. . This paper presents a control algorithm for maintaining constant voltage across DC-LINK in solar PV system. A PI controller is developed to control power flow. The proposed strategy is evaluated in MATLAB/SIMULINK and result is presented.

Keywords:- MPPT, DC-LINK, SOC, PI controller, battery.

I. INTRODUCTION

The electricity demand is increasing day by day because of tremendous increase in the energy consumption leading to decay of fossil fuels and global warming. To avoid this, we need to go for an alternative energy sources like solar, wind, fuel cell, tidal etc. To face the increase in electricity demand the grid connected or standalone system has captured excellent interest.

In remote area standalone PV system have established wide applications to meet the demand. But each renewable energy source has its own drawbacks. For instance, solar panel has low efficiency and its power output depends on climatic conditions like irradiation and temperature. To avoid these drawbacks, more panels can be added to meet the demand. However it could add to increased cost and more space therefore instead of increasing the energy production, we can share the load in between these power sources according to their availability. So, hybrid system is the most desired and emerging solution in Renewable Energy sector to overcome the respective disadvantages of individual systems. Hybrid power system has advantages like, batteries are not deeply discharged, reserve capacity in batteries can be used for peak power demand to support inrush current to start air-conditioners etc. So an auxiliary source like a battery should be introduced into PV system. Many types of battery are available such as lead acid, NiCad, NiFE, Lithium ion. Here lead acid battery is used because of easily availability and true deep-cycle batteries. In a conventional standalone PV system the battery is directly connected in parallel with DC bus and the charging and discharging current of the battery cannot be controlled. In order to protect the battery from inrush current which depends on load fluctuation, a bidirectional converter is installed between the DC bus and the battery to control the charging and discharging current of the battery.

The block diagram of stand-alone PV power system is shown in fig.1 is consist of a solar panel, battery, a maximum power point tracker i.e. uni-directional DC-DC converter and bi-directional DC-DC converter. The solar panel and battery are being connected to the same DC-link through a unidirectional DC-DC converter and bidirectional DC-DC converter respectively.

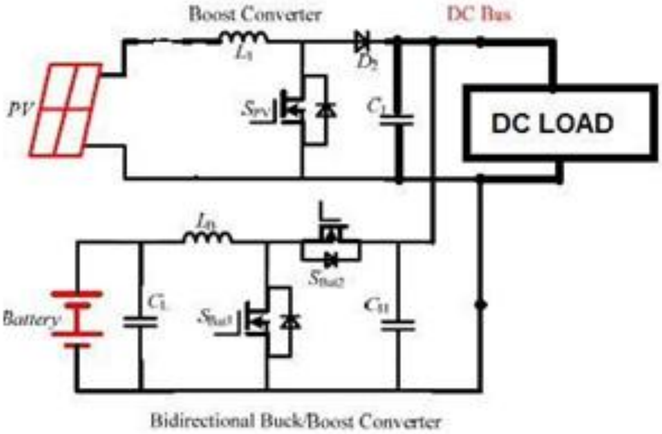

Fig.1 Stand-alone PV system

II. POWER MANAGEMENT

There are two possible configurations which can be considered when combining the battery storage with solar PV array in a hybrid system. In first configuration the battery is directly connected across the DC-link and in other configuration the battery is connected to the DC-link through a bidirectional DC-DC power converter. In the former configuration, the DC-link voltage can be evaluated by nominal voltage of the battery. In this case the battery's SOC can be maintained within predefined limits by controlling the output power of the solar PV array. As a consequence the DC-DC converter will not be able to track the MPP all the time moreover a battery may get damaged due to large surge currents, because of large decrease in the value of load. In the latter configuration, the battery is connected to the DC-link through bidirectional DC-DC converter which allows controllable charging & discharging. Battery stores excess PV power in order to balance the system and also provides more flexibility in choosing the battery nominal voltage, supplies peak power load as well.

The DC-link voltage is regulated by bidirectional converter and the PV side boost converter is used as MPPT tracker which tracks the maximum power point during normal operating condition.

A. MODES OF OPERATION

1) MODE 1:

In this mode of operation the power supplied by PV array is less than the power demanded by the load. The UDC works in such a way that the PV array works at a MPPT point. But the irradiation at the PV array is not at optimum. Thus the power produced at a PV array is less than the power required at the load, so the BDC should work in BOOST mode. The remaining power required at the load side is supplied from battery. Thus the battery gets discharged.SOC of a battery gives the status of battery. The discharging current is considered positive. The PI controller is used to maintain constant voltage across DC link.

