Modified Energy Management Strategy for DC Microgrid With PV/Battery Systems

A PROJECT REPORT

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CERTIFICATE

This is to certify that the Project report entitled **'MODIFIED ENERGY MANAGEMENT STRATEGY FOR DC MICROGRID WITH PV/BATTERY SYSTEMS'** submitted by **Mr. DEEPU V** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirement for the award of the Degree of Master of technology in Power System, Electrical and Electronics Engineering is a bonafide record of project work carried out by her under guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

It is a great challenge for DC microgrids with renewable sources and volatility loads to achieve better operational performance. A microgrid is the combination of distributed energy resources (DER), distributed storage (DS), and load. By understanding the need for electricity and available energy sources and storage, energy management can be done. The task of the Energy Management System is to manage the energy between source and load. Efficient management of these microgrids and their seamless integration within smart and energy-efficient buildings are required. This project is based on an energy management and control strategy (EMCS) of DC Microgrid with PV/Battery system feeding a DC load. The energy management system is based on the state of charge of the battery. It takes the battery life into consideration by applying constraints to its charging/discharging currents and state-of-charge (SoC). This work mainly focuses on the design and implementation of a control strategy for efficient energy management.

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ABBREVIATIONS

SOC	State of Charge
PV	Photo Voltaic
MPPT	Maximum Power Point Tracking
LPM	Limited Power Mode
IoT	Internet of things
UPF	Vehicle-to-grid
SMC	Sliding mode control
VSC	Voltage source converter control
BDDC	Bidirectional DC DC converter

Chapter 1

INTRODUCTION

1.1 General background

Since last few years the consumption of Renewable energy resources (RERs) has been increasing day by day. The reason behind this is the damage of conventional energy sources and the presence of green house gases in the earth . The RERs can be integrated with the present non- renewable energy resources to enhance the system reliability. Among the RERs, PV is one of the main technologies used. The PV generation mainly depends on two factors the climatic condition and irradiation from the sun. So, we need to integrate this with the Energy Storage System. The main need of integrating RERs with ESS is to avoid the change in solar energy and wind energy as per the environment conditions. The necessity of AC Bus in the conventional energy Network is that for long distance transmission, AC Supply is required. So many devices that run by DC power is converted to AC powerusing DC to AC converter before they are used. Dc equipment's have many uses eg: LED lighting, electric vehicle etc. So hence AC microgrid have many benefits when compared to DC microgrid. Not only that it can easily be integrated with the DC microgrid. On coming from AC microgrid to DC microgrid the excessive use of converter decreases. Such that the consumers can easily make use of the power. As a result,comparing with the

AC microgrid the DC microgrid appears to be more efficient. The PV, Battery with the load can be a basic form of microgrid. The maximum power which generated from the PV is extracted here using maximum power point tracking (MPPT) technique. Recently there are many MPPT algorithms being proposed for tracking max power point for PV modules. The proposed MPPT is also used for similar purpose. This MPPT reduces the oscillation associated with the maximum power point. Moreover it increases the tracking performance of PV power. There are mainly two algorithms used. They are perturb and observe (PO) algorithm and the incremental conductance (IC) algorithm. Particle swarm optimization, fuzzy logic control and artificial neural networks are other advanced algorithms used. In case of standalone application, the excessive power generated cannot be transferred to the grid. The system cannot track the maximum power point all the time, so it must limit to the PV source power in order to meet the supply/Demand balance. Therefore it is necessary to prevent the over charging and deep discharging to increase the life of the battery and to make its charging and discharging in a proper way.

Here, we using an energy management strategy for controlling power flow of the DC micro grid. this energy management algorithm mainly based on SoC of battery and power demand, which will controlling over charging and over discharging of battery system, and also proposed an zero osculation P & O algorithm, which will eliminate osculation around steady state value of power ripple.

1.2 Motivation & Objectives

- To simulate Energy management strategy for DC microgrid and thereby achieving a good performing and stable system.
- To simulate a microgrid system operating in both grid-connected and standalone mode.

1.3 Organization of thesis

The entire thesis is organized on follows:
It consist of six chapters. Chapter 1 includes a brief introduction, motivation and objective. Chapter 2 deals with the literature review. Chapter 3 gives the overall idea about the components used in the system. Chapter 4 deals with the system modelling, which includes PV modelling, Bidirectional and Boost converter modelling. Chapter 5 deals with the result and discussion in which different modes of energy management control strategy simulated and results are analysed. Chapter 6 concludes the work.

1.4 Summary

The general background, motivation and aim of thesis work were discussed in this chapter. It can be concluded that proper control of power flow will enhance the better utilisation of energy.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter deals with the literature review of Energy management algorithm, MPPT modelling, Different converters, battery modelling etc.

2.2 Literature Review

In[7]the author proposed droop control based strategy for the parallely operating batteries with optimized load sharing in DC microgrid.In this control strategy, the state of charge is equalised and also during delivering or absorbing power,parallel batteries will operate equally in terms of state of charge.The battery life can extended ,when the power sharing is done in correct way.Inorder to find out the actual capacity of the battery a metaheurasitic algorithm is also proposed in this paper.The charging and discharging of the battery is controlled by bidirectional DC/DC converters.The evaluation of the control strategy is evaluated by using different scenarios like using similar,disimilar capacity of battery and also by disconnection of the battery.

In[8]the author proposed an optimal energy management strategy for DC microgrid.The system combines of a PV,fuel cell,battery storage system and a bidirection DC/AC grid converter.The control strategy used for the optimal energy management is salp swarm algorithm.The proposed algorithm is compared with PSO,the result shows that the proposed algorithm outperforms the PSO algorithm.

In[2]the author proposed control strategy for energy management in DC microgrid,with a dual energy storage systems.The system consist of photovoltaic system as the source with dual battery system.The incorporation of dual battery system is to improve the dynamic performance of DC microgrid due to the load fluctuation as wells as the output from the solar PV.The main aim of the control strategy is to enhance the lifetime of the energystorage battery and voltage stability.

In[6]an energy management system is applied to the standalone DC microgrid,with a system consist of Photovoltaic system(PVS), a battery, an DC load, and a capacitor as a backup storage element.The configuration of the system is such that it enables the PV system to manage the power generation and also to ensure the limit of the state of charge of battery.A capacitor is used as a backup energy storage to ensure the connectivity when the main energy storage that is battery is disconnected.This will avoid the charging and discharging subcycles in the battery.

In[5],the author multiple step size P&O algorithm for to attain the maximum power point with fast changing weather conditions.The proposed algorithm show less oscillation in the steady state and better tracking performance compared to the conventional P and O algorithm.Here two step size values are taken by trial and error method for the tracking of maximum power point.

In[9]author proposed an optimal energy management strategy working on different working modes,which is decided by the battery stage SOC.The three stages are high,normal and low SOC.The control objective of the proposed model is life,efficiency of distributed directions,lower cost of the system and maintenance of battery's state of charge.

In[1] author proposed an energy management strategy for power flow control of the DC micro grid. P&O MPPT used for extracting maximum power from PV module. Bi-directional converters are controlled by PI controllers. Energy management algorithms classified system operations based on the state of charge of the battery. The power ripple and losses due to power transferring on the micro-grids discussed.

In[10] author proposed to improve the operating efficiency of the photovoltaic system, electronic/mechanical trackers are employed in the system. The tracker continuously monitors the variations in the input/output of the photovoltaic system and modify the system operation for maximization of efficiency. The electronic tracker called as Maximum Power Point Tracker (MPPT) uses the electrical, physical parameters for the detection of Maximum Power Point (MPP).

2.3 Summary

In this chapter, different control strategy of energy management in DC micro-grid in various literature's are analysed. The proposed energy management control strategy can be used for the power flow control and also ensures the battery life.

Chapter 3

SYSTEM DESCRIPTION

3.1 Introduction

DC microgrid is used to provide supply to DC load. In the propsed system,it comprised of 1 100Watts PV module,lead acid Battery a DC load. The solar panel is connected with boost converter. Which is used to extract. Maximum power from PV system with respect to the Irradiation and temperature condition. A zero oscillation PO MPPT is used for the switching of boost converter,Which will help to track maximum power point of PV module. A storage battery is connected to the DC bus via bidirectional converter. Which is help to control charging and discharging of battery system. Another main function of a bidirectional converter is to maintain bus voltage.Load is connected to the DC bus and utility grid. The switch S2 is used to connect DC bus to load and switch S3 is used to connect utility to load via AC to DC converter. At a time one switch is operating. Because utility is not directly supply power to the battery system. Switch S1 is used to isolate PV power.

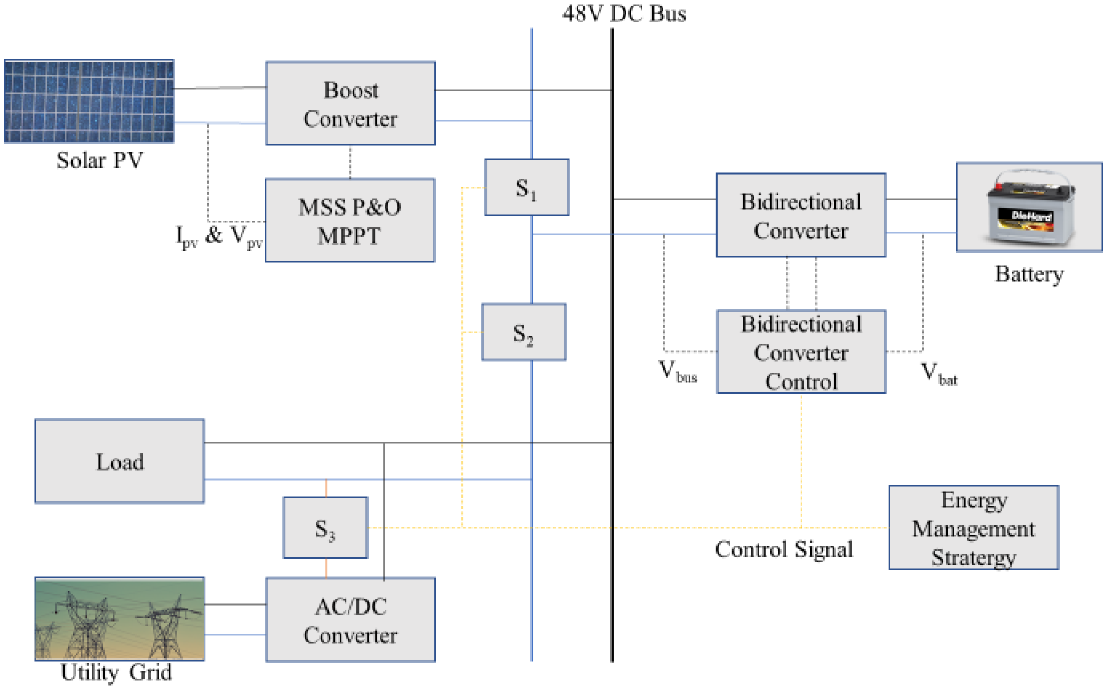

Figure 3.1. Structure of the DC microgrid

3.2 Boost Converter Model

The DC-DC Boost converter is used to convert low voltage to high voltage. It consist of a switch, a diode, output capacitor.The converter produces smaller impedance compared to the load impedance. Fig Shows model of boost conveter. The main useof boost converter is to connect PV module and DC Bus. Which is also help to extract maximum power from PV module.

