DESIGN, CONTROL & ANALYSIS OF HYBRID AC/DC MICROGRID

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ABSTRACT : In these recent times, where the renewable energies are the new trend and the sustainable energies are starting to play a big role in the society in order to eliminate the dependence on the fossil fuels, funding a way to collect these clean energies and to convert them into electricity at their highest performance is without any doubt essential. Nevertheless, the way to link the power generator from these renewable resources to the main grid is significant. The present work studies step by step the design, modelling, control and simulation based on photovoltaic (PV) system, and it is integrated to the utility grid with the help of power electronic converters. This work can be carried out using many software. MATLAB/SIMULINK will be used for design, control and analysis in this project owing to its user-friendly characteristics. Modelling of the equivalent circuit model to simulate the working principle of PV cell is studied in detail and a Maximum Power Point Tracking (MPPT) control algorithm to force the PV system works as its highest operating point is applied. A large battery unit is employed to meet the critical loads in the absence of PV power and the utility grid. This unit is integrated to the grid with the usage of DC-DC converter. In this analysis, it would result in a constant grid voltage which has a reliable continuous power without any significant repercussions. And the PV and the battery will supply the load and the remaining power is fed back to the grid.

Keywords: Photovoltaic (PV) system,Maximum Power Point Tracking (MPPT), DC-DC converter, MATLAB/SIMULINK.

I. INTRODUCTION

The microgrid is a grid system of smaller scale capable of operating autonomously or in conjunction with the primary electrical grid of the surrounding area. Microgrids often employ a range of energy sources to facilitate the integration of sustainable power. There exist two primary classifications of microgrid systems, namely, the direct current (DC) microgrid and the alternating current (AC) microgrid. The present framework employs a direct current bus system as its principal means of providing electrical support and distributes energy to a cluster that encompasses several dozen to a hundred domiciliary units within a given locale. Various energy sources such as solar cells, fuel cells, and batteries are utilised within a DC microgrid system to provide power to connected loads. In order to attain the rated DC voltage, a buck or boost converter has been employed within the microgrid for the purpose of voltage conversion. In order to maintain a consistent output voltage reference, a

DC-DC converter is regulated through the implementation of a proportional integral (PI) controller.

This work features a photovoltaic (PV) array with a capacity of 300 kilowatts (kW) and a battery capacity of 500 kW. The DC bus voltage exhibited a value of 800V, while the AC bus voltage, as measured in terms of line value, was observed to be 415V. The alternating current (AC) side exhibits a load of 200 kilowatts (kW), while the direct current (DC) side presents a critical load of 11.59 kW.

The microgrid design and its control is studied by many researchers. El-Shahat, Adel, and Sharaf Sumaiya made a detailed study on the DC microgrid system design and control [1]. This paper presents an overall study of the microgrid with the PV array connected to the grid. Kouro and Samir gave an organised approach to the PV connection to the grid [2]. Joyce, A. and Huan-Liang discussed the implementation of the PV in the MATLAB/Simulink [3-4]. Maximum power point tracking using Perturb and Observe technique and the closed loop control of the boost converter of PV is discussed by Jacob James and Nibedita Swain [5-6].

Text book on Power Electronics [7] has extensively covered various techniques and methodologies used in the converter control. Xue, Meifang and O’Rourke have covered the technique of developing a PWM rectifier and its control using the park transformations [8-9]. The design of LCL filter to reduce the supply current harmonics is studied by Mustafa and Marcelo Godoy Simões [10-11].

Battery selection and the design in the MATLAB/Simulink and the control of the Bidirectional Buck-boost converter is referred [13-18]. The ultimate control of the grid is referred to in the research done by Poh Chiang Loh and Saroja Kanti [19-20].

II. **Methodology**

2.1. Block diagram of the Micro grid

Fig (1) shows the block diagram of microgrid based on photovoltaic systems, the battery unit and their integration to the utility grid with the help of power electronic converters.

