Power Management Control Strategy for Renewable Energy based DC Microgrid with Load Shedding Algorithm

Synopsis

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I. INTRODUCTION

The increasing need for energy generated with clean technologies has triggered researchers to develop distributed power generation systems using renewable energy sources. On the other hand, the integration of a large number of distributed generations into distribution networks is restricted due to the limitation of the network capacity and unidirectional power flow behavior. Such barriers have motivated the search for an alternative conceptual solution to enhance the distributed generation integration into the distribution networks.

“Micro-grid” approach was proposed as a means of integrating more distributed generations into the distribution networks. Distributed Generation in micro-grid operation provides multi-benefits to the utility operators, DG owners, and consumers in terms of reliable power supply, reduction in transmission system expansion, and enhancement of renewable power penetration.

The current work presents the simulation of a microgrid model that includes renewable energy source Photovoltaic and Fuelcell also two operational modes of operation (island and Grid connected) are investigated.

II. LITERATURE SURVEY

Manoj Kumar Senapati et al. (2018) developed an effective real power management scheme among the variable generation (wind,solar) and energy storage devices such as the battery,FC for mitigating the DC-link voltage fluctuations during system contingencies. For a reliable operation of the DC MG under standalone or prolonged islanding mode of operation a priority based load shedding algorithm is proposed for maintaining proper power coordination between different energy sources and storage devices.

N.Eghtedarpour et al. (2012) proposed the operation and control strategies for the integration of PV and BESS in a DC micro-grid. It enables the maximum renewable energy utilization during different operating modes of the micro-grid i.e., grid connected, islanded or transition between these two modes, whilst making an allowance for the DC voltage control and DC-loads supply. When the system is grid connected and during normal operation, active power is balanced by the AC grid converter to ensure a constant DC voltage. To achieve the system operation under islanding conditions, a coordinated strategy for the BESS, PV and load management including load shedding and considering battery state of charge (SoC), are proposed.

N C Sahoo et al. (2015) developed two control algorithms for maintaining constant DC bus voltage under wide variations in generation and loading conditions in a DC micro-grid.One is the traditional voltage based control and the other is a modified voltage plus SoC (state-of-charge)-based control. The DC micro-grid consists of a photovoltaic (PV) system, a wind energy system based on permanent magnet synchronous generator (PMSG), a fuel cell system, an energy storage system (battery), and electrolyzer as a dump load, and DC loads. It has been observed that the voltage plus state of charge (SOC) based control method gives better performance than the traditional voltage based control method in terms of effective maintenance of constant DC bus voltage as well as power balance of the power management system.

III. PROBLEM IDENTIFICATION

i. De-centralized AC Microgrid produces conversion losses namely conduction and switching losses when subjected to AC-DC-AC conversion operations. DC loads but are supplied using AC to DC converters when connected to AC source. So, enormous power is wasted during the conversion process.

ii. Solar generates DC power whereas it is inverted using converters in the conventional system.

iii. The wind is drastically intermittent by nature hence; it faces a lot of issues when connected to the AC grid. If a wind turbine is disconnected from the grid it takes minimum of 20 mins to resynchronize with the AC power grid. Wind power output cannot be connected to the grid directly instead of AC-DC-AC employed.

iv. Generally battery backup is used for lighting & fan loads. Battery source, lights & fan loads are DC operated, whereas in conventional technique battery backup is made utilized by inversion. The battery is charged using rectifiers. The inverted AC power is supplied to DC load by rectifiers.

v. As the Microgrid system involves different intermitted energy sources and loads 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, amanagement of power flow algorithm is developed. As different energy sources like solar, wind, fuel cell, can be integrated into the DC bus, control strategy for Management of power flow among these sources is essential. As the regulation of voltage profile is important in a standalone system, a dedicated converter is to be employed for maintaining the DC link voltage. DC link voltage is regulated by the SoC based battery circuit. A priority based load shedding algorithm is developed and it is tested for various load conditions and fluctuations in solar and wind power in MATLAB/SIMULINK environment.