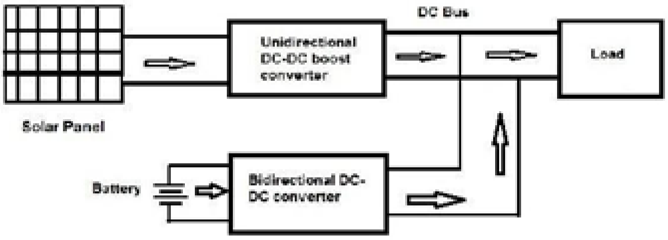

Fig.2 current direction during MODE1

2) MODE 2:

In this mode of operation the power supplied by PV array is more than the power demanded by the load. The UDC works in such a way that the PV array works at a MPPT point. The irradiation at the PV array is more than the optimum value. Thus the power produced at a PV array is less than the power required at the load, so the BDC should work in BUCK mode. The additional power at the load side is supplied to the battery. Thus the battery gets charged.SOC of a battery gives the status of battery. The charging current is considered negative. The PI controller is used to maintain constant voltage across DC link.

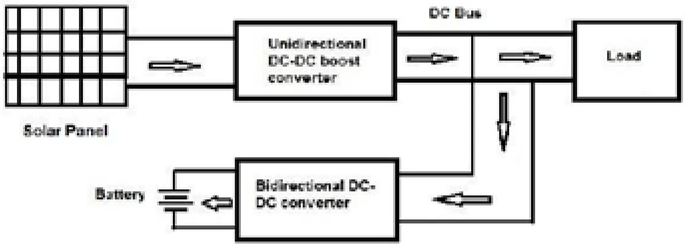

Fig.3 current direction during MODE2

3) MODE 3:

In this mode of operation the power supplied by PV array is very less than the power demanded by the load. The UDC works in such a way that the PV array works at a MPPT point. But the irradiation at the PV array is very less compared to optimum value. Thus the power produced at a PV array is very less than the power required at the load, so the BDC should work in BOOST mode. The power flow is from only battery. The

PV array does not contribute to any power across the DC link. Thus the battery gets discharged.SOC of a battery gives the status of battery. The discharging current is considered positive. The PI controller is used to maintain constant voltage across DC link.

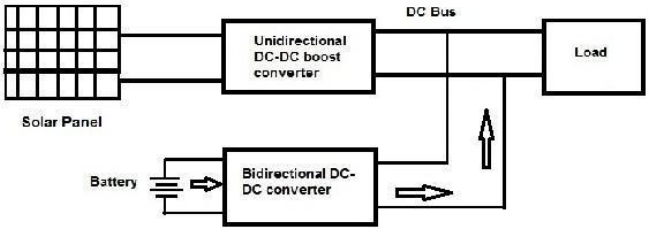

Fig.4 current direction during MODE3

4) MODE 4:

In this mode of operation the power supplied by PV array is very less than the power demanded by the load. The UDC works in such a way that the PV array works at a MPPT point. But the irradiation at the PV array is v very less than the optimum value. Thus the power produced at a PV array is less than the power required at the load, so the BDC should work in BOOST mode. The battery is also completely discharged. Thus the battery as well as PV array does not supply any power to the load. This mode is known as shutdown mode.

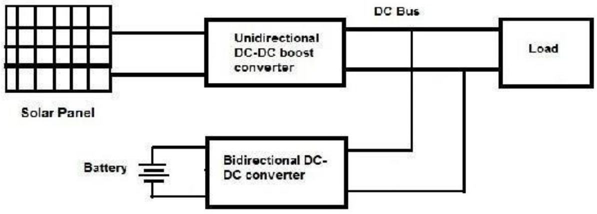

Fig.5 shut down MODE4

II. CONTROL STRATEGY FOR OPERATION

Fig.6 explains the flowchart during charging and discharging operation. The first and foremost thing to do is to calculate power across the DC link and power developed due to PV array. If the power developed across PV array is greater than the load power, the charging of the battery takes place. When the PV array power developed is less than the load power, the battery is discharged. The SOC is used to avoid over charging and over discharging of a battery.