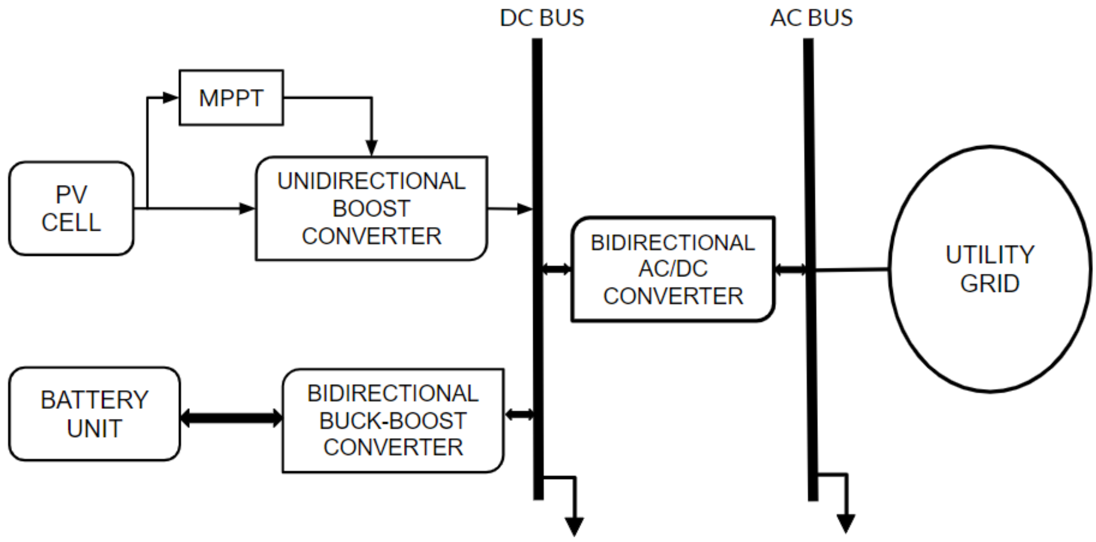

Fig. 1 - Block Diagram of the micro grid

2.2. Modelling of Photovoltaic Energy System

In this MPPT technique P&O algorithm is used to take out maximum solar power output with approximately no oscillation in output PV power. The perturb and observe (P&O) algorithm is based on the observation of the array output power and on perturbing (increasing or decrementing) the power based on increments of the array voltage or current, as the name implies. The maximum quantity of power is tracked by the P&O approach using oscillations around the MPP. When the sun irradiance and temperature conditions fluctuate, the P&O MPPT algorithm is helpful in resolving these changes by reducing perturbation and slowing the tracking. The P&O MPPT system operates based on changes in panel voltage and comparisons to PV output power values from prior cycles. Based on the provided values, the P&O algorithm generates the suitable duty cycle to coincide with the MPP and recuperate the maximum power with a good precision under varying climatic conditions. The system is modelled with the help of MATLAB/SIMULINK as shown in Fig(2).

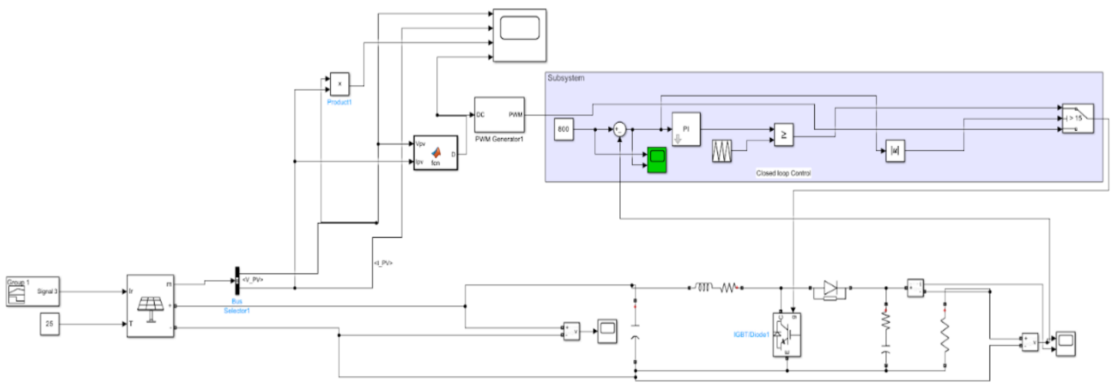

Fig. 2. Photovoltaic Energy system simulation

2.3. Modelling of Battery unit

The Lithium-ion battery utilised in this project possesses a capacity of 500 kilowatt hours. Lithium-ion batteries offer several advantages over other types of rechargeable batteries. They have a higher energy density, which means they can store more energy in a smaller package. They also have a longer lifespan than other rechargeable batteries, with some models capable of lasting for over 10 years. Lithium-ion batteries also have a relatively low self-discharge rate, which means they can be stored for longer periods without losing their charge. Fig (3) shows the simulation diagram of Battery unit.

