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Energy Management Scheme in Photovoltaic Based DC Microgrid

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ABSTRACT

This paper explores the need for renewable based DC microgrid and proposes characteristic features of a standalone DC microgrid. The need for energy management system and its role in DC microgrid has been emphasized. Renewable generating sources such as wind turbine generator and photovoltaic panel require stringent control for harnessing maximum available energy, energy storage system demands efficient management, and DC-link voltage must be maintained constant. Microgrid is a small modular and distributed power generation and distribution system that combines power quality management and enduser energy utilization technology based on distributed power generation technology based on distributed resources or users' small-scale power plants. The solar-based DC Microgrid has been proposed from the following controller and two compensation systems, . It forms a system of three rings, and feeds each load. Load balancing and voltage regulation are the main aspects for designing the model. The voltage is kept constant at 48V in the voltage control loop. Advantages of DC microgrids include easy control, high system efficiency and low energy conversion. The centralized monitoring controller has been designed to control current sharing and voltage regulation together in a PV-based DC microgrid.

KEYWORDS: *PV Panel, Photovoltaic System, Pv Module, MPPT, PV Control Strategy*

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1. INTRODUCTION

Renewable based DC microgrid is at the upfront for achieving rural electrification, especially in developing nations such as India. DC microgrid is a self-sufficient and independent power system which includes one or more generating sources, energy storage system, energy management and loads. Such a system may or may not be connected to the grid. The need for renewable based DC microgrid arises to fulfill energy requirement of rural, isolated regions. Grid connected systems are mainly established in cities and have sparsely reached villages or isolated regions. The regions where grid connected supply is available pay for poor quality of supply, the supply is time-limited and this hampers the social and economic growth of that region. Existing energy sources such as coal and fossil fuels have significantly increased their use of renewable energy due to the substantial depletion of energy that provides most of the energy needed for development in the past and present. increase. They are depleted over time in such nature. Fossil fuels that are used continuously have a great impact on the environment, which depletes the biosphere and induces global warming. Renewable energy is a source of efficient electricity production when used wisely with the right technology. Renewable energies come from the sun, wind, tides, geothermal and wind. These are clean and pollution-free power sources unlike conventional power sources, which is what has fascinated the planet today, so huge capital investments are being made to harvest these resources[1].

2. MODELING OF SYSTEM AND CONTROL:

Solar PV based stand-alone systems used in islanding regions are generally designed as shown in Fig. 1 which requires some additional attention [31, 32]. The standard voltage level of such applications generally in the range of 220–250 V AC. As a result, the voltage level of the DC link of the DC–AC inverter that feeds these loads needs to be maintained around 360–400 V. One possibility to achieve such a high DC voltage is to use DC–DC boost converter to boost up the PV voltage. The voltage levels of the PV modules that are available commercially are generally in the range of 12–35 V. Therefore, to form a DC bus of around 360– 400 V several PV modules are to be connected in series to form PV string. However, with such an arrangement, the system exhibits multiple local maximum power points under nonuniform solar irradiation levels[2]. Use of maximum power point tracking (MPPT) using DC–DC converter varies the output DC voltage due to varying MPP voltage because of varying PV cell temperature and solar irradiance [6]. Variable DC link voltage across the PV inverter can affect the sensitive loads