IV. OBJECTIVES

i. To integrate the generation of different DGs directly with the DC grid instead of AC. (Which results in an easier way of synchronizing the micro grid with the utility.)

ii. To limit the conversion process (AC- DC-AC) only when renewable power is in abundance and during scarce. (hence, multiple power conversion and the respective losses are minimized).

iii. To establish a priority based load shedding algorithm inorder to maintain a reliable operation in DC MG under Grid connected and islanded mode of operations.

DC MICROGRID

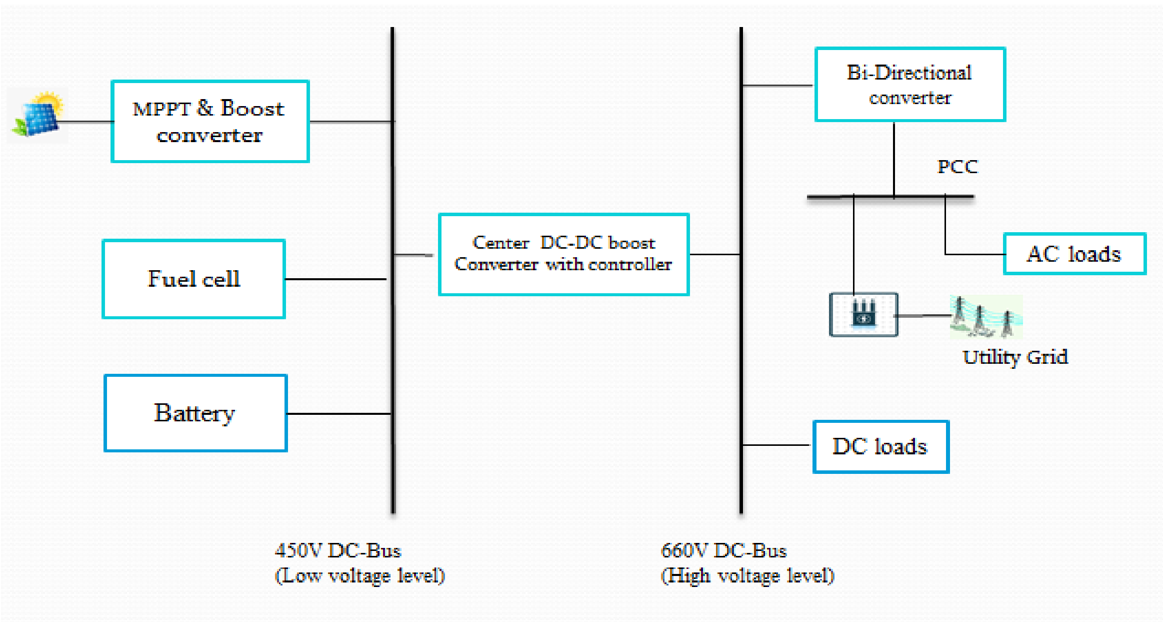


Figure.1 Proposed DC Microgrid

V. Modeling of Microgrid Components

As mentioned above the components of the identified system are modeled using MATLAB/SIMULINK software tool.

1.1 Solar module specification

Irradiance	500-1100 Watts/m^2
Temperature	25˚C
Open circuit voltage	33 V
Short circuit current	8.21 A
Voltage at maximum power point	26.3 V
Current at maximum power point	7.61 A.
Cells per module	54
Series connected module per string	4
Parallel strings	13

1.2 Solar module

The PV system is interfaced with the DC MG through a DC–DC converter as shown in Fig.2.The hill climbing algorithm is employed in this work, for maximum power point tracking (MPPT).