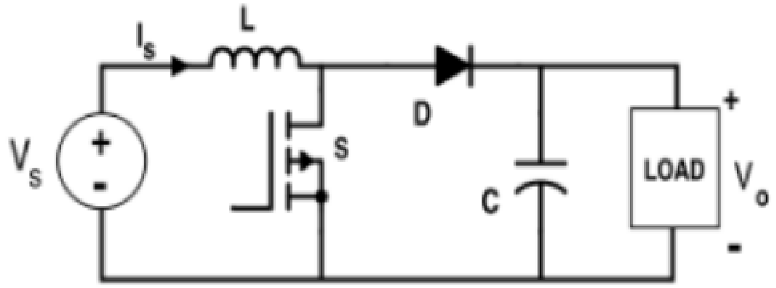

Figure 3.2. Boost Converter

The operation of the boost converter can be divided into two intervals. These are the equation for modelling for a boost converter.First interval begins when the switch S is on.The current flows through the inductor L and switch S.During this mode of operation energy is stored in the inductor L.During the second mode of operation,when the switch S is switched off.The polarity of the inductor changes and the flow of the current is directed through inductor and the diode D,Capacitor C,load and the supply Vs.The inductor currents falls until the switch is turned on. The duty ratio of the Boost converter is set by MPPT controller.The input of the boost converter is fed from the PV panel.Voltage and Current is sensed by the MPPT controller.Later the MPPT algorithm tracks the maximum power point of the PV panel to extract maximum power.The voltage and current is updated according to the MPPT algorithm. The processed value is sets the appropriate duty cycle for the switch.

$$I_{out} = \frac{P}{V_{out}} \tag{3.2.1}$$

$$\frac{V_o}{V_{in}} = \frac{1}{1-D} \tag{3.2.2}$$

$$\Delta I_L = 0.4 * I_{out} * \frac{V_{out}}{V_{in}} \tag{3.2.3}$$

$$L = \frac{V_{in}(V_{out} - V_{in})}{\Delta I_L * f_s * V_{out}} \tag{3.2.4}$$

$$C = \frac{I_{out} D}{f_s \Delta V_o} \tag{3.2.5}$$

3.3 Bidirectional Converter Model

Bidirectional converter is used in the microgrid system to facilitate the storage and supply of the power between the energy storage system and the PV module and ensures the necessary protection of the battery.The main objective of the bidirectional converter is to maintain the DC bus voltage constant.The outer loop is for the DC bus voltage regulation, which generates the reference current for the inner loop. This tracks the reference current of the inductor by changing the duty cycle of the PWM signals, which control the gates of the power MOSFETs of the bidirectional converter.The structure of the converter allows the bidirectional power flow,the converter works in two modes of operation,buck and boost mode.

- Boost mode -The converter works in the operational mode depending upon the switching.when switch S1 on the converter's low-voltage side is closed, switch S2 on the high-voltage side shows an opened state,due to a complimentary mechanism between the switches.In this mode, the inductor voltage vLm and voltage VL on the low-voltage side are equivalent since the inductor Lm and low-voltage supply VL are connected in parallel.

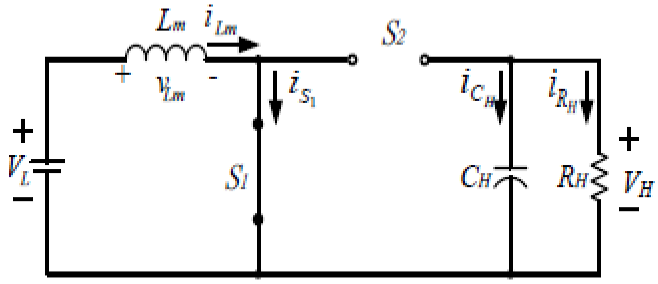

Figure 3.3. Bidirectional converter operation under boost mode,the switch S1 is closed

Switch S2 on the high-voltage side of the converter displays a closed state, when switch S1 on the low-voltage side of the converter is operating in an open mode.

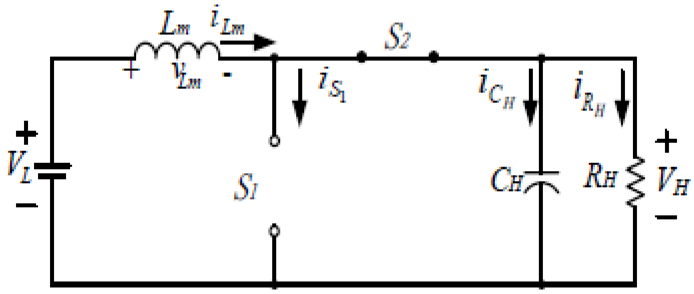

Figure 3.4. Bidirectional buck-boost converter operating under boost mode,switch S1is opened

- Buck mode -when switch S2 on the high-voltage side of the converter is closed, switch S1 on the low-voltage side is in an opened state,due to the complimentary mechanism between the signals regulating the switches on the low-voltage and high-voltage sides.In this mode of operation, the inductor current changes at a positive rate, resulting in a linear increase.

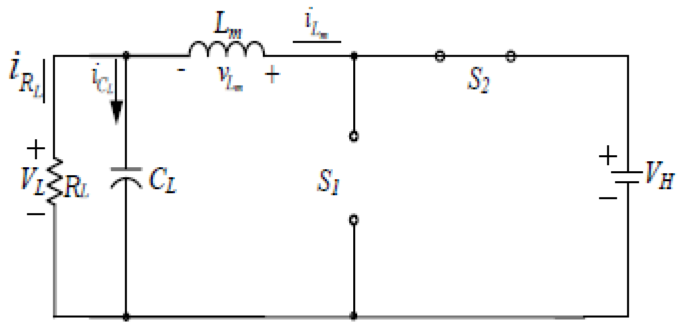

Figure 3.5. Bidirectional converter buck mode operation,the switch S2 on the high-voltage side is closed.

when switch S2 on the high-voltage side is open.Switch S1 on the low-voltage side of the converter is in a closed condition.In this mode of operation, the inductor current changes at a negative rate, resulting in a linear decline.

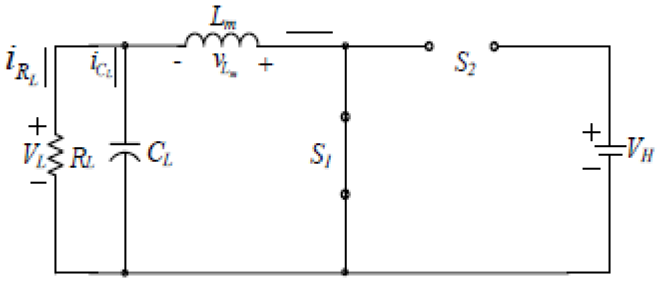

Figure 3.6. Bidirectional converter is operated under buck mode,the switch S2 on the high-voltage side is open.

To design the PI controller for the outer loop, the term ILmRLm is neglected. Equation can be written in the following form.

$$L = \frac{(V_o * (V_{in} - V_o))}{(I_{ripple} * f_{sw} * V_{in})} \tag{3.3.1}$$

$$C = \frac{I_{ripple}}{8 * f_{sw} * V_{ripple}} \tag{3.3.2}$$

3.4 MPPT Algorithm

a novel multiple step size PO MPPT algorithm with zero oscillation is proposed. The method proposed in is considered to satisfy the condition of maximum power point. The proposed algorithm has multiple step size for fast tracking and it has no oscillation around the MPP after reaching steady state.

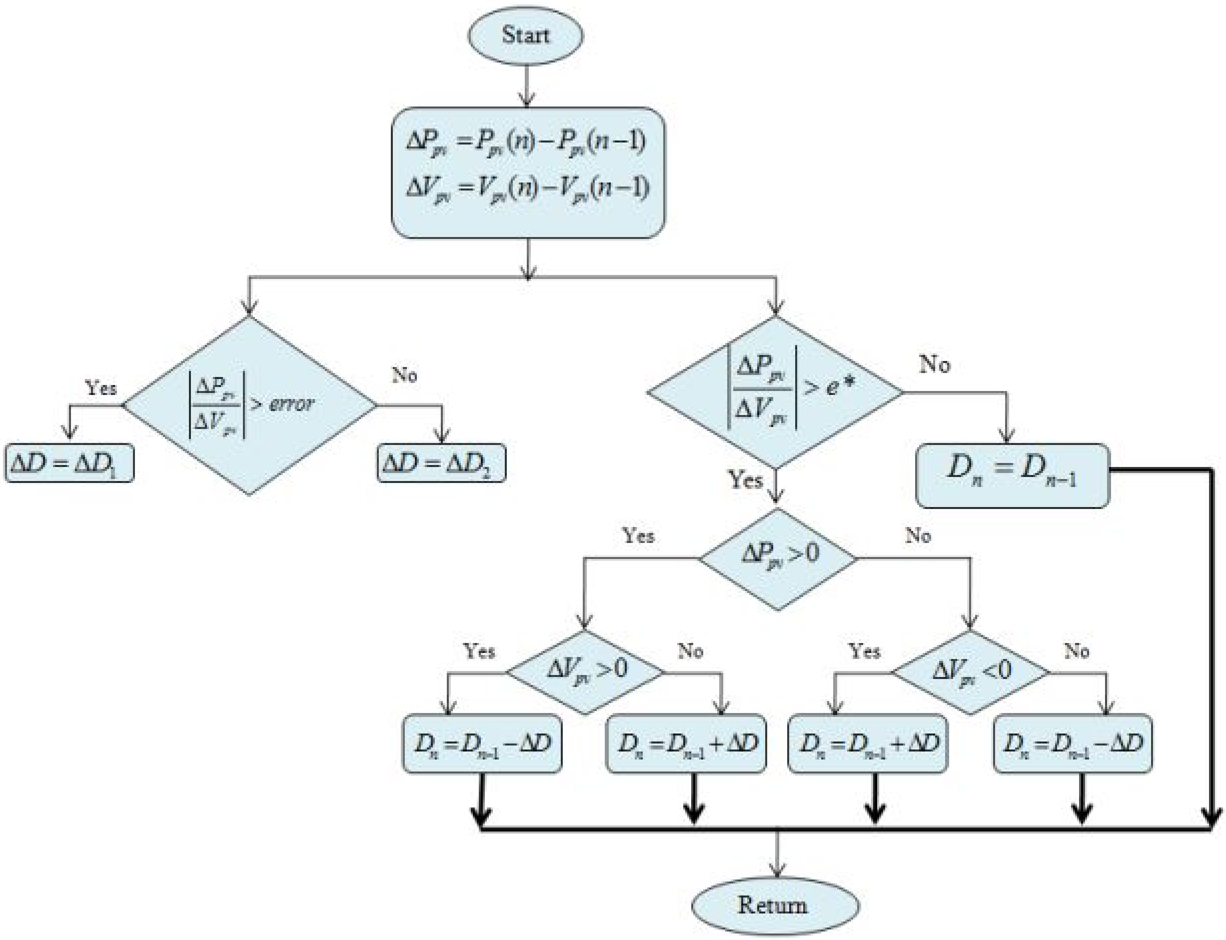

Figure 3.7. Multiple Step Size PO Algorithm

Figure 2.4 shows Multiple step size P& O MPPT. Here we taken two error values and two duty cycle values. these values are taken by taril and error method. The large step value is use for initial tracking of MPPT, after near to Maximum power point the step value is changed to smaller step value. use of two step value help to elimnate oscillation near to the maximum power point.