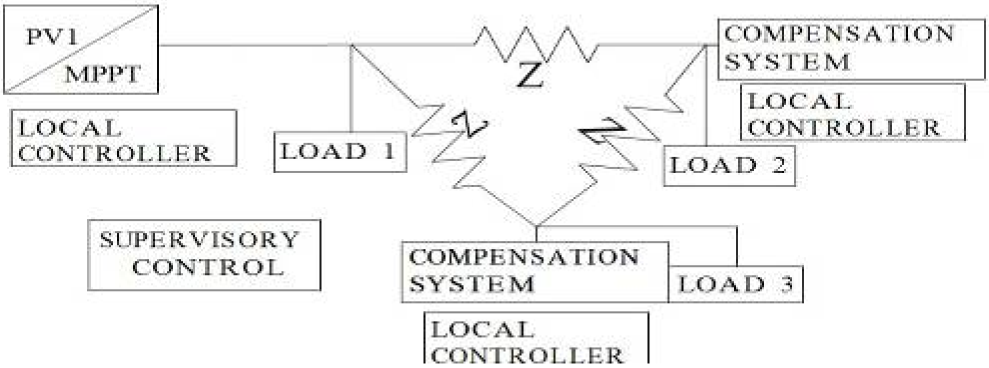

Figure 1: Block diagram of system

In this work a PV array working on MPPT along with its battery and control unit to the other two compensation systems with their controllers has been simulated. The nodes here are three busses connected in a ring system. At bus 1, PV and battery unit are connected with its control unit and at bus 2 and bus 3, compensation systems are connected with their controller. The load 1, load 2 and load 3 are variable load i.e. keeps varying with time. A supervisory control is present to manage the energy of the system. In this controller the voltages at node 2 and node 3 are kept into check. Whenever there is change in the voltages of these two nodes, Load is managed accordingly by the PV unit and compensation systems[3].

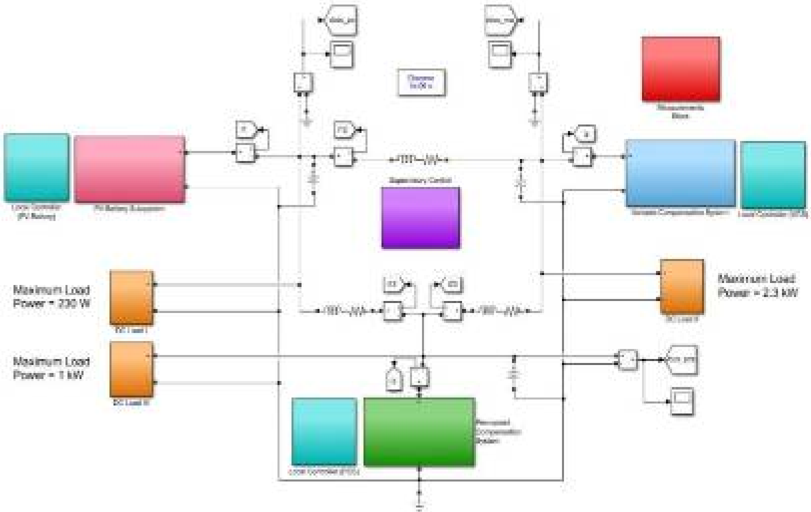

Fig.2 Simulink Model of system

3. PV ARRAY WITH MPPT:

The PV module is working on MPPT, through Incremental conductance method maximum power is being extracted from the Solar PV panel[4]. Variable duty cycle is provided to the switch of the DC/DC boost converter. So that the output impedance matches with the input impedance.