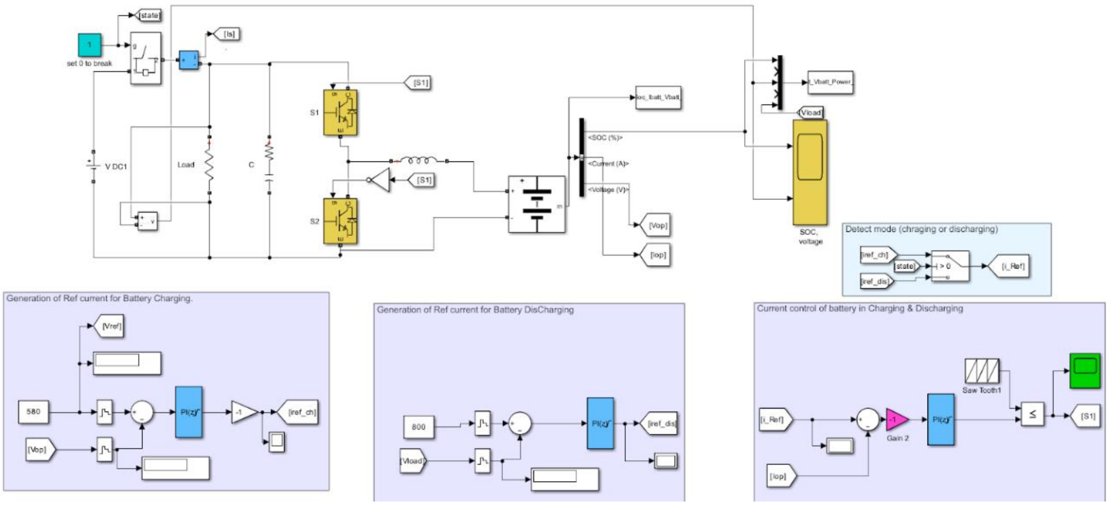

Fig.3. Battery Unit simulation

2.4. Modelling of Bidirectional AC/DC converters

Bidirectional AC/DC Converters is mainly used for the bidirectional power flow. It mainly constitutes of the 3-leg, 6-switches IGBT bridge circuit with the control. The converter converts AC to DC in the rectifier mode and from DC to AC in the inverter mode of operation.

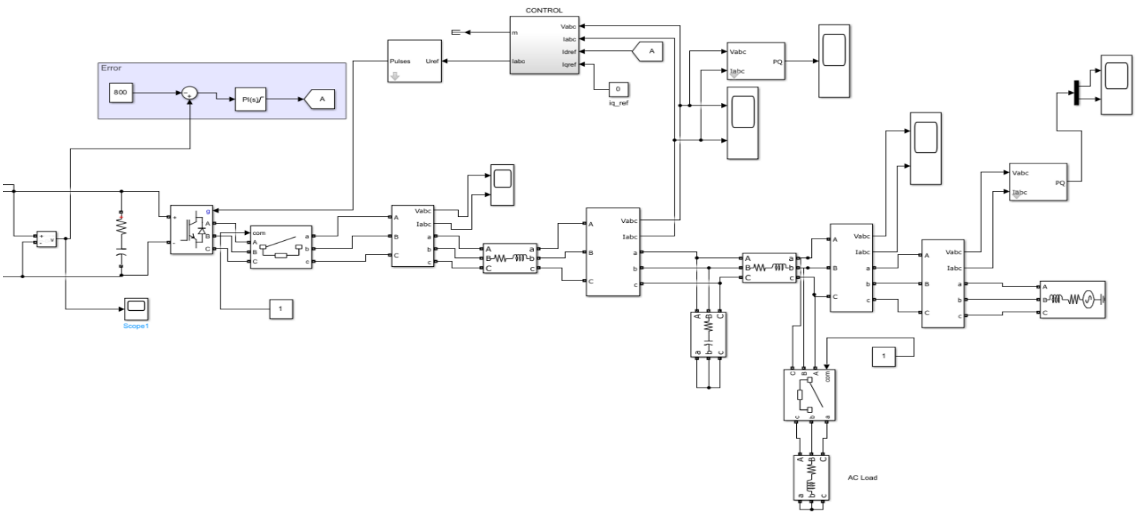

Fig .4. Rectifier Circuit (SIMULINK)

The converter control is designed based on the PWM pulse generation using the park and inverse park transformations. Here the reactive (q) component is made zero by comparison and the active (d) component is being employed for the control. The control circuit is shown in Fig(5).

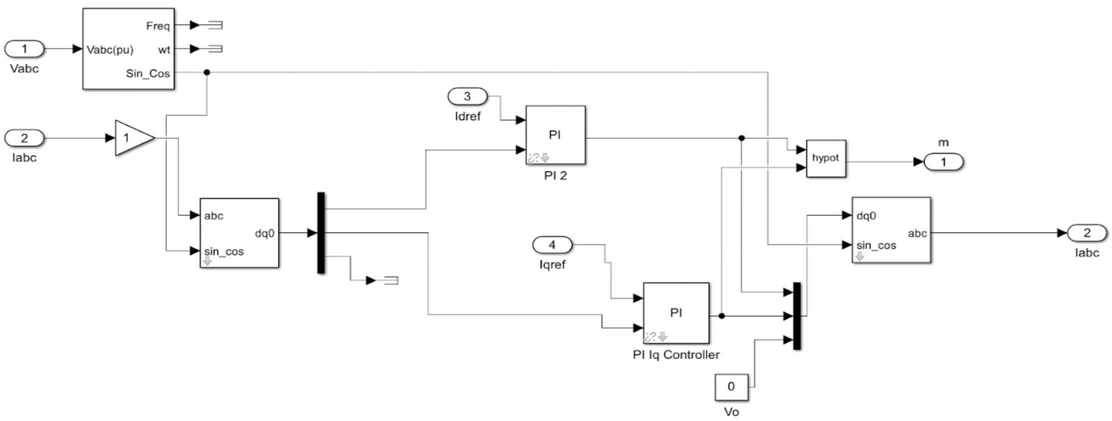

Fig.5. Control Circuit (SIMULINK)

2.4. LCR filter designing

The application of a filter at the output of the inverter is deemed essential. As such, the aforementioned signal exhibits the presence of harmonic components at both the switching frequency and its associated multiples. The output of the inverter is filtered with an LCL filter. The foremost rationale for opting for the aforementioned filter is its ability to function effectively at reduced switching frequencies, as well as its superiority in terms of filter dimensions, when compared to traditional "L" and "LC" filters. Additionally, it demonstrates significantly reduced voltage drop and improved damping properties, in contrast to conventional "L" and "LC" filters. A model of a three-phase inverter circuit interfacing with the grid is presented below in Fig (6).