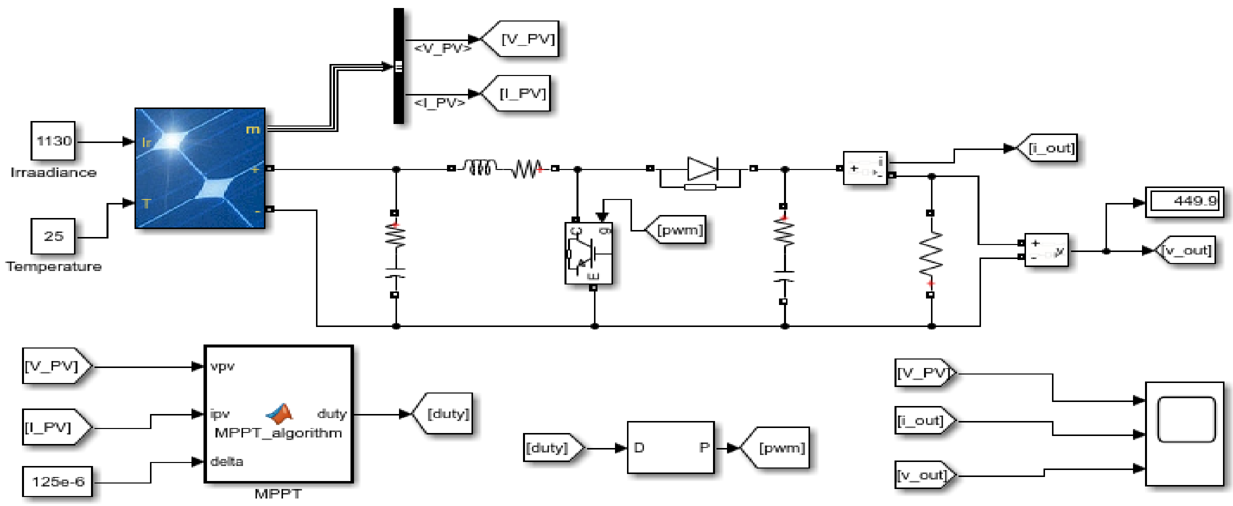


Figure.2 Solar PV model

1.3 OUTPUT VOLTAGE OF SOLAR ARRAY

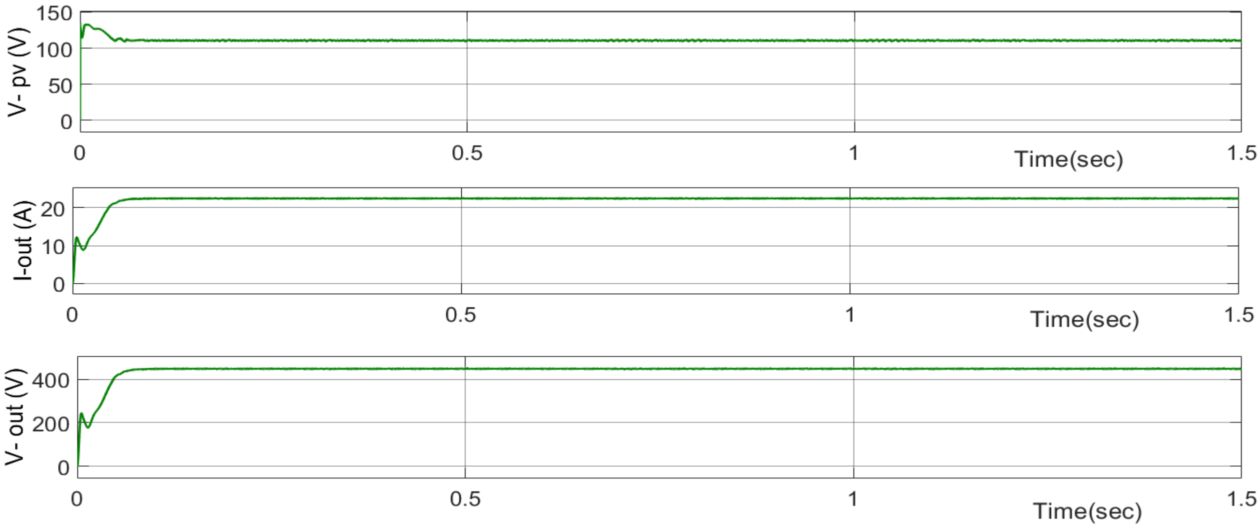


Figure 3.Output voltage of Solar module

2. Fuel cell Module

In this proposed model, a solid oxide fuel cell (SOFC) model is used The SOFC is interfaced with the DC MG through a boost converter as shown in Fig.4 During the normal operating condition, Fuelcell (FC) operates in standby mode. At the inception of any abnormal condition, it supplies power to the DC MG.

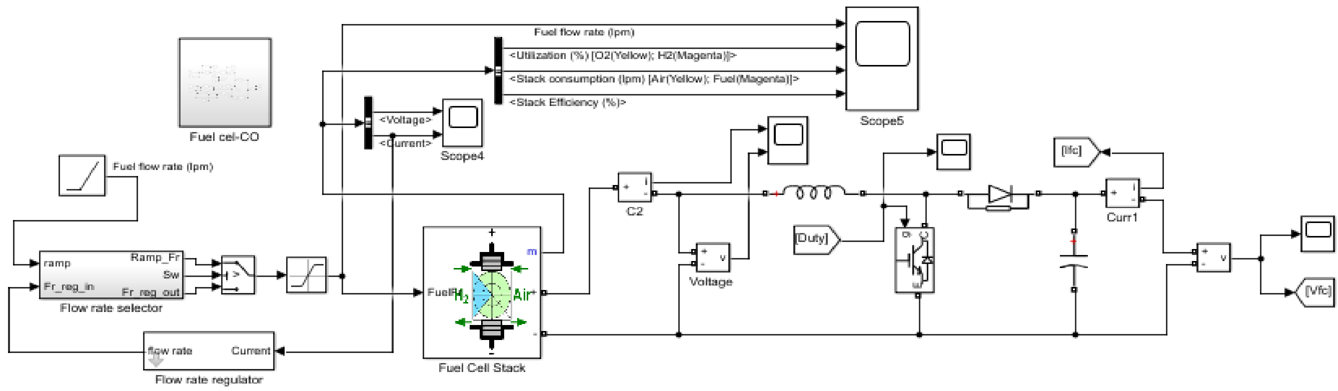


Figure.4 Fuel cell simulink model

2.1 Control block diagram for the coordinated operation of FC

I_g is the generated current of PV, I_L is the DC load current, and I_{fc} is the Fuelcell (FC) current in the DC MG. Whenever there is an increase in load, the extra load power is provided by the FC excluding the power supplied by the generation and the battery. The extra demanded power of the load is fulfilled by the FC when the SoC of the battery is <20% and the voltage level is <450 V. The modified FC coordination control to interface the power converter with DC MG is shown in figure.6. It is based on combined voltage and battery

SoC, Current control scheme of Microgrid operation. The Fuzzy Interface System is developed which uses Mamdani Fuzzy logic controller. It provides relevant duty signals depends on the corresponding error mapping.