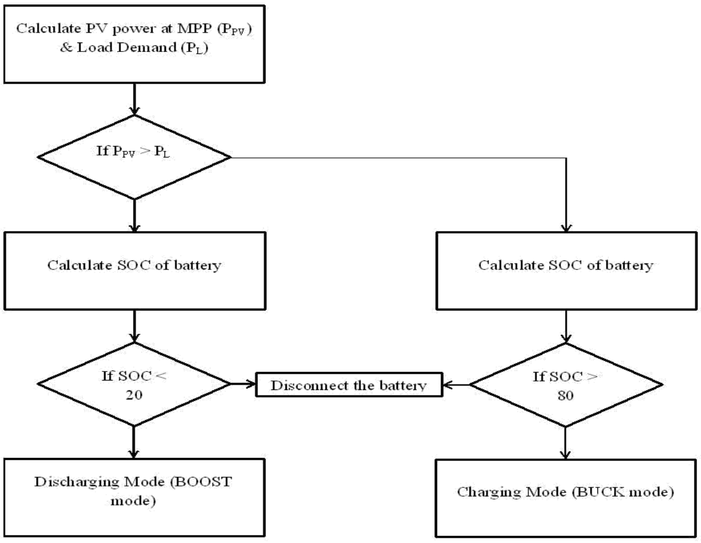

Fig.6 flowchart for control strategy of BDC with PV array

A. *MPPT TRACKING WITH INCREMENTAL CONDUCTANCE (IncCond)*

The efficiency of PV array is very less. In order to operate PV array at a higher efficiency MPPT is used. PV array should be connected to either to BOOST converter or CUK converter to maintain the operating point across MPPT. The most widely used algorithm is P&O and INC. The downside of using P&O is that the system won’t stabilize at MPP but instead it will make the system oscillate across MPPT, because of which the energy is dissipated in terms of heat. Incremental Conductance is used because the system reaches at a MPPT instead of oscillating across MPPT. Thus the dissipation ion power is very less.

From the P-V graph of the panel the basic idea for the incremental conductance will get. The basic equations for incremental conductance are given below

$$\frac{\Delta P}{\Delta V} = 0 \quad V = V_{mp} \text{ at the MPP} \qquad (1)$$

$$\frac{\Delta P}{\Delta V} < 0 \quad V > V_{mp} \text{ left side of the MPP} \qquad (2)$$

$$\frac{\Delta P}{\Delta V} > 0 \quad V < V_{mp} \text{ right side of the MPP} \qquad (3)$$

From the above equations the incremental conductance could decide the direction of the tracking the MPP. Incremental conductance flow chart is given below

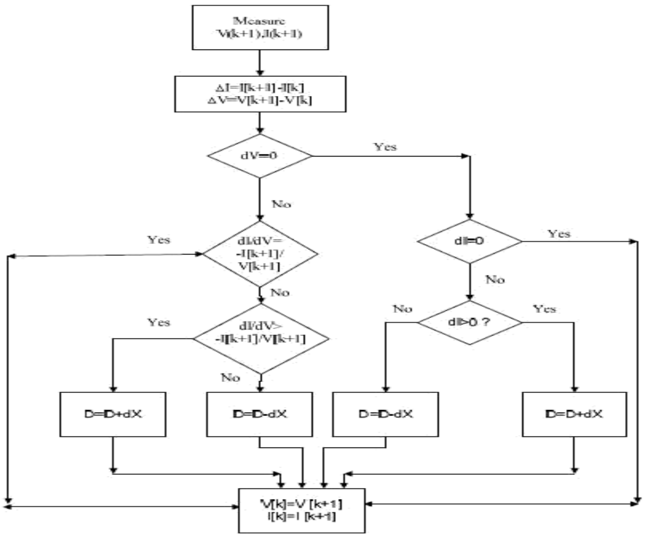

Fig. 7 algorithm for calculation of INC

From the I-V graph of the panel conclude that the MPP is located at the knee point. Where change in conductance is equal to the instantaneous conductance.