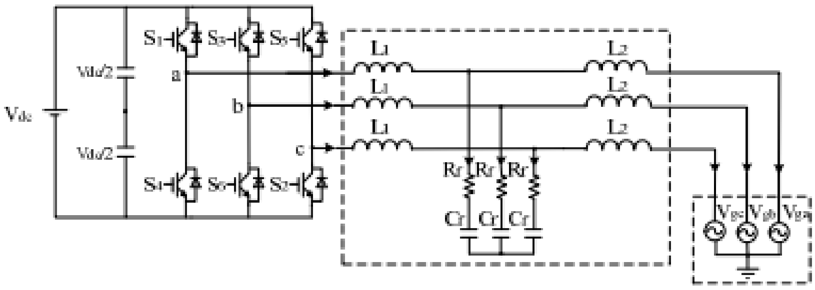

Fig .6. Voltage source inverter circuit with LCL filter

III. Modelling of overall micro grid

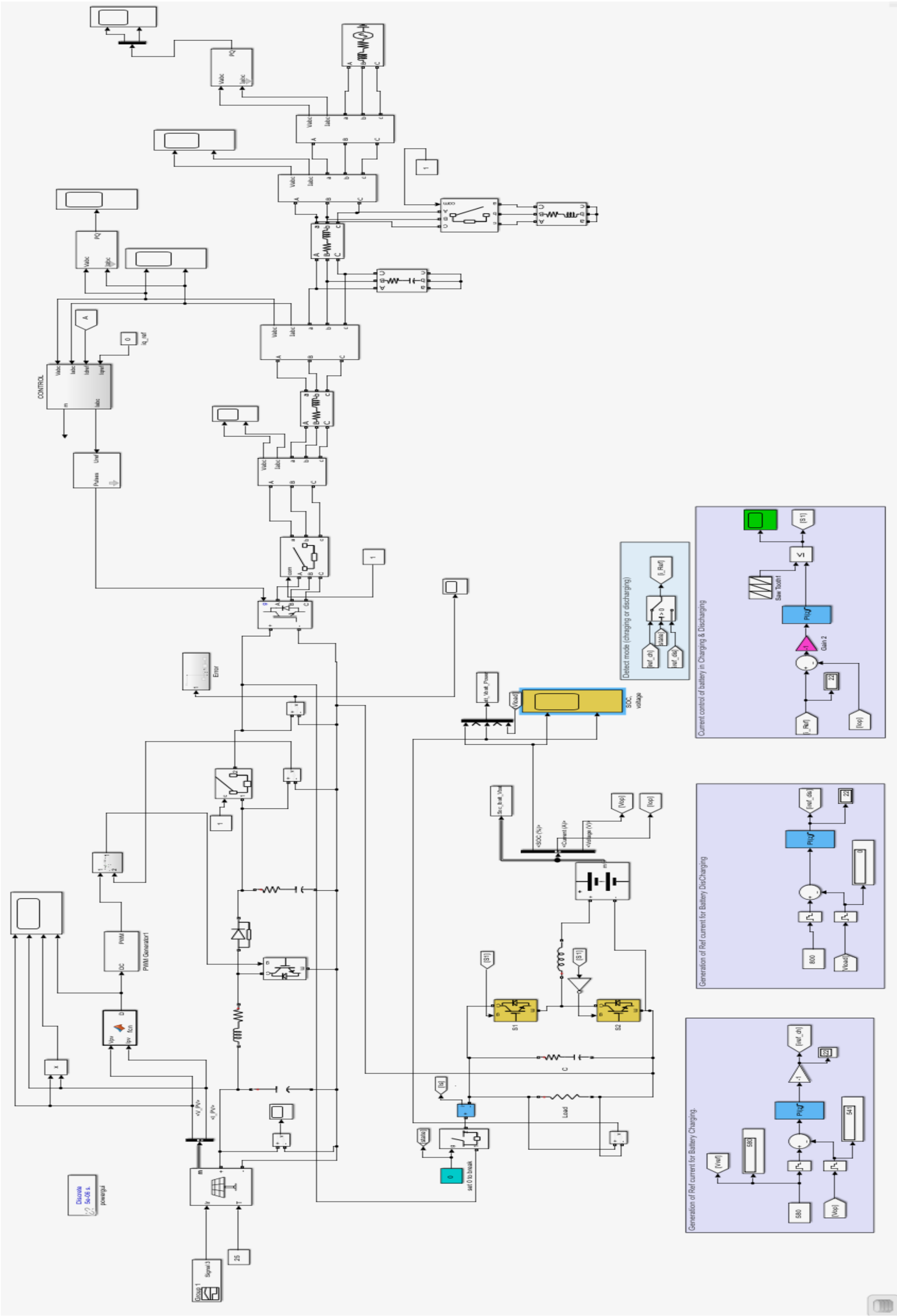

Fig.7. Simulation of overall block diagram

IV. Results and Discussions

Simulation of a 300kW solar array and the 500kWh battery unit to the utility grid, assisted by power electronic converters is shown in fig 7. Few case studies are performed on the simulation and results are shown from Fig (8) to Fig (22).