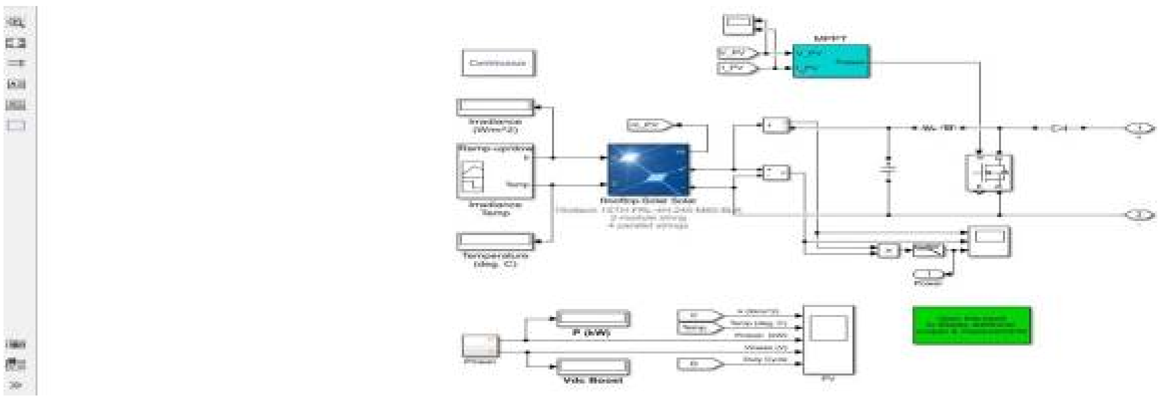

Fig.3 Simulink Model of PV Array with Booster Converter

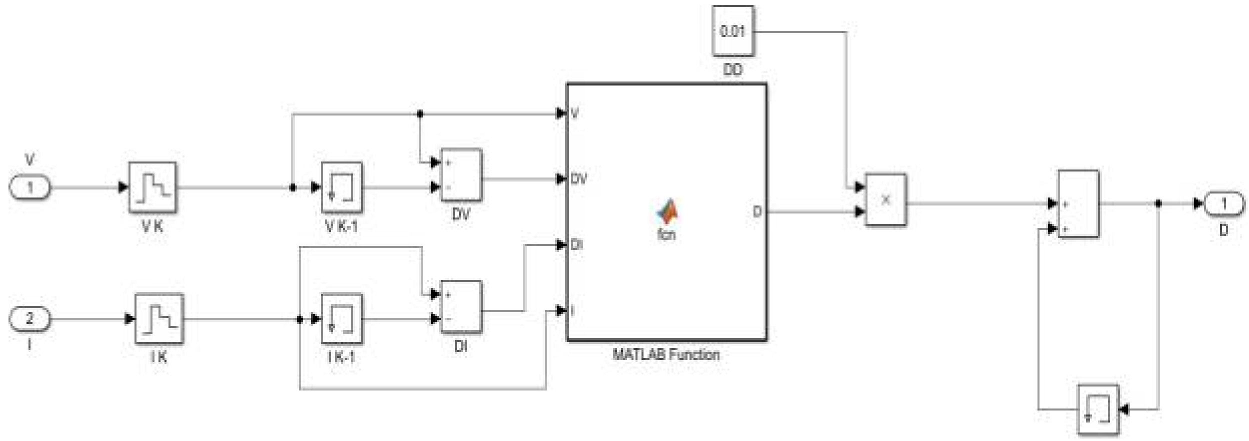

Fig.4 Simulink Model of MPPT

4. BIDIRECTIONAL BATTERY:

The battery is working in both the modes i.e. charging when there is ample supply from the PV array and discharging when the supply from PV array is less or weak. For working in both the modes power electronic switches are being used as DC/DC buck and boost converter[5].