3.5 Energy management strategy

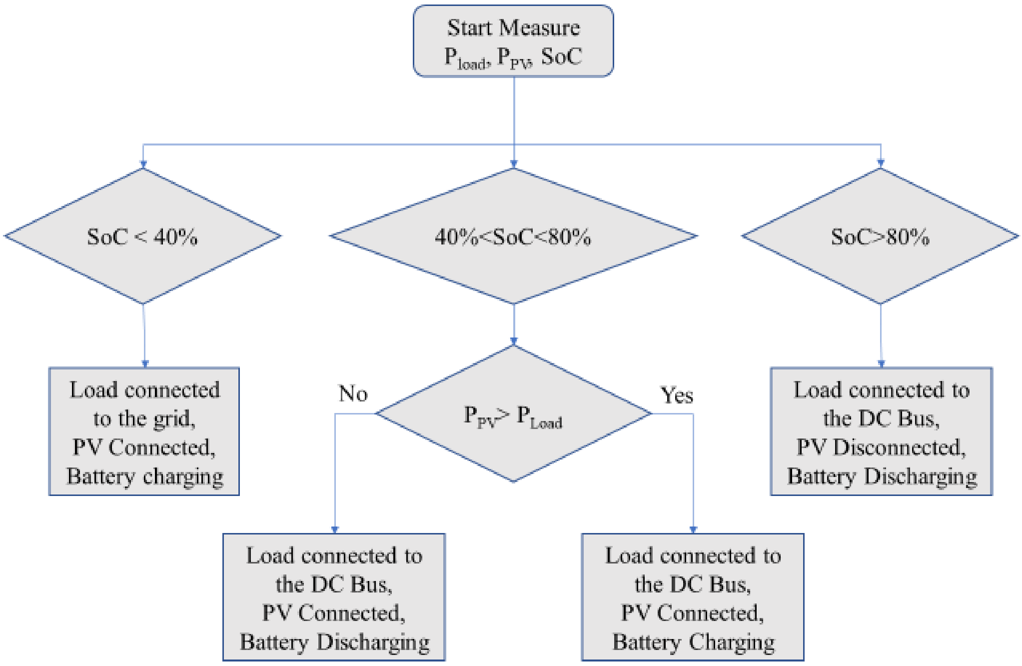

Figure 3.8. Flow chart of energy management strategy

Energy management strategy mainly controls the power flow of the DC micro-grid. The proposed energy management strategy works on four modes of operation. In the first mode of operation ,state of charge(SoC) between 80 to 40 percentage,which will check whether the generated PV power is greater than demand. If this condition satisfy ,load is directly connected to the DC bus and during this mode ,battery operates in charging mode.In the second mode of operation, SoC between 80 to 40 percentage, and also check generated Pv power is grater than demand, if the demand is satisfy load is connected directly to the grid and power to the grid is supplied by PV and Battery, so battery is in discharging mode.

In the third mode of operation,Soc is greater than 80 percentage. if this condition is satisfied PV module is disconnected form the DC bus, and battery works in discharging mode,inorder to avoid overcharging. The load demand is satisfied by the battery power. In the fourth mode of operation,SoC of battery less than 40 percentage, in this mode load directly connected with grid and PV is directly connected with battery.

3.6 Summary

This chapter analysed about the different components of DC microgrid such as boost converter, Bidirectional converter and their control. A novel Multiple stepsize P&O algorithm with zero oscillation and better tracking speed is also described in this chapter.

Chapter 4

Simulation parameters

4.1 Introduction

The energy management system used in this project consist of PV module,boost converter,battery and a bidirectional converter.The table shows the simulation parameters of the componnts respectively.

4.2 Simulation parameter

Table 4.1. PV Parameters.

PARAMETERS	SPECIFICATIONS
P_{PV}	100W
V_{oc}	22.42V
I_{SC}	5.9A
V_{mp}	18.18V
I_{mp}	5.5A

Table 4.2. Boost Converter Parameters.

PARAMETERS	SPECIFICATIONS
Input Voltage	18V
Output Voltage	48V
Inductor	506.33 μH
Capacitor	27.12 μF
Load	23.043 Ω
Switching Frequency	20kHz
Duty	0.625

Table 4.3. Bidirectional Converter Parameters.

PARAMETERS	SPECIFICATIONS
Input Voltage	48V
Output Voltage	12V
Inductor	90 μH
Capacitor	52.0833 μF 32.551μF
Battery rating	7AH 12V
Switching Frequency	20kHz
Duty	0.25 0.75

4.3 Summary

In this chapter, various component of the system used in developing the DC microgrid is modelled. A PV module of 100 watts is designed, boost converter of rating 18V/48V, bidirectional converter of rating 12V/48V, inductor and capacitors of rating 90 μH *and* $52.083\mu F$,$32.551\mu F$ *respectively*.

Chapter 5

RESULTS AND DISCUSSION

5.1 Introduction

In this section, simulation of a microgrid system consisting of a boost converter, DC-DC bidirectional converter and energy management control operating at four modes are analysed and comparison between these different modes are studied.

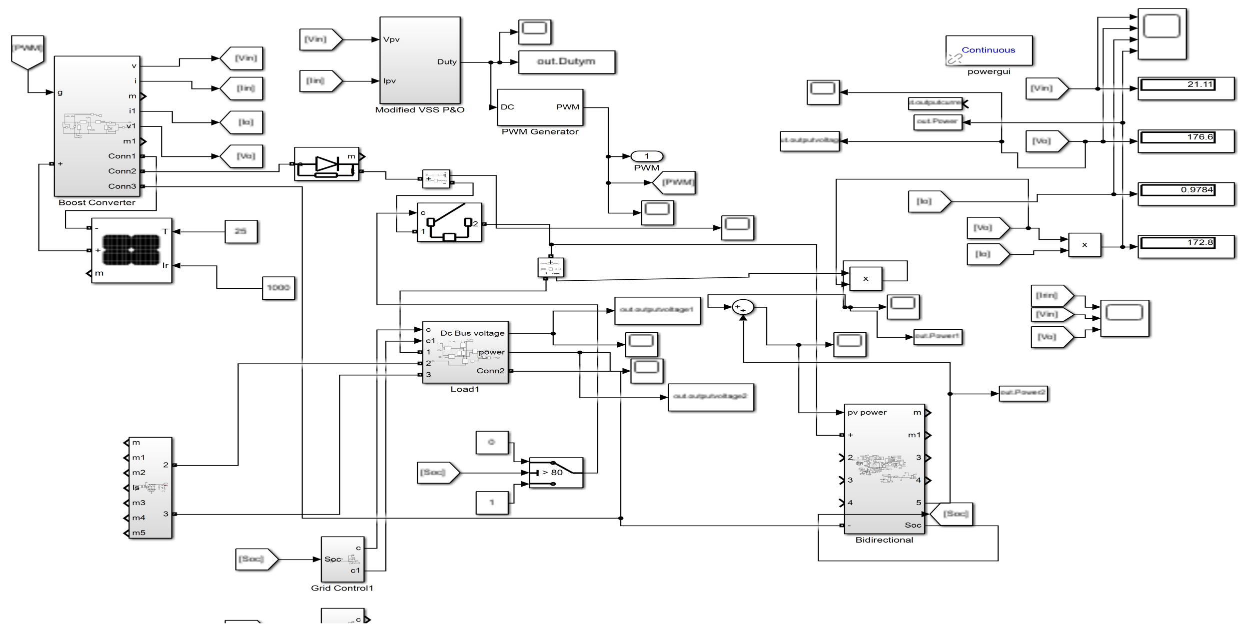

Figure 5.1. Simulation of DC microgrid

5.2 Simulation of Boost Converter with conventional P&O MPPT

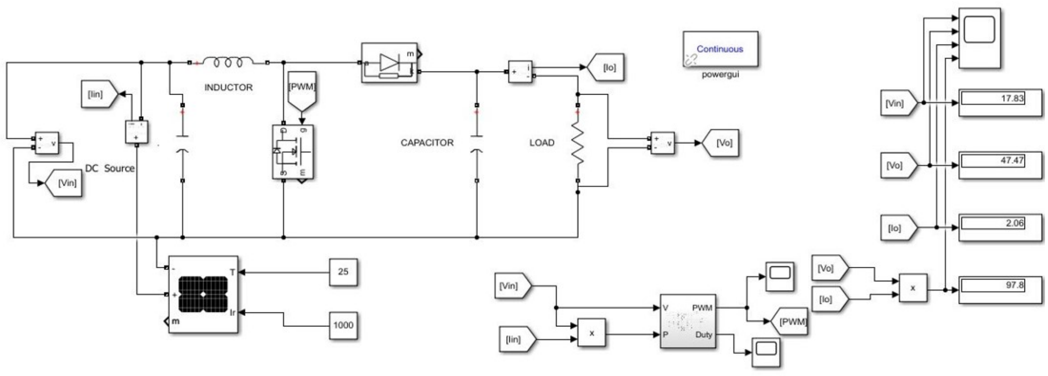

Figure 5.2. Boost converter along with PV system using conventional P&O

Figure 5.2 shows th simulation of Boost converter with conventional P&O MPPT. The converter step-up the voltage from the PV module, switching of the converter is controlled by the duty cycle set by the MPPT algorithm.

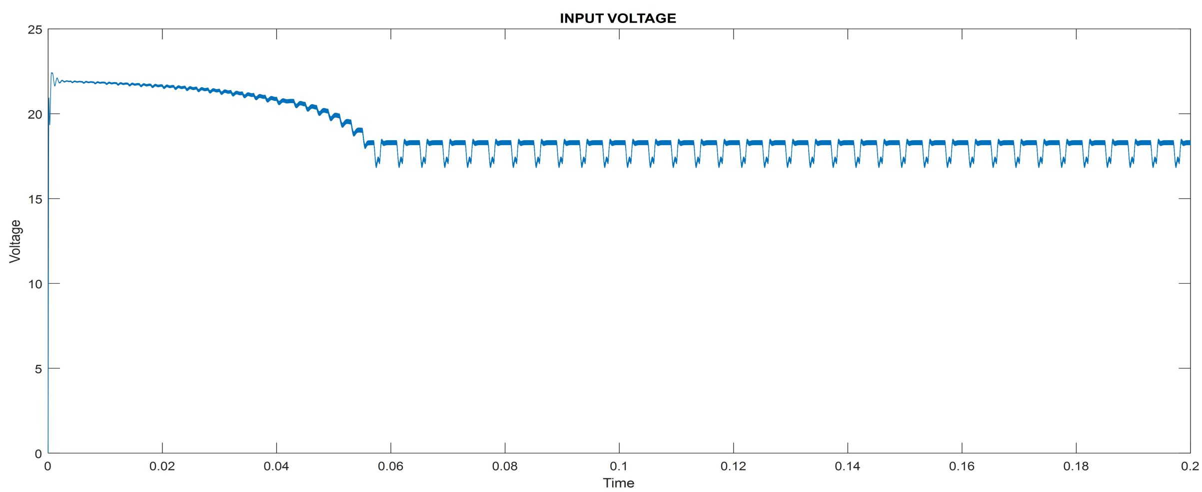

Figure 5.3. Input Voltage of Boost Converter

The rating of Boost converter is designed for 18/48V.The input of the solar panel is

1000 w/m^2 irradiance.