4.1.Case 1

PV is connected to the grid; Battery is disconnected and under no-load. Irradiance is varied from 300 to 1000 W/m^2.

Initially assuming that the solar irradiance is 300W/m^2, and is being varied linearly to 1000W/m^2. Later the irradiance is maintained constant for the simulation at 1000W/m^2. By the variation of irradiance, the power delivered by the PV is varied. As no load is connected to the system, the power supplied by the PV is fed to the grid. DC Bus Voltage is maintained at 800V with the help of closed loop control of the Boost Converter.

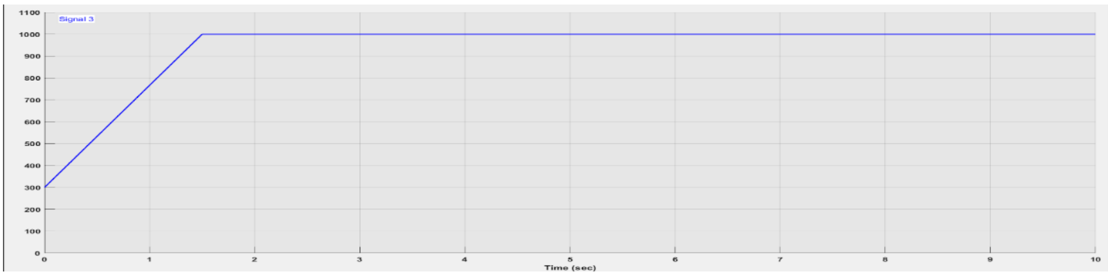

Fig. 8. Solar Irradiance

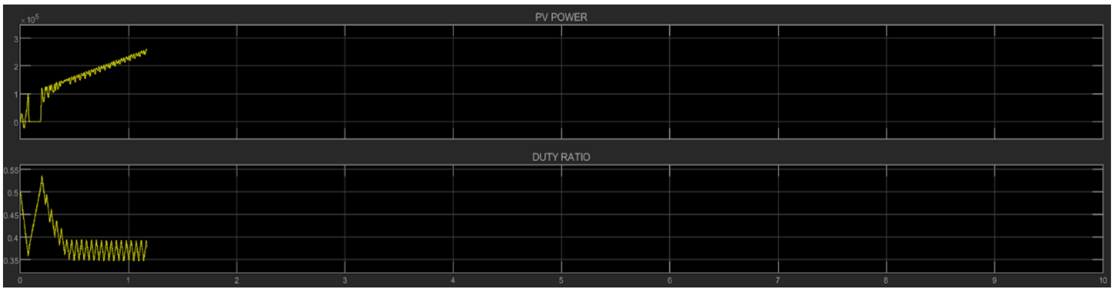

Fig. 9. PV Power and Duty Ratio of Case 1

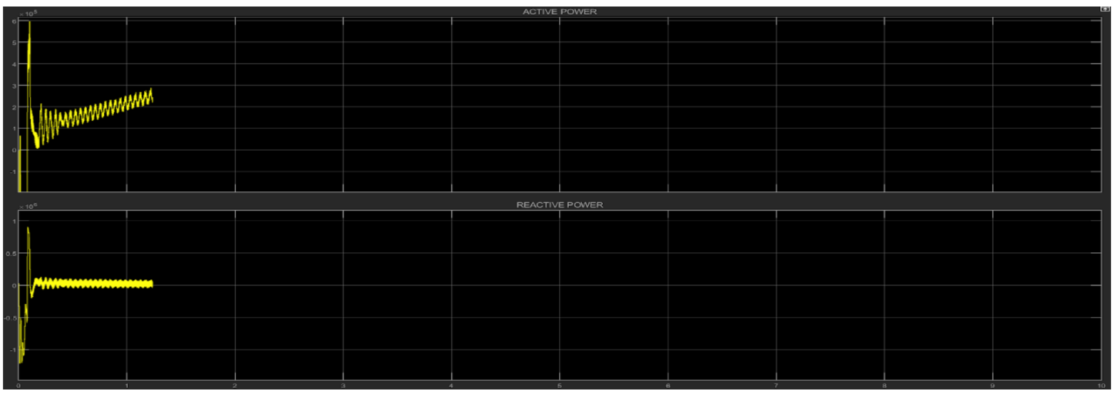

Fig.10.Grid Side Active and Reactive Power of Case 1

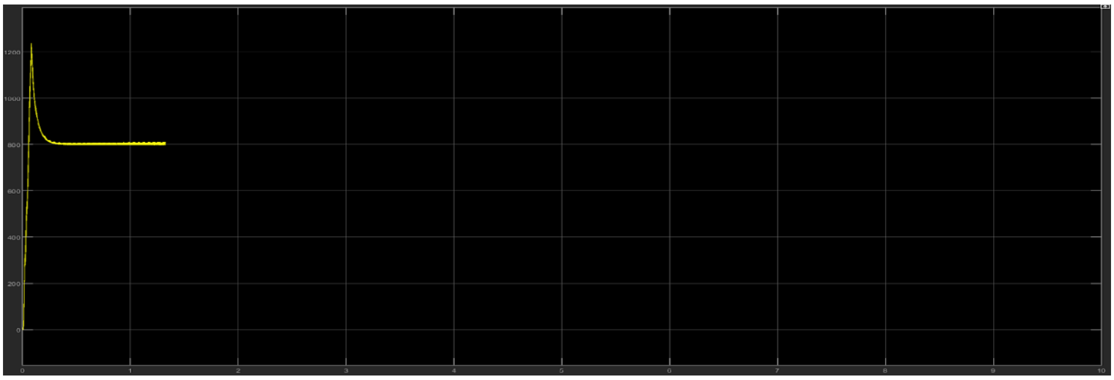

Fig. 11. DC Bus Voltage of Case 1

4.2. Case 2