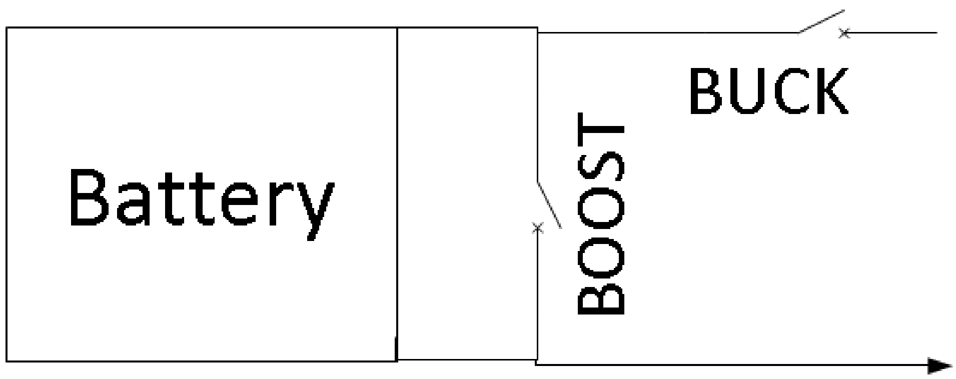

Fig 5 Block Diagram of Bidirectional Battery

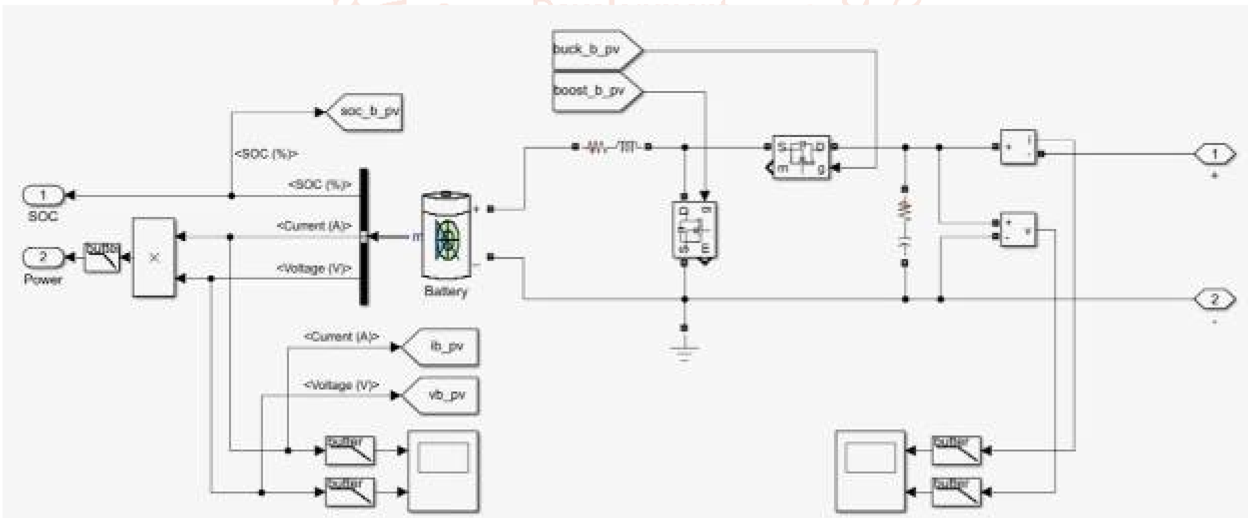

Fig.6 Simulink Model of Bidirectional Battery

The battery is able to work in both these different modes because of the voltage and current loop in the battery control. Basically, it decouples the dynamics and works appropriately to choose the working mode[6]. Voltage loop takes the actual and the reference value of the voltages then the absolute value is made to pass through PI controller to generate current reference and the pulse is provided accordingly to the appropriate dc/dc converter.

5. SUPERVISORY CONTROL:

A supervisory controller is used to manage the energy supplies to the loads and batteries at various instants. Depending on the node voltages it gives command to the various units to work.