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I + V\frac{dI}{dV} = 0 \qquad (4)$$

At the MPP~~ fro~~m that is as follows

$$-\frac{I}{V} = \frac{dI}{dV}$$

As in practical case the equation no is not satisfied instead of that there is some error (e) which determines the sensitivity of the system operation. The value of e is selected with respect to chances of fluctuation and oscillations at the point.

$$\frac{I}{V} + V \cdot \frac{dI}{dV} = e \tag{5}$$

For that equation is rewritten as

Here dV=V(k+1)-V(k) (6)

dI=I(K+1)-I(k) (7)

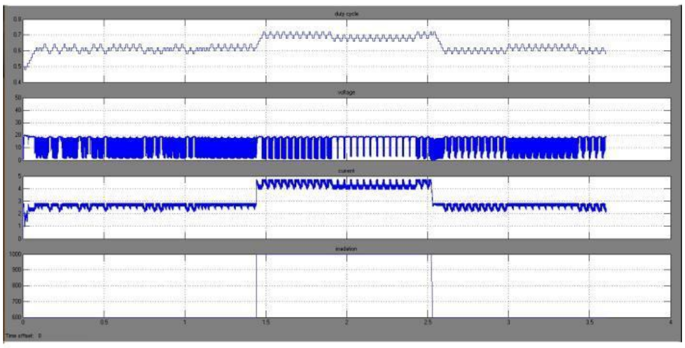

Fig.8change in irradiation across solar PV

Fig.8 shows the MPPT tracking with incremental conductance for change in irradiation. This validates that the INC algorithm is working perfectly.

B. DESIGN OF BIDIRECTIONAL CONVERTER:

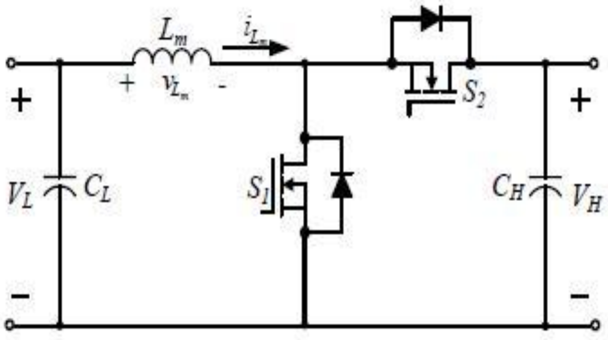

Fig.9 circuit diagram of bidirectional converter

Standalone photovoltaic power generation scheme provides stored power as a supplementary service during shortage of electricity. The fig.9 shows the circuit diagram of buck boost bidirectional converter which manages the storage and supply of power between PV system and batteries. The main advantage of bidirectional converter is that it allows bidirectional power flows, depending on the direction of power flow there can be two modes of operation namely boost and buck.

1) BOOST MODE:

Here in this mode, S2 is always open and S1 is operated. When S1 is closed inductor gets charged. When S1 is open the inductor voltage polarity changes, that makes diode forward biased and the output voltage will be the summation of input voltage and input voltage.

The input voltage is the battery voltage and the output voltage is the voltage across the DC link

The output voltage across DC link is given by eq.8

$$VH = \frac{1}{\quad} VL$$

$$1-D$$

(8)

The design equation for capacitor is given by eq.9

$$CH = \frac{D}{RHf\left(\frac{\Delta VH}{VH}\right)}$$

(9)

The min. value of inductor is given by eq.10

$$L\min \geq \frac{D(1-D)^2 RH}{2f}$$

(10)

2) BUCK MODE:-

Here in this mode, S1 is always open and S2 is operated. When S2 is closed inductor gets charged. When S2 is open the inductor voltage polarity changes, that makes diode forward biased and the output voltage will be the voltage across the inductor.
The input voltage is the voltage across the DC link and the output voltage is the battery voltage.

The output voltage across battery is given by eq.11

$$VL = DVH \tag{11}$$

The design equation for capacitor is given by eq.12

$$CL = \frac{(1-D)}{8\left(\frac{\Delta V^{L}}{VL}\right)Lmf^{2}} \tag{12}$$

The min. value of inductor is given by eq.13

$$L\min \geq \frac{(1-D)RL}{2f} \tag{13}$$

C. DETERMINATION OF SOC OF A BATTERY:

Power supply from PV array may be irregular in nature, thus an additional source is required to maintain the constant voltage across DC link. There are many option for the additional source, we are selecting the battery because of its easy availability and reliability.

Batteries are used for energy storage and supply. The battery's performance depends on the correct estimation of SOC of a battery. The batteries performance may degrade due to change in the environment as well as inaccurate measurement of a SOC. Thus the correct measurement of SOC is required.

There are many methods to calculate SOC such as Direct Measurement, SOC from Specific Gravity (SG) Measurements, Voltage Based SOC Estimation, Current Based SOC Estimation - (Coulomb Counting), SOC Estimation from Internal Impedance Measurements. Out of all the methods we are using current based SOC Estimation-(Coulomb Counting).
The SOC can be defined in terms of current and duration of (dis)charge.