PV is connected to the grid; Battery is disconnected and under no-load. Irradiance is maintained constant at 1000W/m^2

The irradiance is maintained constant at its maximum value of 1000W/m^2. Hence the PV will track the maximum power, using the Maximum Power Point Tracking algorithm, of 300kW. The total developed power by PV power is fed to the grid by maintaining a DC bus voltage of 800V.

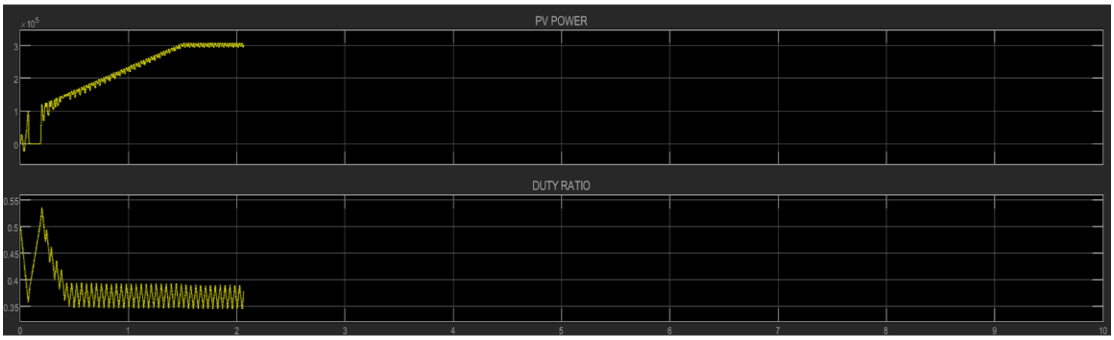

Fig. 12. PV Power and Duty Ratio of Case 2

Fig.13. Grid Side Active and Reactive Power of Case 2

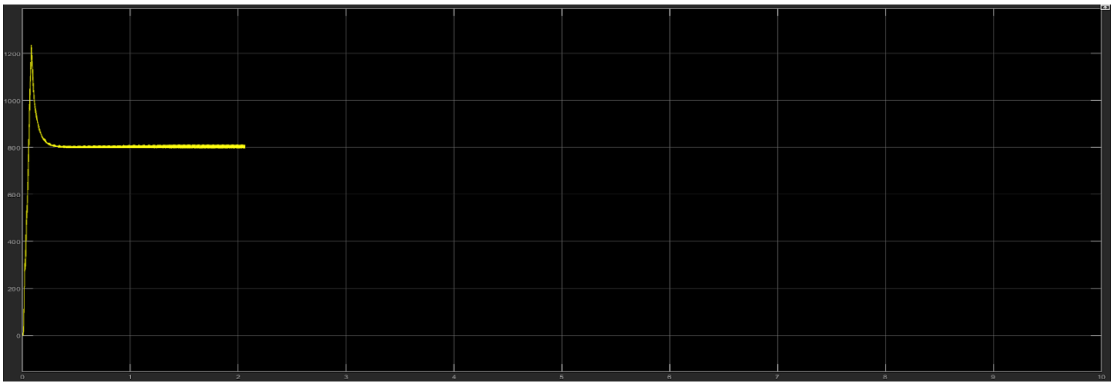

Fig.14. DC Bus Voltage of Case 2

4.3 – Case 3

PV is connected to the grid; Battery is disconnected, and load (200kW) is connected at the AC bus side.

As the load is connected in the system, the power developed by the PV is supplied to the load and the remaining power is fed back to the grid. Even in this case, the DC bus voltage is maintained as 800V.