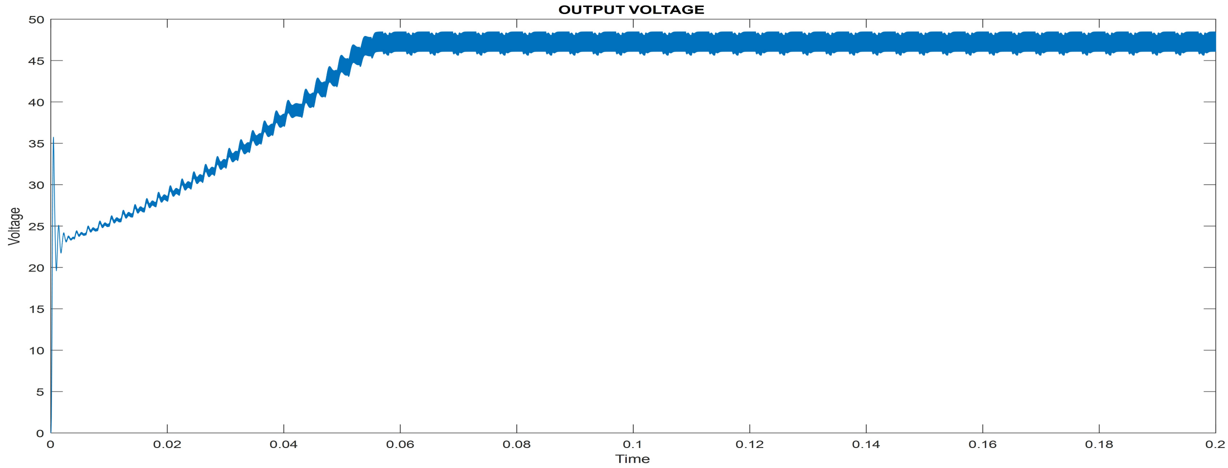

Figure 5.4. Output voltage of boost converter using Perturb and observe MPPT

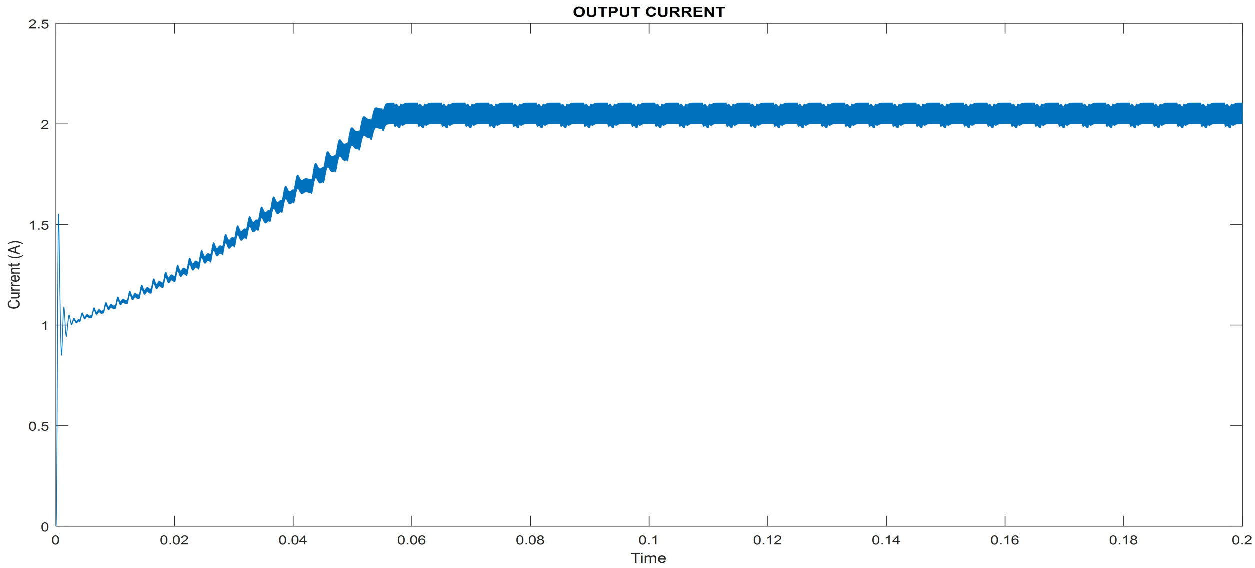

Figure 5.5. Output Current of Boost converter using Perturb and observe MPPT

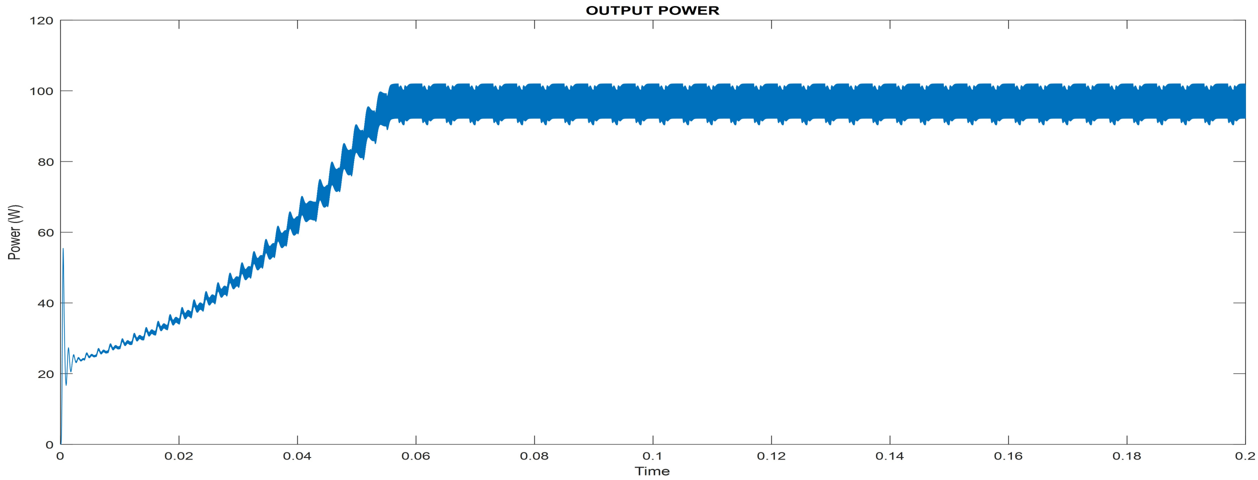

Figure 5.6. Output Power of boost converter using Perturb and observe MPPT

The duty cycle of conventional MPPT algoritham have oscillation around steady state value as shown in figure 5.7, which will results in increasing of ripple in output power and voltage of boost converter.

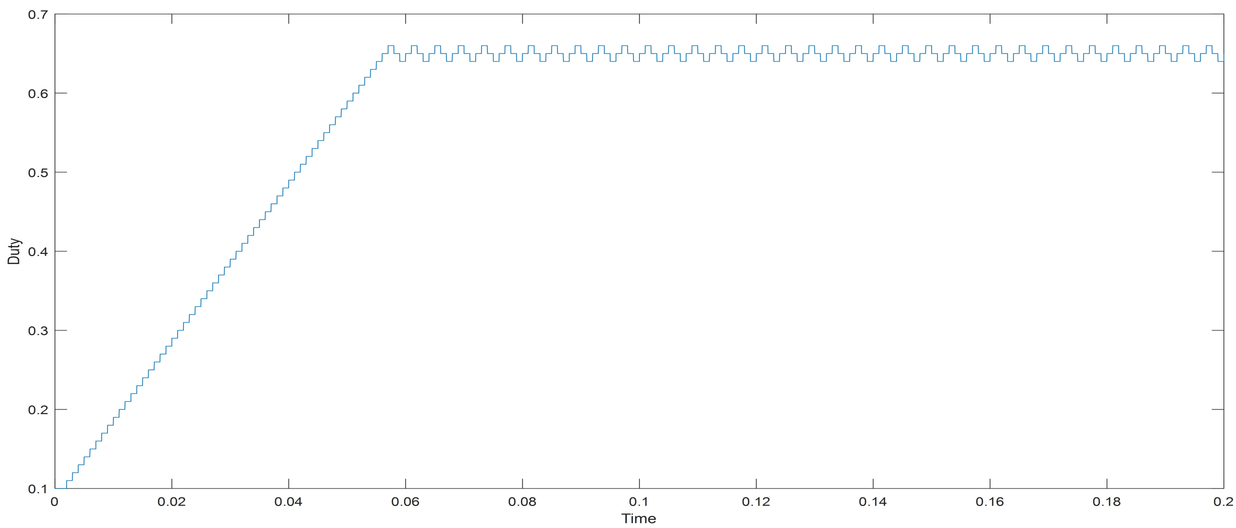

Figure 5.7. Duty cycle of Perturb and observe MPPT

5.3 Simulation of Boost converter with MSS P&O MPPT

Figure 5.8 shows simulation of boost converter using proposed MPPT. The rating of the boost converter is 18V/48V. The proposed MPPT control takes two error values

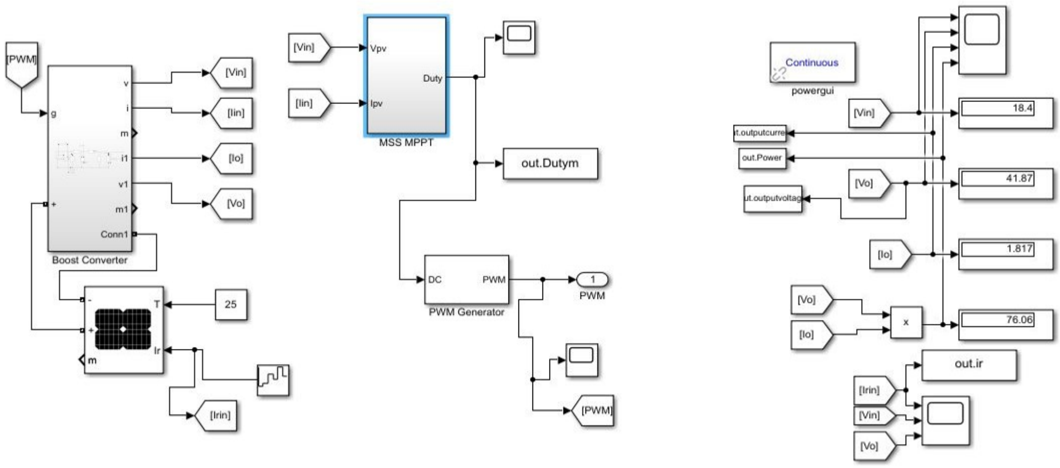

Figure 5.8. Simulation of boost converter with Proposed MPPT

Figure 5.9 shows multiple step size P& O MPPT. Here we takes two error values and two change in duty cycle values, one large step and a small step size value. The values are taken by trail and error method.The large step value is used for initial tracking. When it is near to Maximum power point, step values are changed to the smaller step. Which eliminates oscillation near the maximum power point.

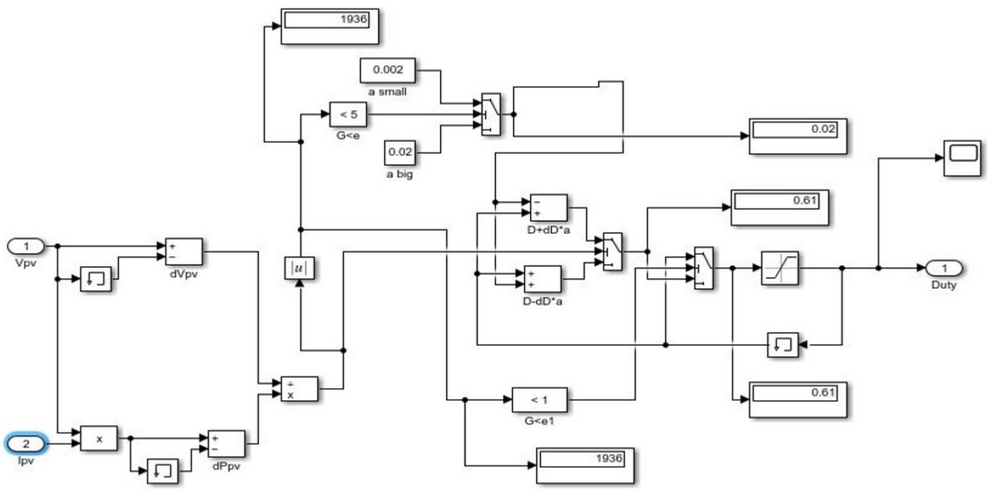

Figure 5.9. Multiple step size PO

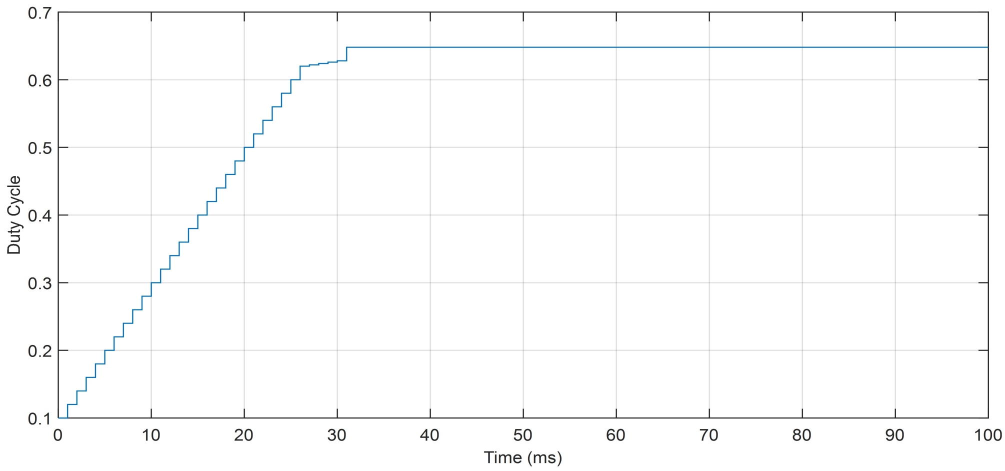

Figure 5.10. Duty Cycle at 1000W/m^2

Figure 5.10 shows the duty cycle of proposed MPPT, which has no osculation around the steady state value. Thereby reducing the ripple of the voltage and power of boost converter. Output voltage and power of the boost converter using modified MPPT with reduced power ripple is shown in figure 5.11 & 5.12