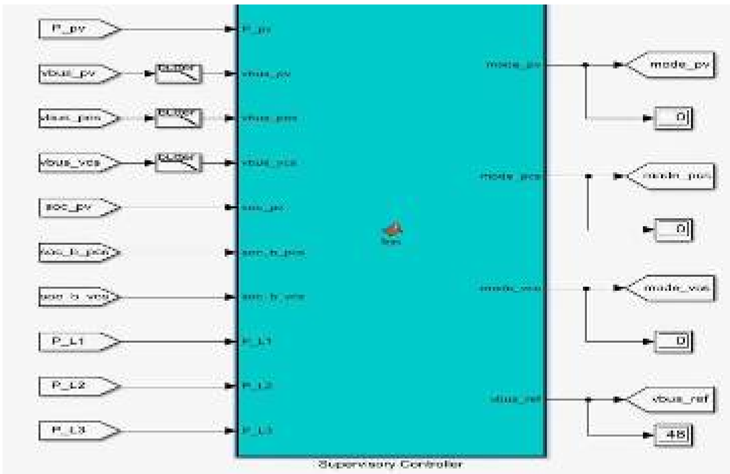

Fig. 7 Simulink Model of Supervisory Controller

6. Results:

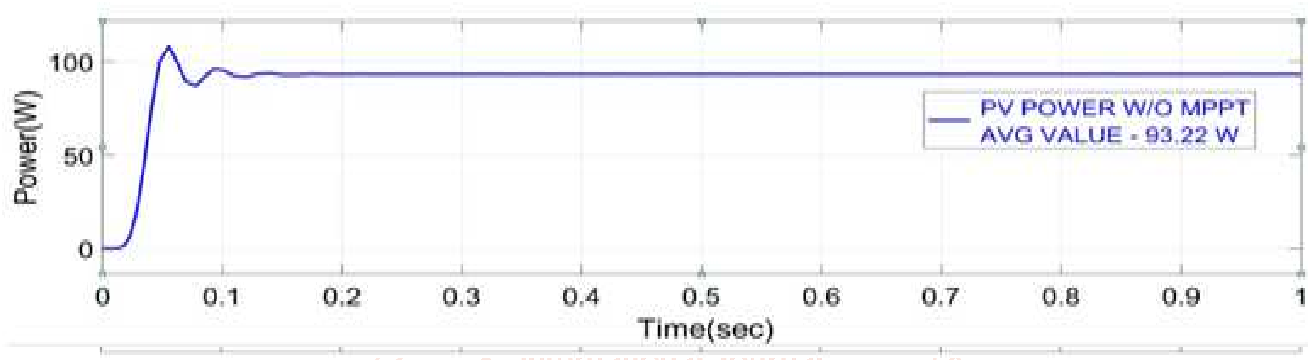

Fig.8 Comparison between PV Power with and without MPPT

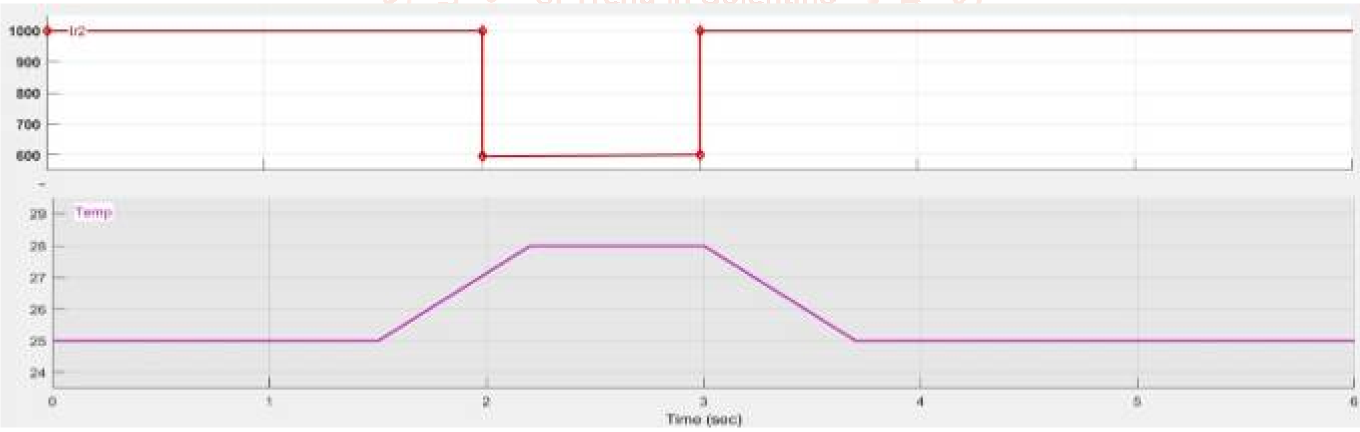

Fig.9 Irradiance and temperature input to the rooftop solar unit

TIME	VALUE	TYPE
0 – 02 sec	1000 W/m^2	CONSTANT
02 sec	1000 W/m^2 to 600 W/m^2	STEP DECREASE
02 – 03 sec	600 W/m^2	CONSTANT
03 sec	600 W/m^2 to 1000 W/m^2	STEP INCREASE

Table 1: Variable Irradiation

TIME	VALUE	TYPE
0 - 1.5 sec	25^{o}C	CONSTANT
1.5 - 2.2 sec	25^{o}C - 28^{o}C	LINEARLY INCREASING
2.2 - 3 sec	28^{o}C	CONSTANT
3 - 3.7 sec	28^{o}C - 25^{o}C	LINEARLY DECREASING

Table 2: Variable Temperature

Simulink graphical results of the PV panel current voltage and power is shown in the following figures