Fig. 15. PV Power and Duty Ratio of Case 3

Fig. 16. Grid Side Active and Reactive Power of Case 3

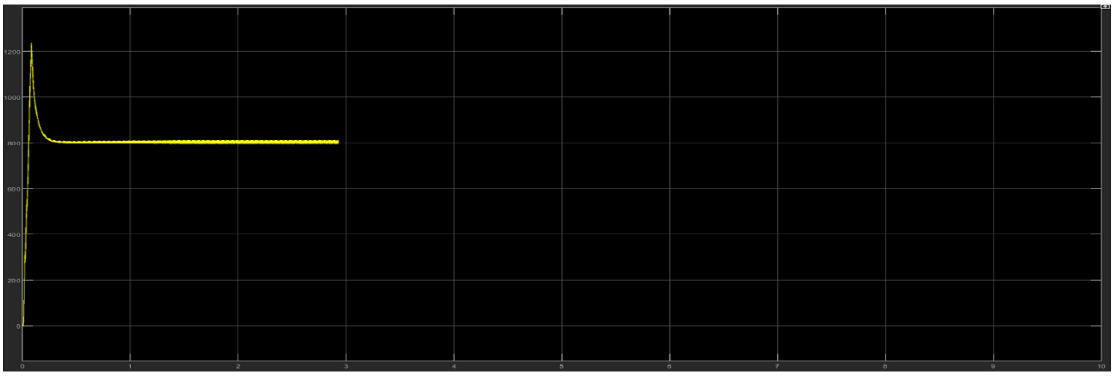

Fig. 17. DC Bus Voltage of Case 3

4.4 – Case 4

PV is connected to the grid; Battery is connected, and load (200kW) is connected at the AC bus side.

As the battery is connected in the system, the battery gets charged using the grid and PV power, maintaining the DC bus voltage at 800V and delivering the power to the connected load at the DC and AC busses.