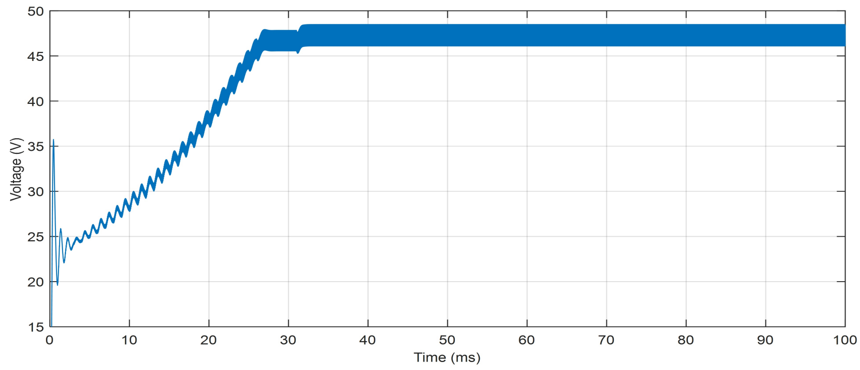

Figure 5.11. Output Voltage of boost converter at 1000W/m^2

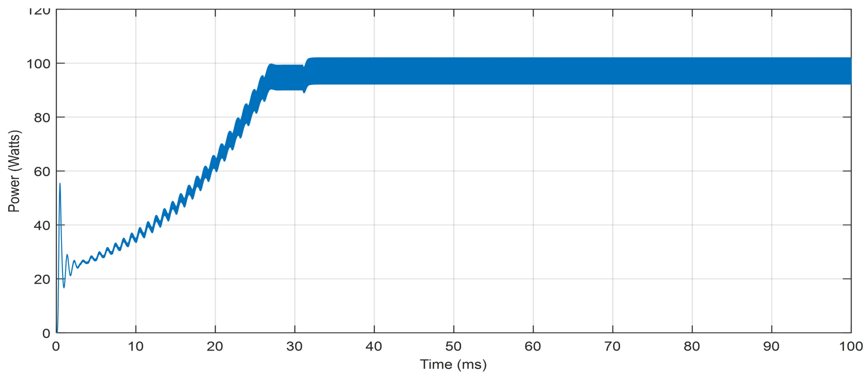

Figure 5.12. Output Power of boost converter at 1000W/m^2

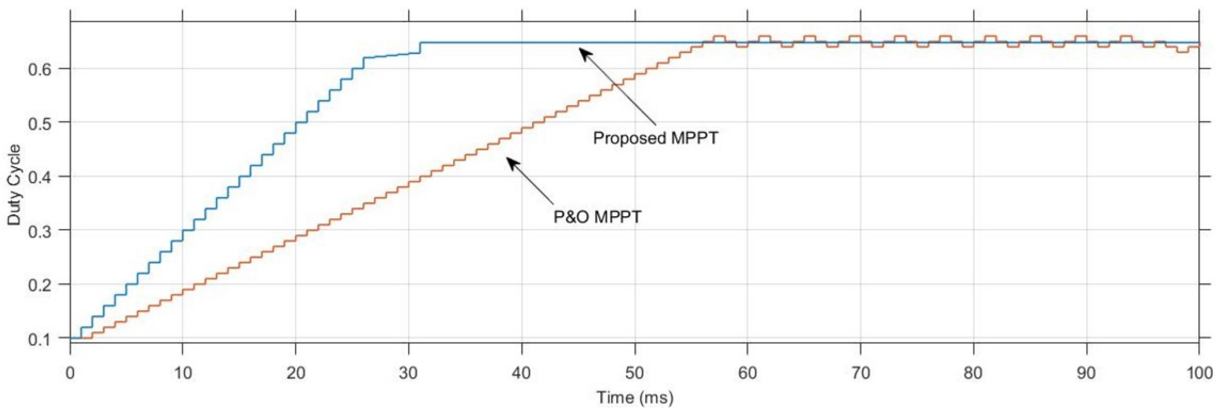

Figure 5.13. Duty cycle of conventional and proposed MPPT at 1000w/m^2

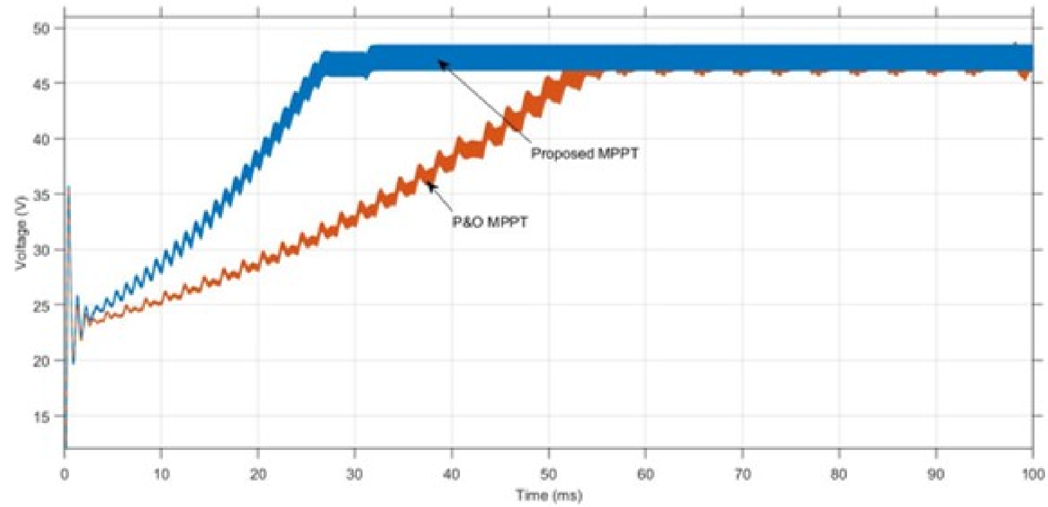

Figure 5.14. Output Voltage of conventional and proposed MPPT at 1000w/m^2

Figure 5.13 shows the compararison of duty cycle between the conventional and modified MPPT. The proposed MPPT shows less osscilation around the maximum power point with a better tracking speed than the conventional.

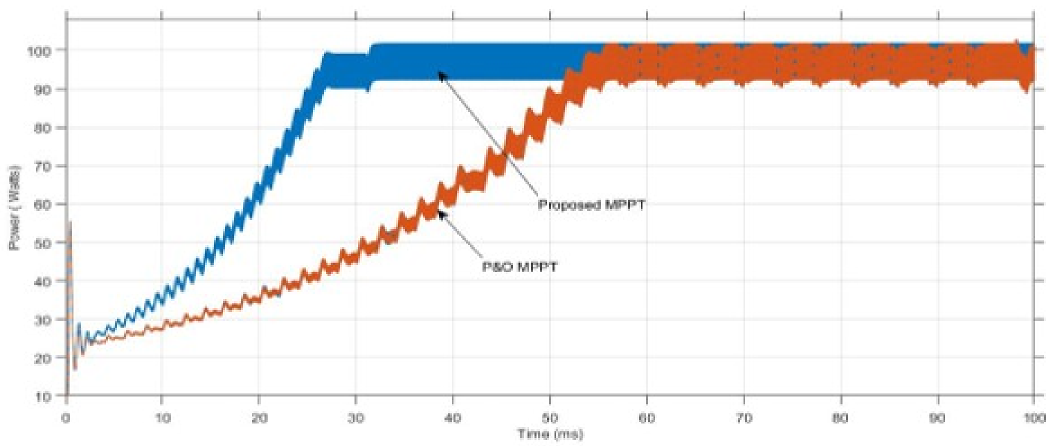

Figure 5.15. Output Power of conventional and proposed MPPT at 1000w/m^2

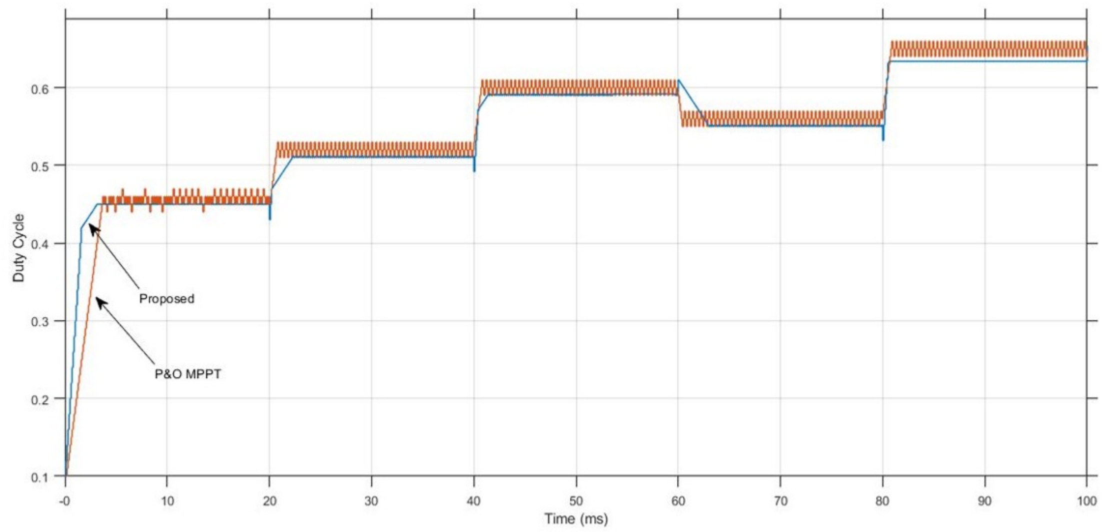

Figure 5.16. Duty Cycle of conventional and proposed MPPT at Different irradiation

Figure 5.16 shows the comparison of duty cycle between modified and conventional MPPT for different irradiance condition.