SOC during Charging of battery is given by eq. (14)

$$SOC = \frac{-\int I(t)dt}{Qrated} 100\%$$

(14)

SOC during discharging of battery is given by eq.15

$$SOC = (100 - \frac{\int I(t)dt}{Qrated})100\% \quad (15)$$

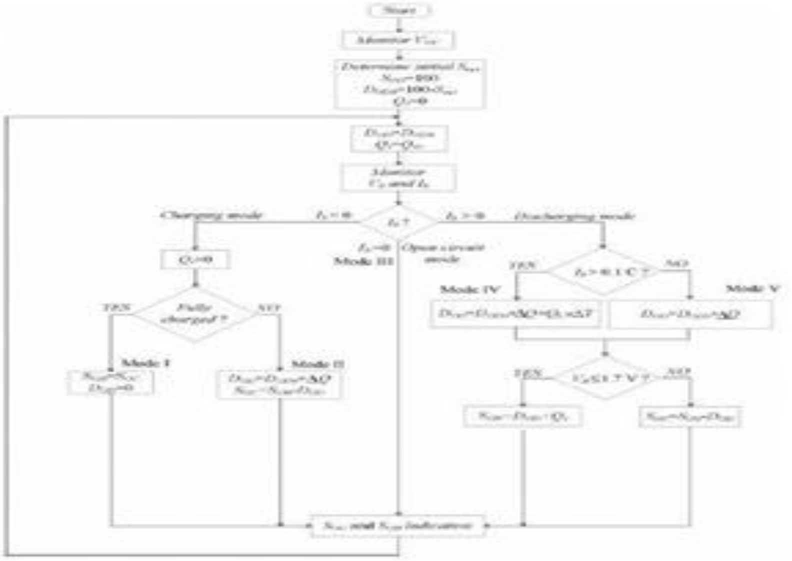

Fig.10 Flowchart for measurement of SOC

III. SIMULATION RESULTS

Fig.11 shows the output voltage waveform during 800 Watts/m^2 irradiation on solar PV. The power supplied by the solar PV is 62W. The output load requirement is 70W. Thus the remaining power should be supplied by the battery. So the battery gets discharged. The SOC during discharging is given by fig.13 PI controller is used across BDC to maintain constant voltage across load. Fig.12 shows the constant 70V across the load.