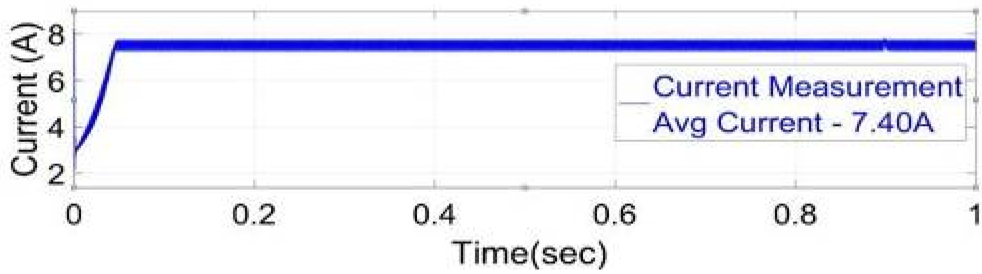

Fig.10 Current and Power measurement of PV Panel

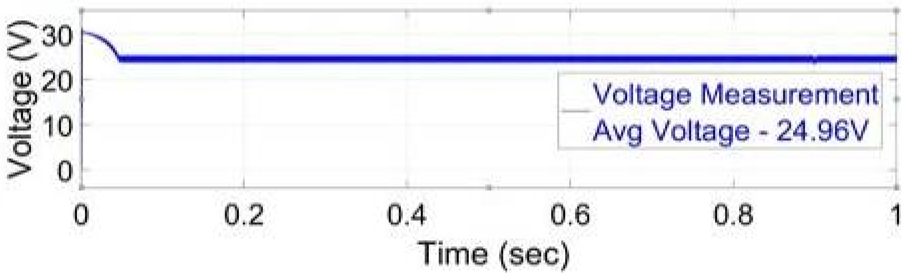

Fig. 11 Voltage measurement of PV Panel

From the tables1,2 it is clear that current increases linearly with the increase in irradiation and decreases with the decrease in irradiation. The voltage on the other side increases logarithmically with the increase in irradiation. With the increase in temperature, Current increases while the voltage decreases.