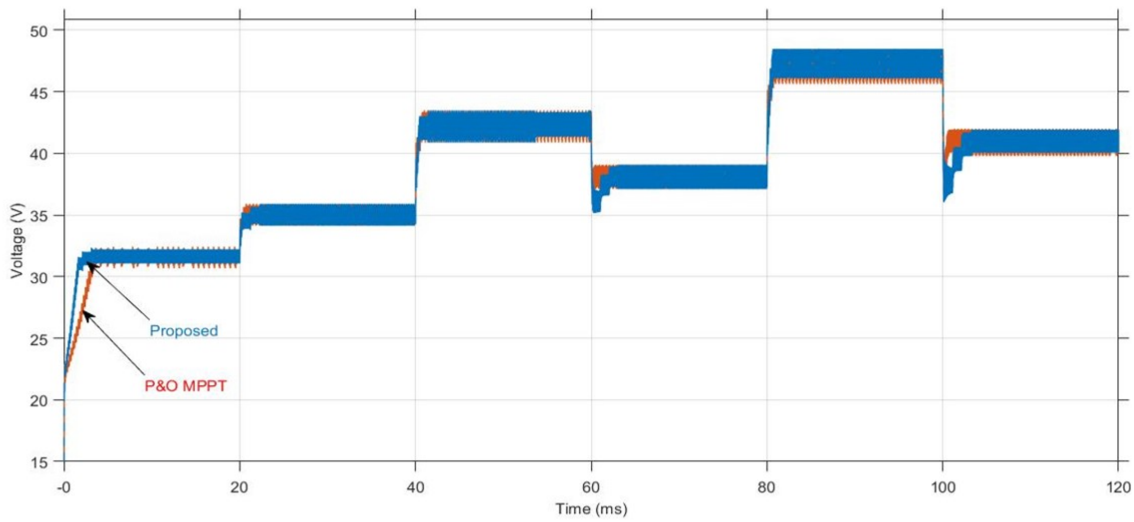

Figure 5.17. Output Voltage of conventional and proposed MPPT at Different irradiation

5.4 Simulation of Bidirectional converter

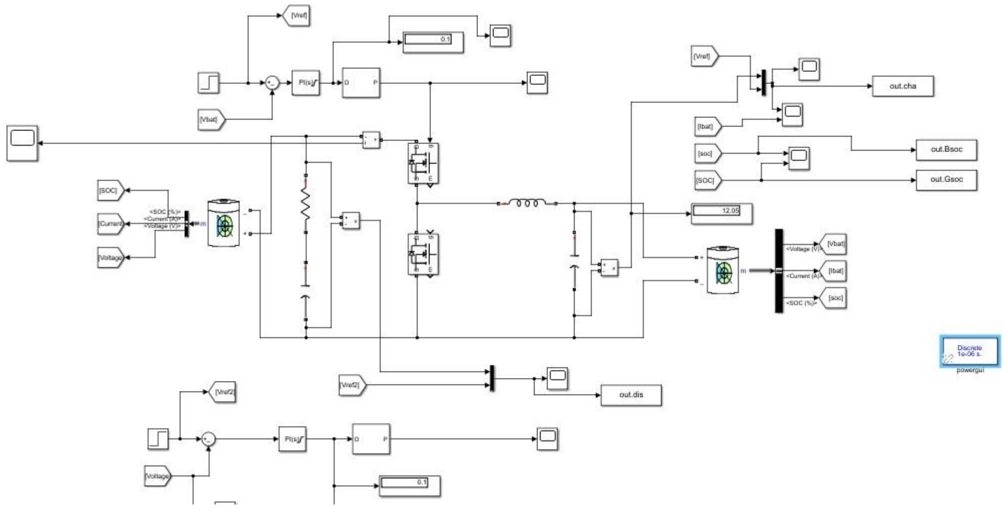

Figure 5.18. Simulation of Bidirectional converter

Figure 5.18 shows the simulation part of bidirectional converter. The converter is designed for 12V/48V. PI controller is used for controlling the duty for charging and discharging of the battery. The battery is designed for 12V, 7Ah battery.

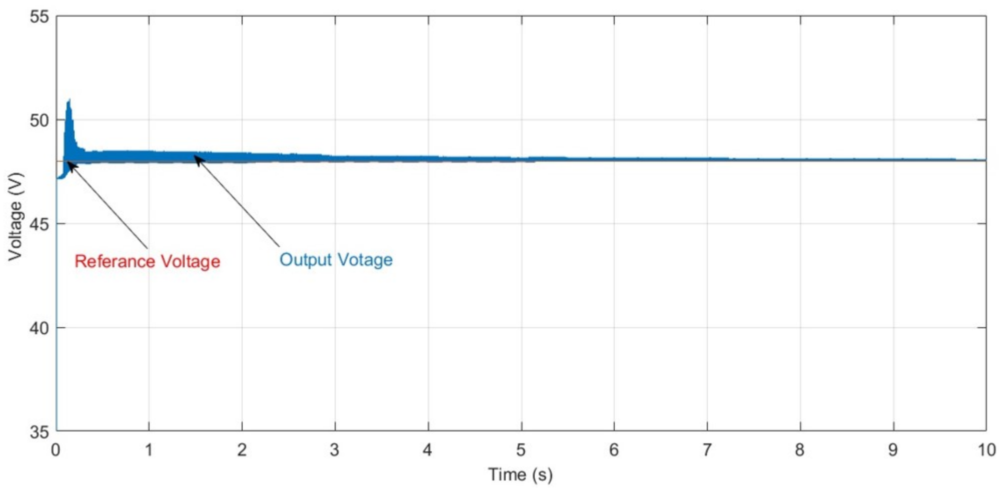

Figure 5.19. Output Voltage at battery discharging mode

Figure 5.20 shows battery SoC at discharging mode. During the discharging mode, the battery SoC percentage decrease gradually from 80 %

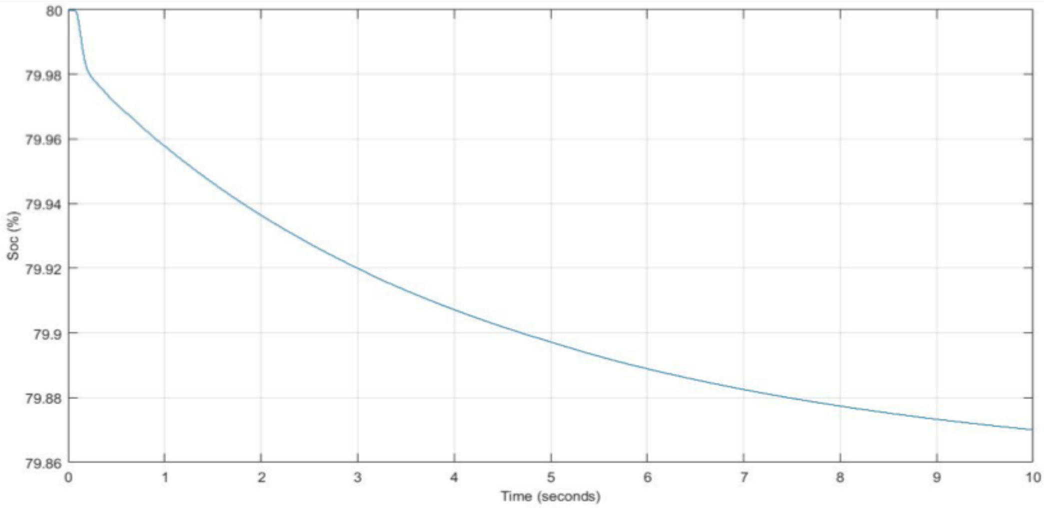

Figure 5.20. SoC of battery at discharging mode

Figure 5.21 shows the output voltage of the battery at charging mode, the output voltage is maintained at 12V

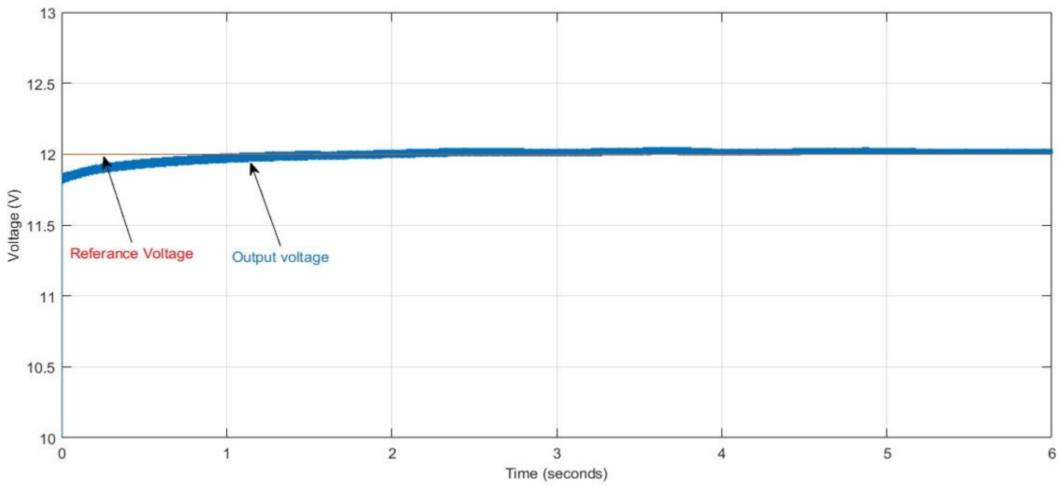

Figure 5.21. Output Voltage at battery discharging mode

Figure 5.22 shows battery SoC for the charging mode, the battery SoC percentage increasing gradually.

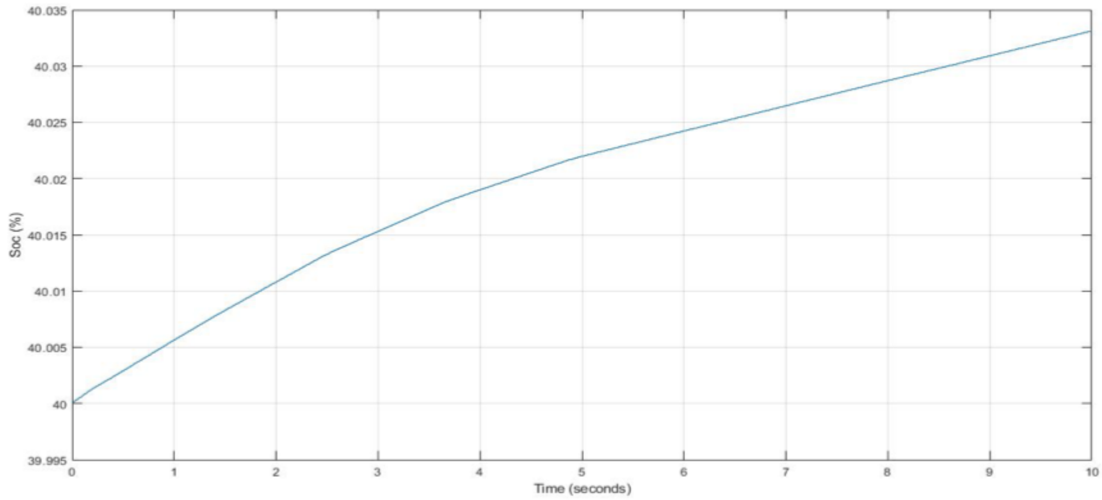

Figure 5.22. SoC of battery at charging mode

5.5 Simulation of rectifier circuit

Figure 5.23 shows simulation of rectifier circuit. Utility grid is connected to rectifier circuit with a step down transformer, which is step down the voltage to 48V AC.The output of the transformer is connected to the rectifier circuit which converts 48V AC to 48V DC. Filter capacitor is used to eliminate the output ripple.

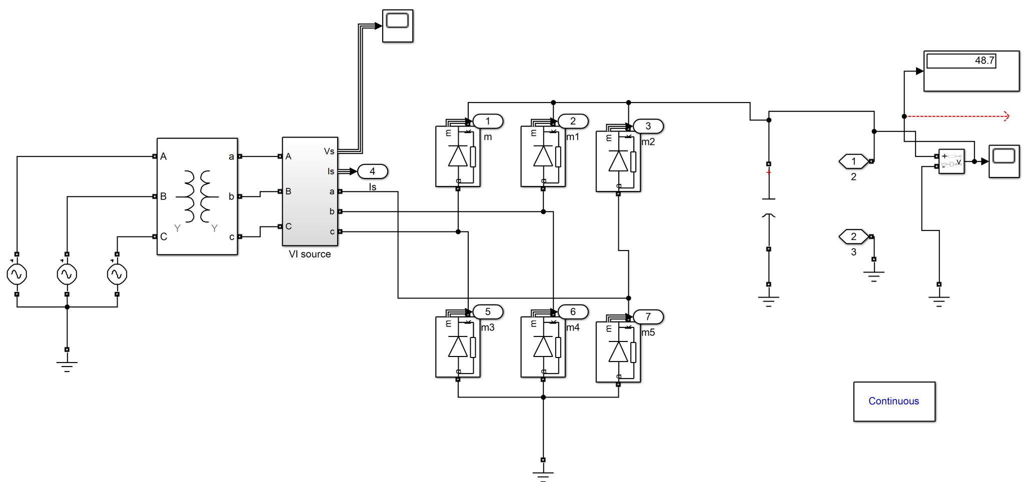

Figure 5.23. Simulation of rectifier circuit

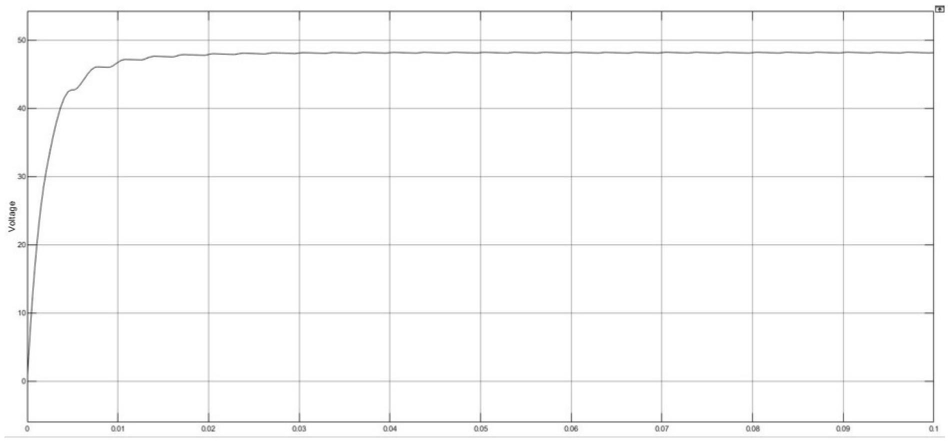

Figure 5.24. Output voltage of rectifier

Figure 5.24 shows the output voltage of rectifier circuit, and it is maintained at 48V DC.