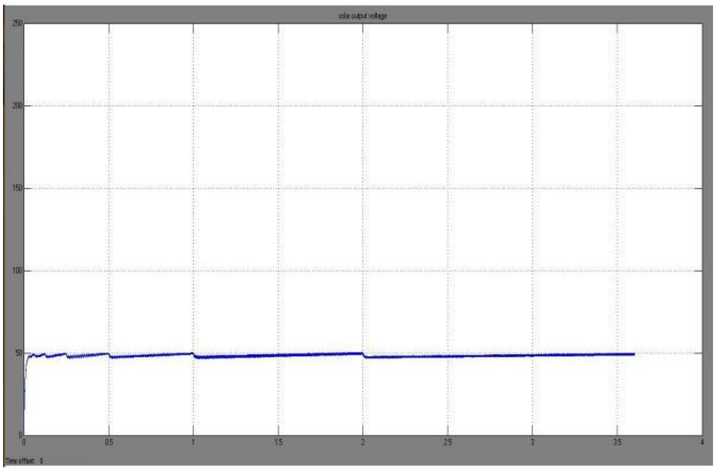

Fig.11 output voltage of solar panel

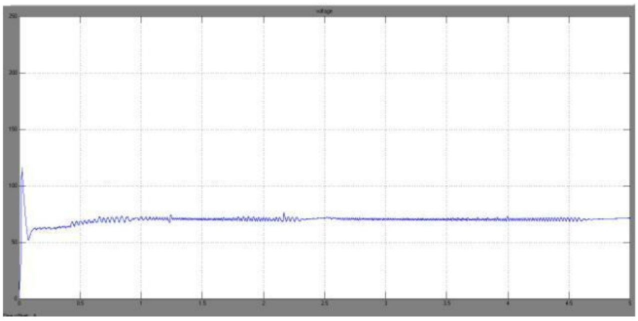

Fig. 12 Output voltage across the DC link during MODE1

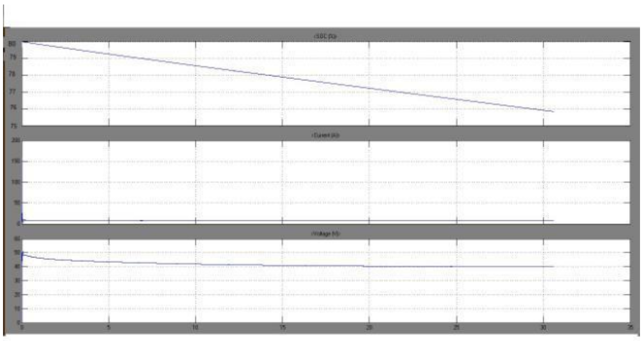

Fig. 13 SOC during MODE1

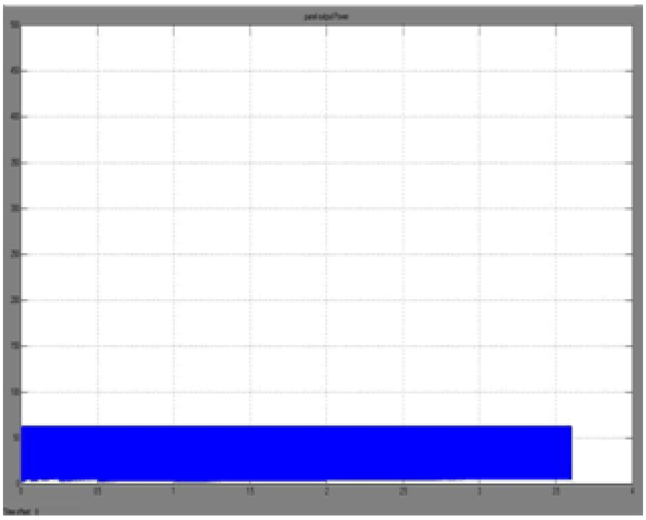

Fig.14 Output power of solar panel

Fig.15 shows the output voltage waveform during 1000 Watts/m^2 irradiation on solar PV. The power supplied by the solar PV is 80W. The output load requirement is 70W. Thus the excess power should be supplied to the battery. So the battery gets charged. Fig.16 shows the constant 70V across the load. The SOC during charging is given by fig.17 .PI controller is used across BDC to maintain constant voltage across load.