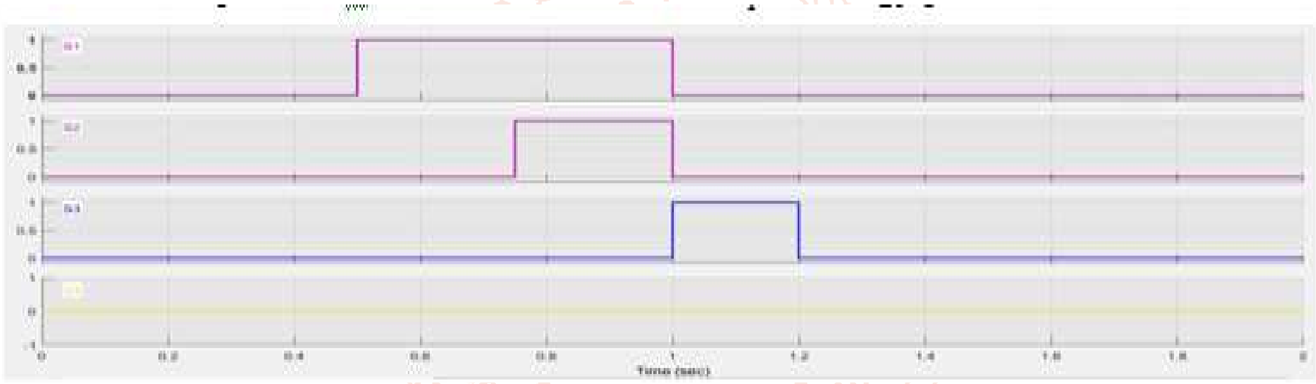

Fig-12 Variable load at bus-1

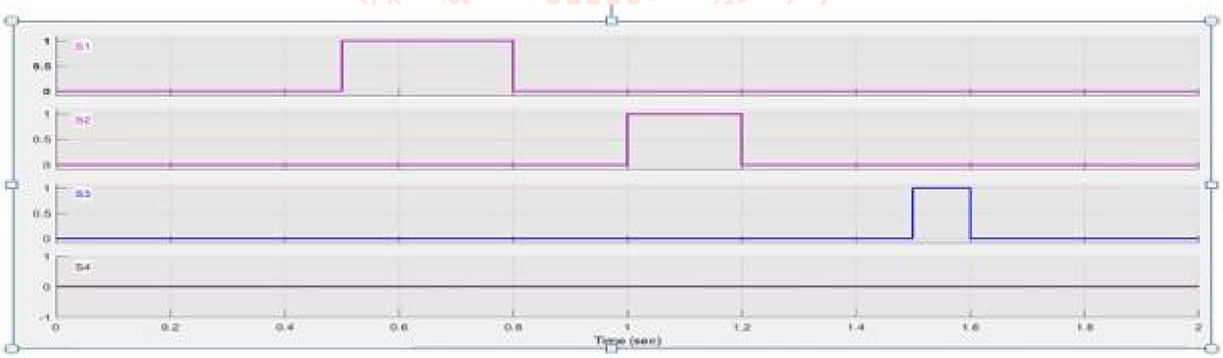

Fig.13 Variable load at node/bus 2

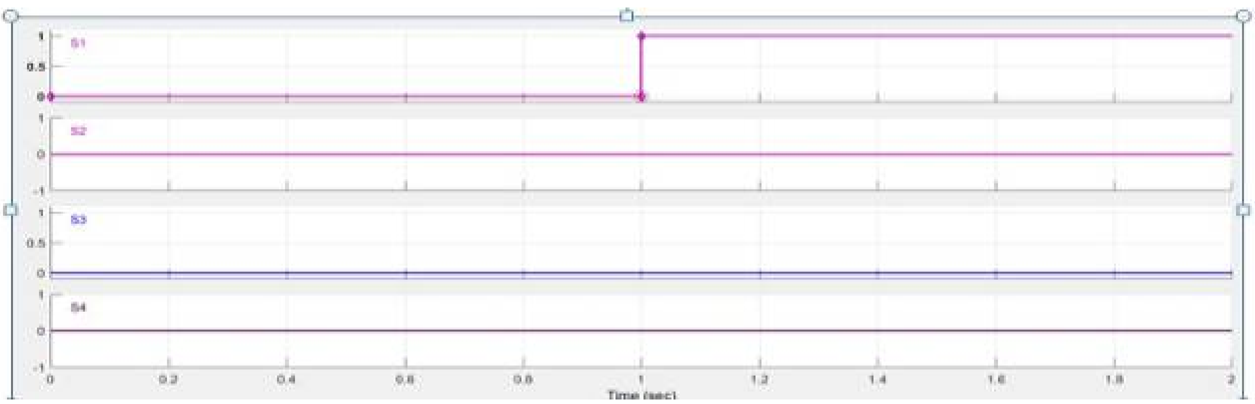

Fig.14 Variable load at node/bus 3

As the load increases PV battery system supplies load 1 and battery 1 and battery 2 supplies load 2 and 3 respectively.

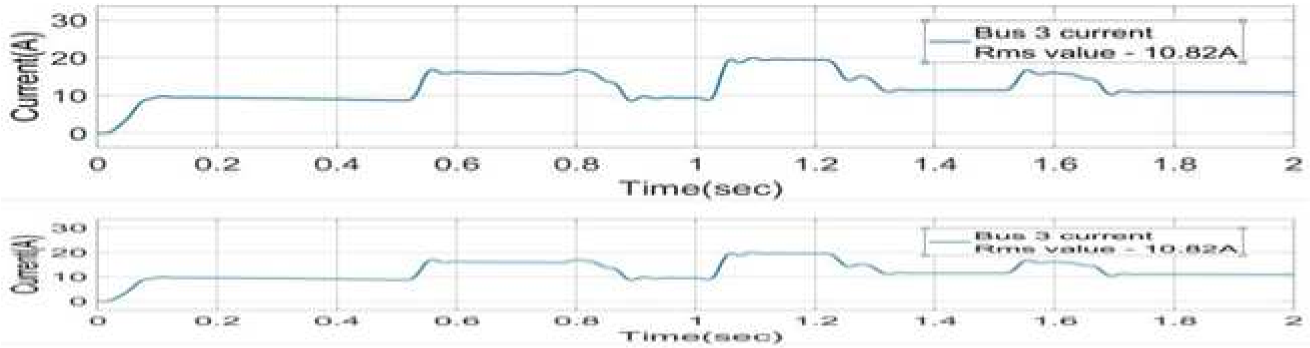

Fig-15 Load current at bus -1 and 2

Controlling is done to maintain the voltages at all buses at 48 V throughout. So that whenever there is a variation in the bus voltage, supervisory controller controls to manage the energy of the system to provide to load and batteries.