5.6 Energy management control

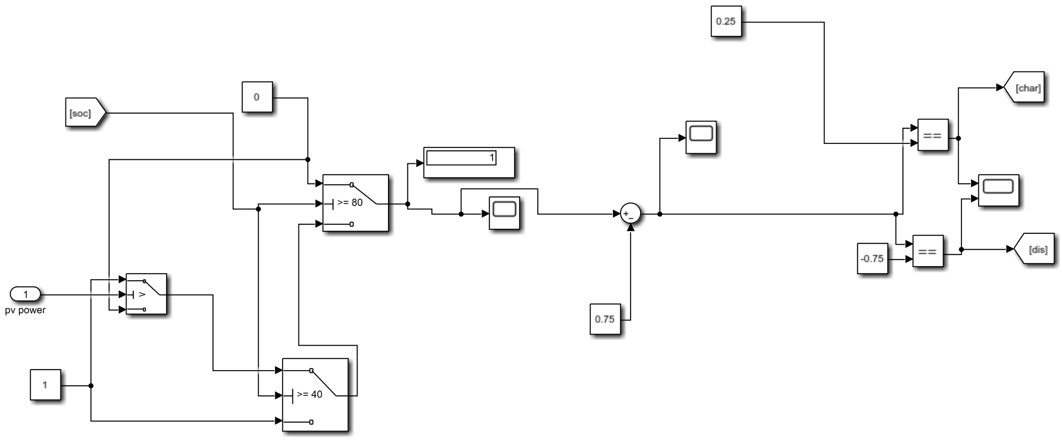

Figure 5.25. Energy management Control for battery

The energy management strategy takes the decisions for management of power flow by taking the inputs from the PV system, load demand and the state of charge of battery.

Here Figure 5.25 shows simulation of energy management control for battery system used for the control of charging and discharging of the battery.

5.6.1 Mode 1

In the first mode of operation the power generated by the PV module is higher than the load demand. So, the battery the battery starts charging to store the excess power.

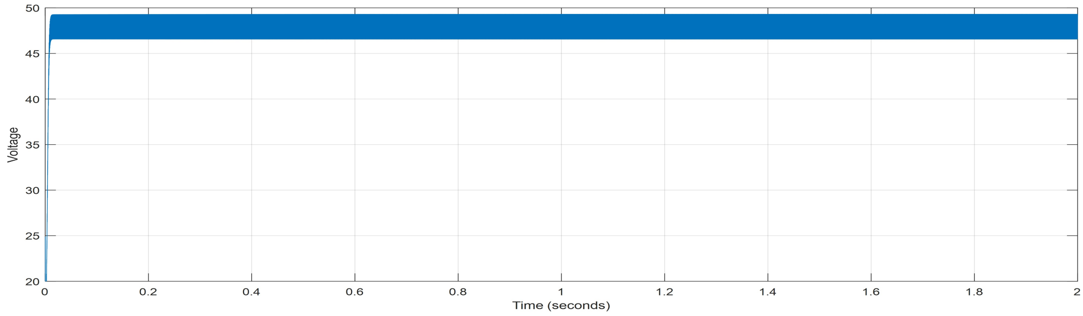

Figure 5.26. DC Bus Voltage at mode1

Figure 5.26 shows the DC Bus voltage for mode 1. figure 5.27 shows load power of 88W and here PV is delivers 100W power is shown in figure 5.28.

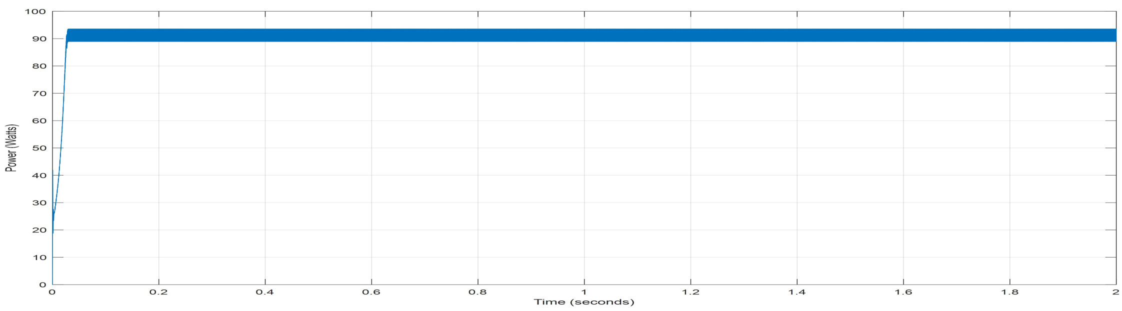

Figure 5.27. DC load power at mode1

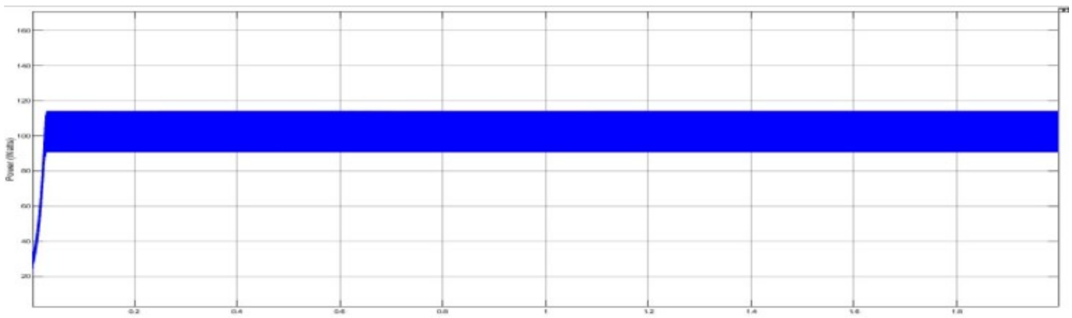

Figure 5.28. PV power at mode1

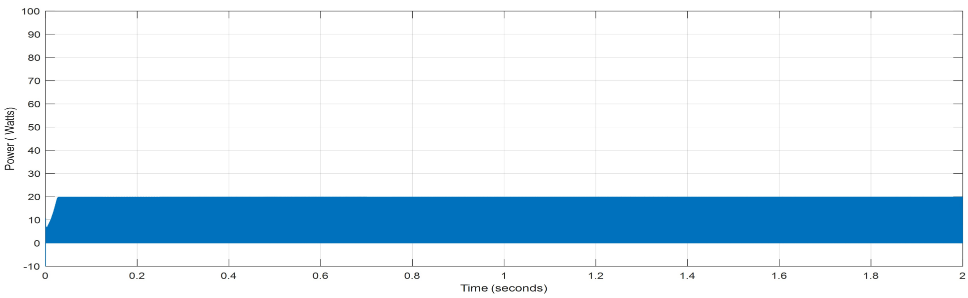

Figure 5.29. Battery power at mode1

Figure 5.29 shows the consumption of battery during charging mode . figure 5.30 shows the increase in the state of charge of battery.

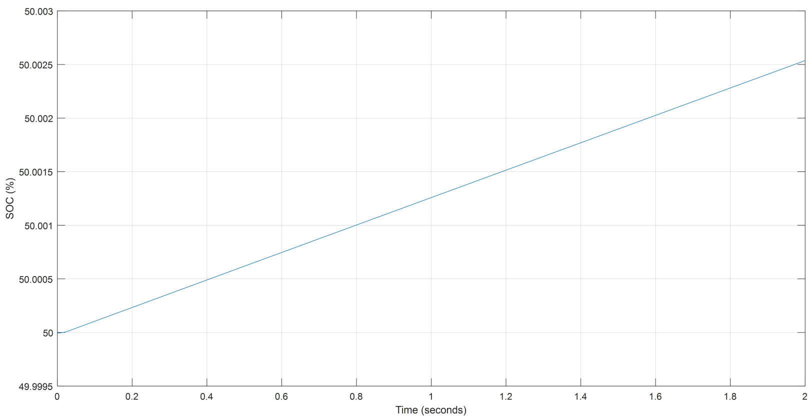

Figure 5.30. SoC of Battery at mode1

5.6.2 Mode 2

In the second mode of operation, the PV production is limited around 50 watts. The PV generation was not able to meet the load demand. As a result the battery operate in the discharging mode.

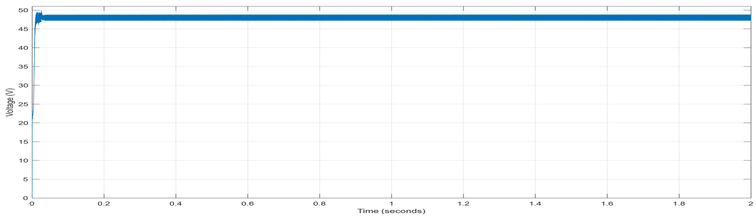

Figure 5.31. DC Bus Voltage at mode 2

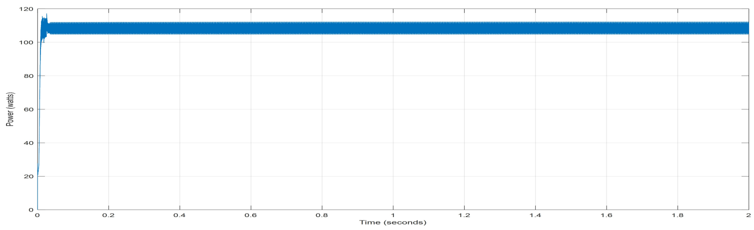

Figure 5.32. Load power at mode 2

Figure 5.31 shows the DC Bus voltage and it is kept at 48V. Figure 5.32 shows the load power of 106 watts. Here PV panel is generate only 50 watts is shown in figure 5.38 and battery discharged 60W as shown in figure 5.39

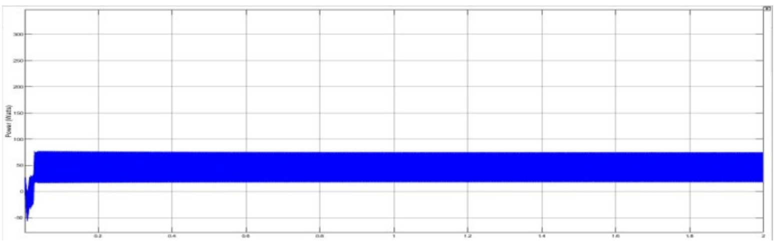

Figure 5.33. PV Power at mode 2

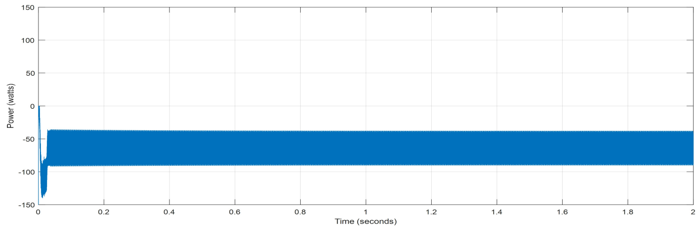

Figure 5.34. Battery Power at mode 2

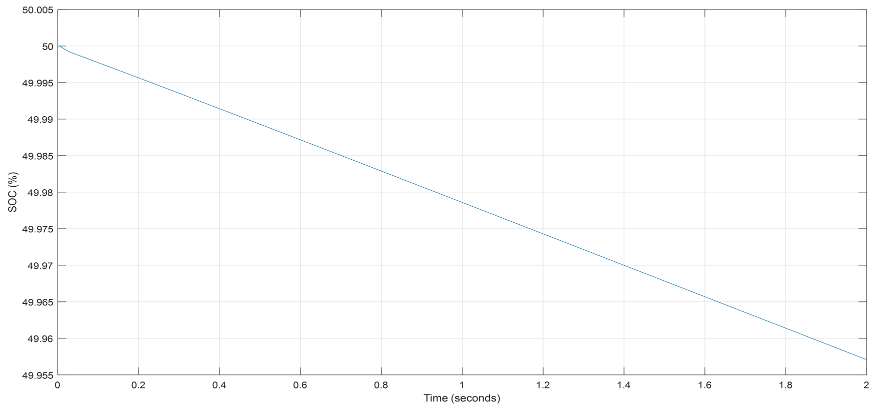

Figure 5.35. SoC of battery at mode 2

Figure 5.35 shows the discharging of battery.The battery SoC is gradually decreasing from 50%.