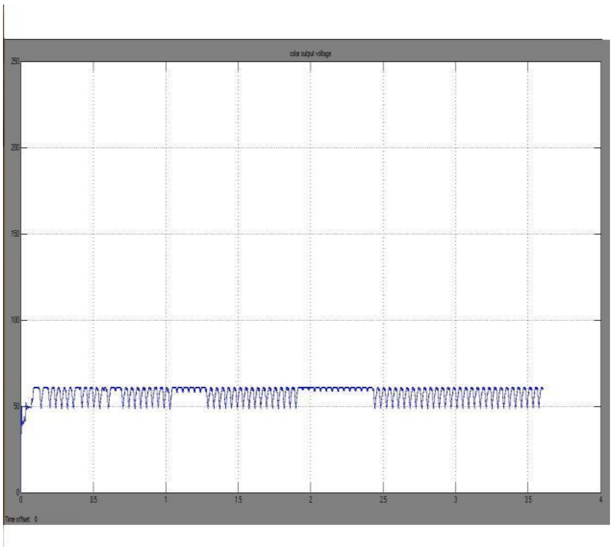

Fig.15 Output voltage of panel

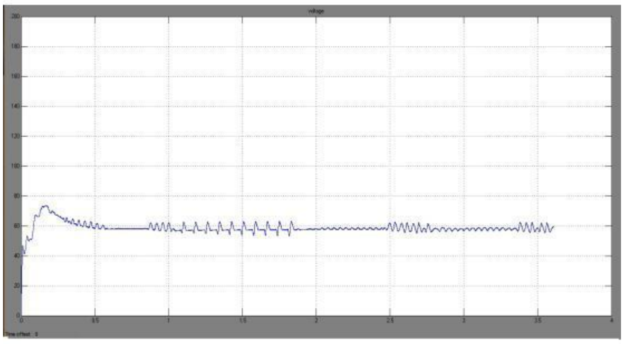

Fig. 16 Output voltage across the DC link during MODE2

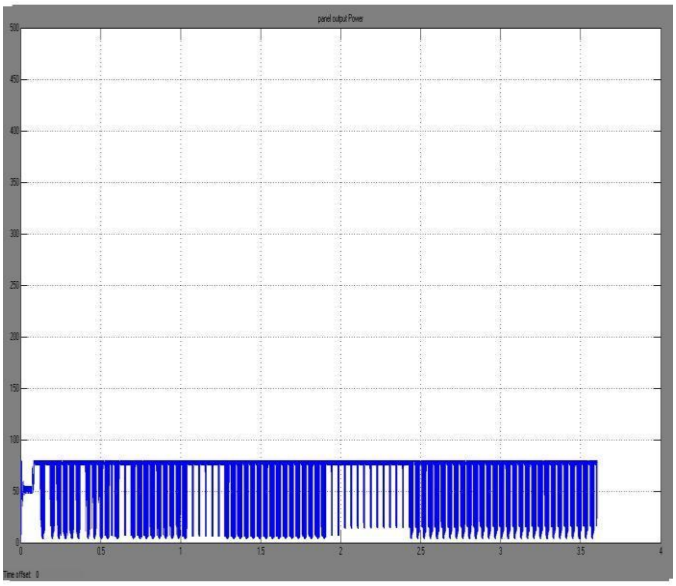

Fig. 17 SOC during MODE 2

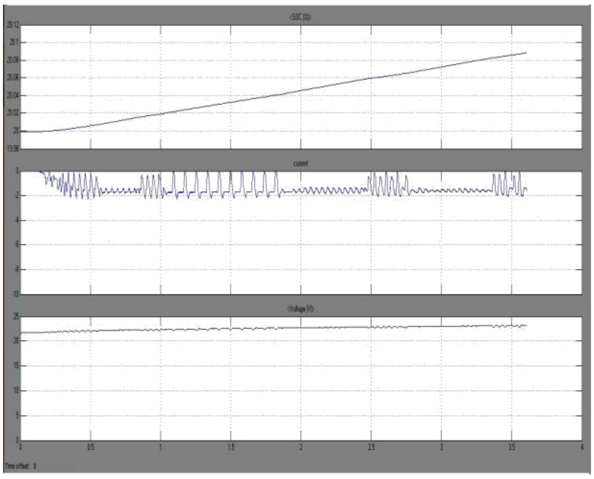

Fig.18 Output power of solar panel

Fig.19 shows the output voltage waveform across the DC link when solar panel output is zero and battery alone maintains constant 70 V across DC link.

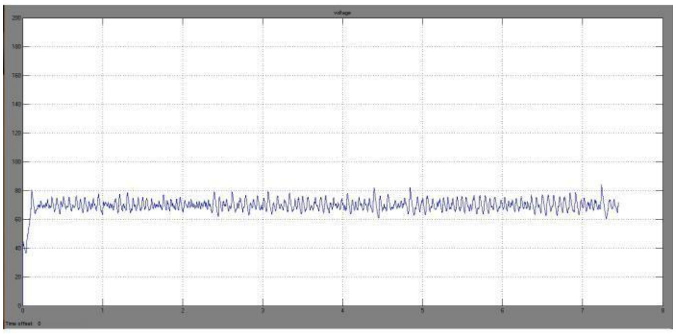

Fig. 19 Output voltage across the DC link during MODE3

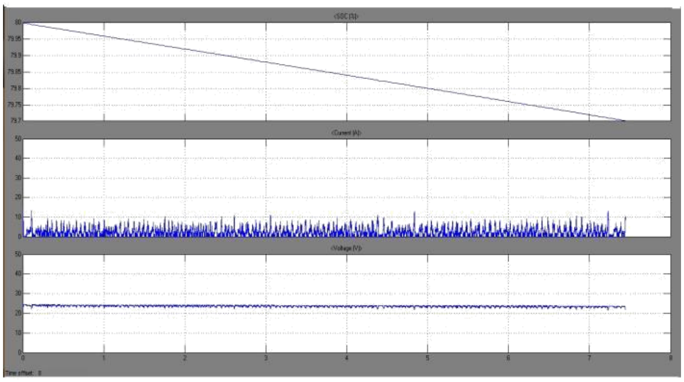

Fig. 20 SOC during MODE3

IV. CONCLUSION

The proposed algorithmic validated with the simulation results. The results shows that with the proposed algorithm the voltage across DC link can be maintained constant, maintaining proper power flow between PV array, battery and load.

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