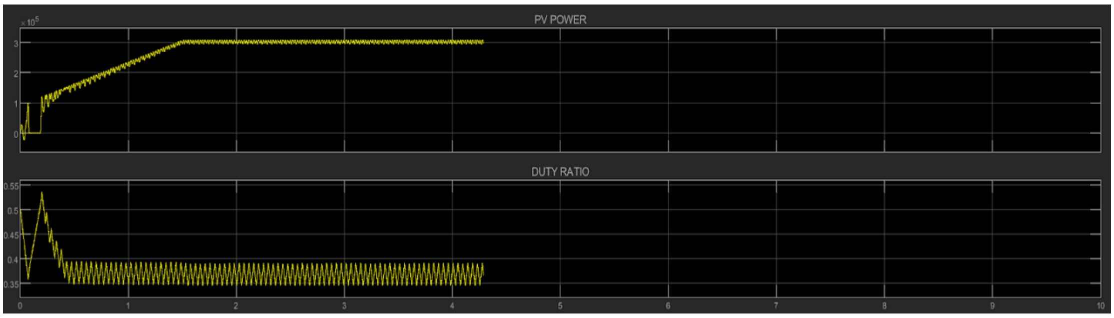

Fig. 18. PV Power and Duty Ratio of Case 4

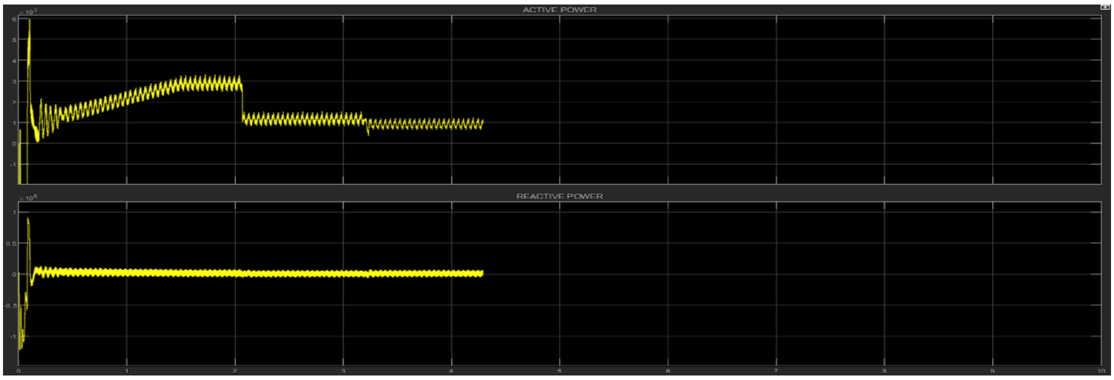

Fig. 19. Grid Side Active and Reactive Power of Case 4

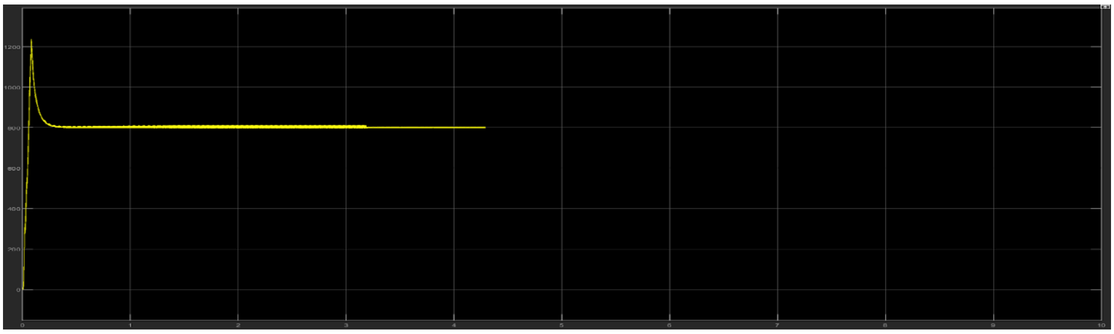

Fig.20. DC Bus Voltage of Case 4

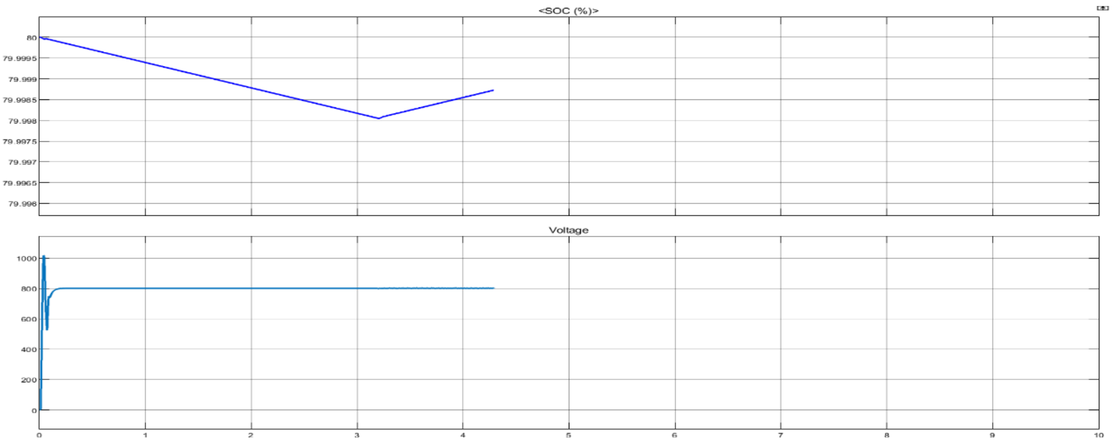

Fig. 21. State of Charge and Voltage of the Battery Unit of Case 4

4. 5 – Case 5

Grid and PV are disconnected, Battery is connected to the critical loads.

It is the case of grid failure and night time in the practical scenario. The large battery unit is connected to supply the critical loads in the system. The battery is getting discharged through the critical loads. The battery is so large that it can supply the load(11.9KW) for around 24 hours.

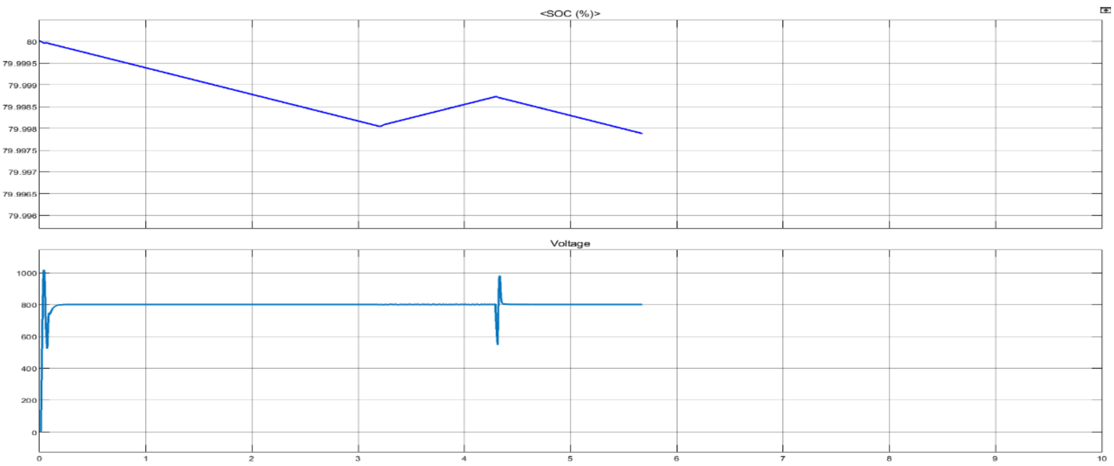

Fig. 22. State of Charge and Voltage of the Battery Unit of Case 5

IV.CONCLUSIONS

The design of hybrid AC/DC Microgrid has been carried out aiming for the continuous power supply to the loads connected to system even if one source is present in the system. The simulations results are evident that this work has achieved the desired output with negligible repercussions in the voltage levels and maintaining the stability of the microgrid.

The integration of the wind unit to this complex system is encouraged to be done for the upgradation of the proposed model.

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