5.6.3 Mode 3

In the third mode of operation, PV is disconnected from the system. During this mode battery discharge to meet the load demand.

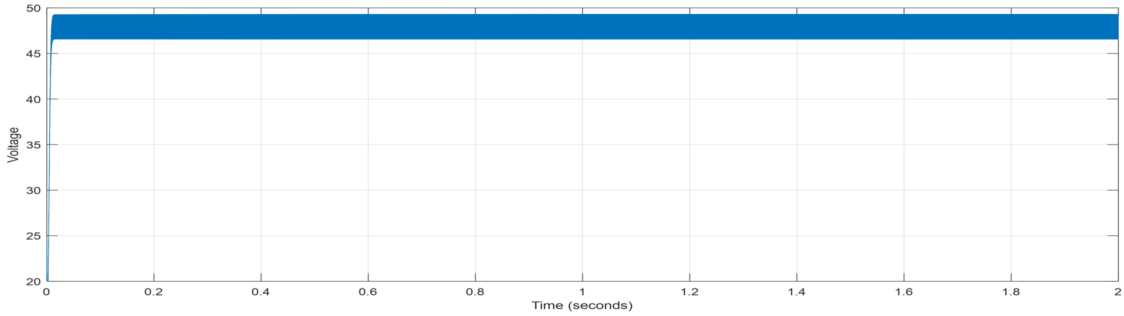

Figure 5.36. DC Bus Voltage at mode3

Figure 5.36 shows the DC Bus voltage maintained at 48V. The battery discharges to meet the load demand of 115 watts.

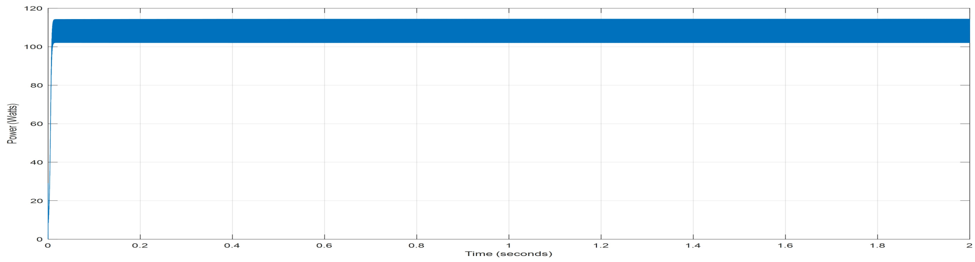

Figure 5.37. DC Bus load power at mode3

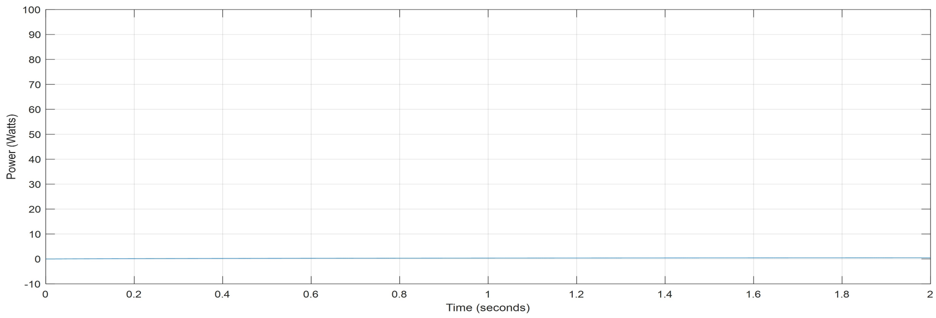

Figure 5.38. PV power at mode3

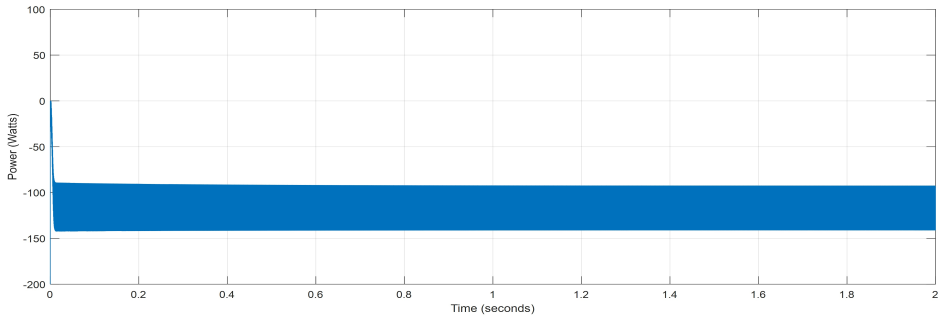

Figure 5.39. Battery power at mode3

Due to the discharging of battery, SoC will reduced from 90 percentage as shown in figure 5.40 and 118W power is delivered from battery.

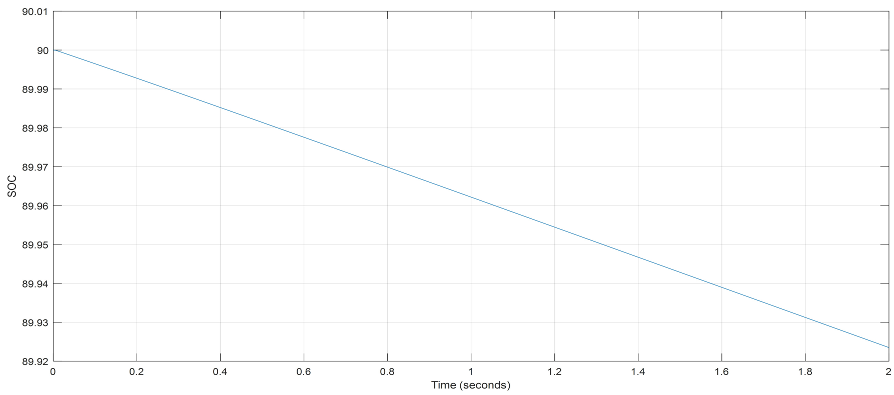

Figure 5.40. Battery SOC at mode3

5.6.4 Mode 4

In fourth mode of operation, when the battery soc is below 40%, the load is disconnected from the DC microgrid. The utility grid will help to meet the load demand. Figure 5.41 shows the DC Bus voltage maintained at 48V

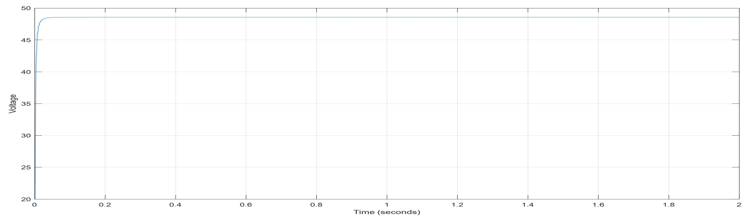

Figure 5.41. DC bus voltage at mode 4

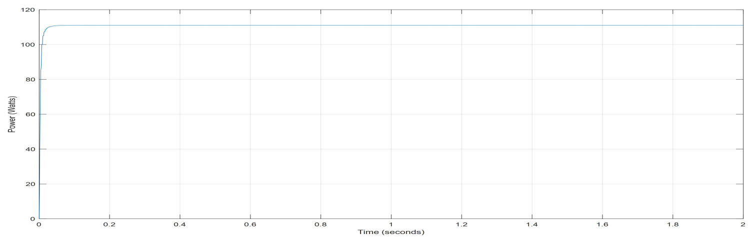

Figure 5.42. Load power at mode 4

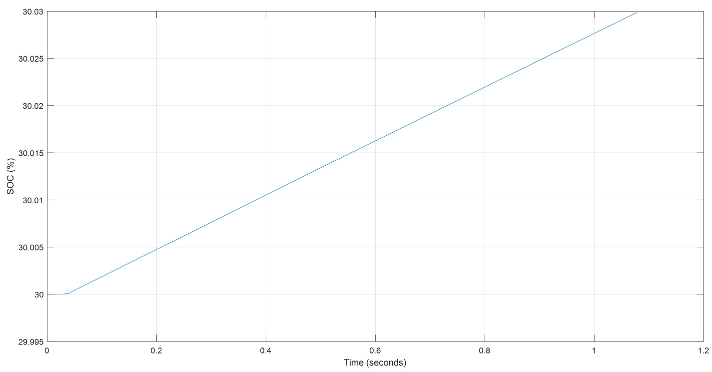

Figure 5.43. SoC of battery at mode 4

Figure 5.42 shows the Load power chara,it consumes 115 W from utility grid.During this , the battery is charging from PV module and SoC of the battery is increasing from 40%. The table below shows the comparison of DC bus voltage,PV power,load power,battery power and powerloss for different operatong modes.

Table 5.1. Comparison of the four operating modes

Operating mode	DC bus voltage(Watts)	PV power(Watts)	Load Power(Watts)	Battery power(Watts)	Power Loss(Watts)
Mode 1	48	100	88	10	2
Mode 2	48	50	106	-60	4
Mode 3	48	0	115	-118	3
Mode 4	48	100	110	98	2

Table 5.2. Comparison of the four operating modes

Operating mode	DC bus voltage(Watts)	PV power(Watts)	Load Power(Watts)	Battery power(Watts)
Mode 1	0	10	3	10
Mode 2	4	10	1	20
Mode 3	2	0.01	5	25
Mode 4	0	10	0	20

The above results shows the good performance and stability of the system. Table 5.3 shows the comparison of power loss of proposed Energy management strategy and conventional energy management strategy[1]. which will shows proposed algorithm reduces power loss with various modes of operation.

Table 5.3. Comparison power loss of conventional and proposed Energy managemt strategy

Operating mode	Power loss of conventionl EMS (%)	Power loss of proposed EMS(%)
Mode 1	5	2
Mode 2	8	4
Mode 3	5	3
Mode 4	4	2

5.7 Summary

The energy management control strategy for different modes of operation were conducted to analyse the efficiency of the proposed control. The conventional and proposed MPPT control algorithm were also compared.

Chapter 6

CONCLUSION

A simple energy management strategy is proposed for DC microgrids working in both grid connected and standalone.The system consist of PV module,battery ,boost converter and a bidirectional converter.Multiple step size P&O MPPT is introduced to track the maximum power point.The energy management startegy is based on the battery's state of charge,this will avoid over charging and deep discharging of the battery.It will ensure the battery life.The results shows the reduction in power ripple and loss during power sharing.

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