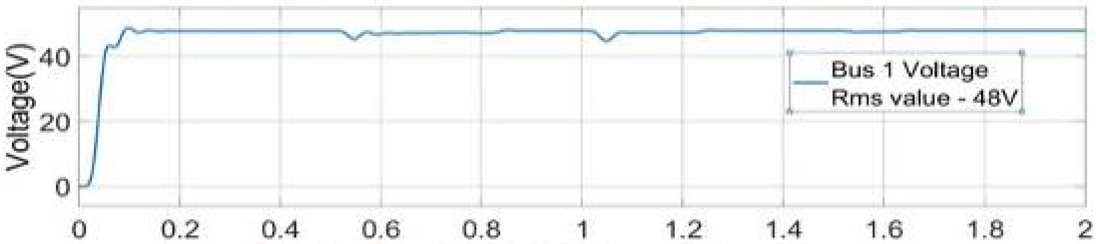

Fig.16 waveform of bus1 voltage

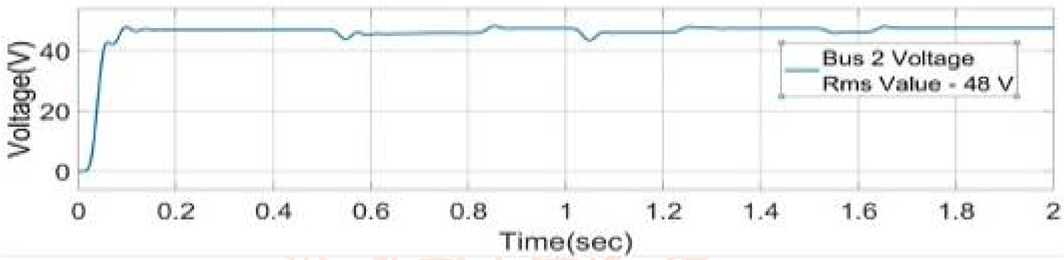

Fig.17 waveform of bus2 voltage

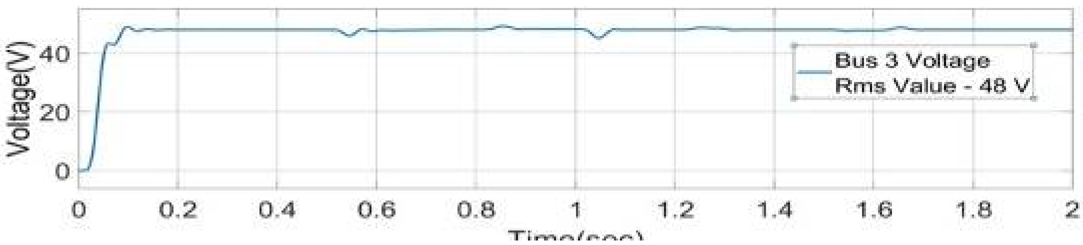

Fig.18 waveform of bus 3 voltage

7. Conclusion:

In this work a model in MATLAB with one PV system operating at MPPT for variable irradiation and temperature and two compensation systems has been simulated, who charge and discharge according to the load requirements, all three in a ring formation. Constant voltage has been maintained using the voltage control loop and the supervisory control maintains the load voltage and current according to the requirement of load. Low voltage DC Microgrid is feasible for remote places where electricity is not able to reach safely through grid. In the near future aim will be to design this model for more than one PV Units and to cooperate loads like electric vehicles. There will be a charging station developed and connected to the variable compensation node i.e. node 2. Whenever an electric vehicle will approach the station to get itself charged, variable compensation system will discharge to supply the power to the electrical vehicle. if it is not sufficient to provide power to charge the vehicle, the controller will give command to the PV units and permanent compensation system to fulfill the demands at node

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