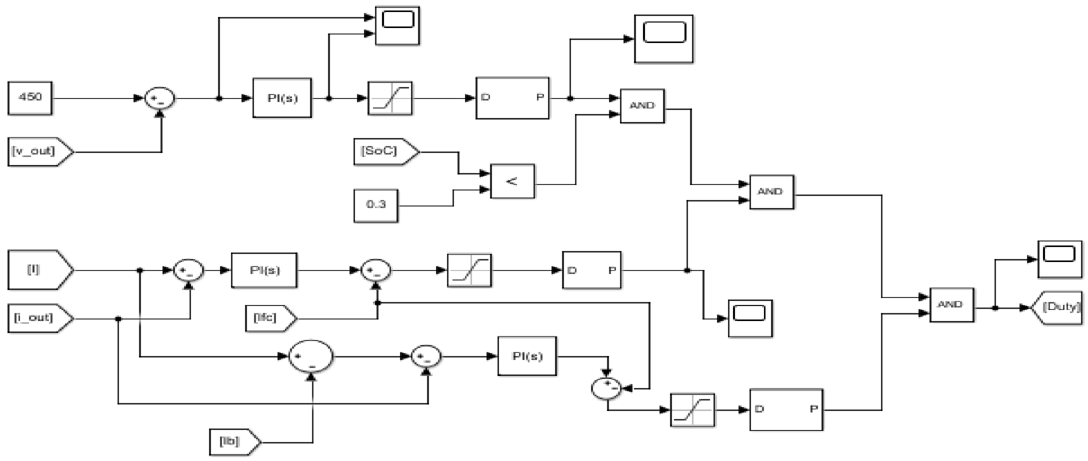


Figure.5 Proposed Fuel cell Co-ordination control block

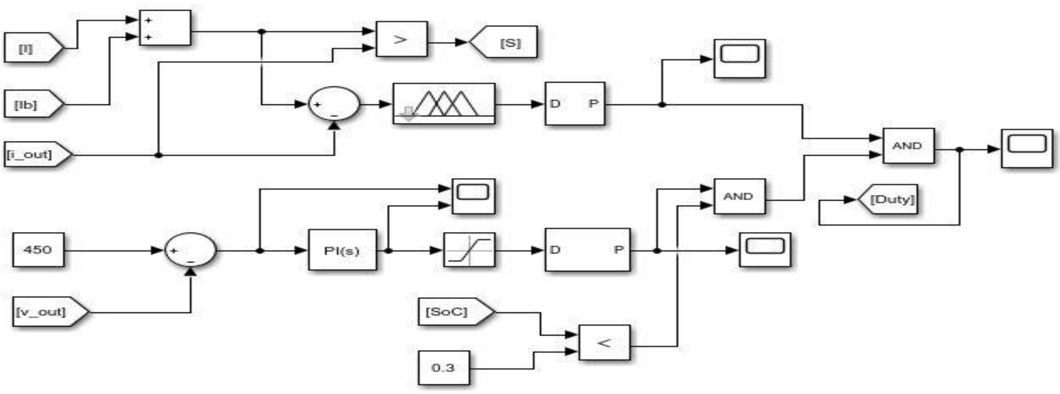


Figure.6 Modified Co-ordinated control block

(3). Battery Energy storage System

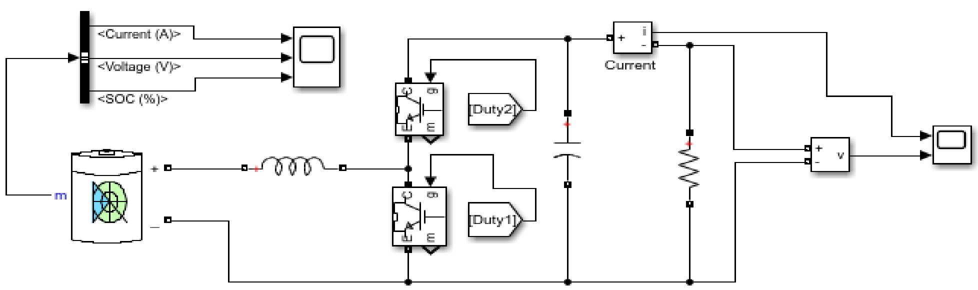


Figure.7 Battery Charging/Discharging

3.1 Control block diagram for co-ordinated operation of the BES system

The BES operates either in standby or in charging/discharging mode in normal operating condition of the DC MG. In SoC-based control method, battery charges or discharges within a specified limit whenever there is a surplus or deficit of solar energy due to high or low solar irradiance/temperature. The excess energy produced by the solar is first received by the battery until it reaches its maximum limit of charge carrying capacity and then any further available excess power is fed to the DC common link. The control diagram of the BESS is shown in Fig.8

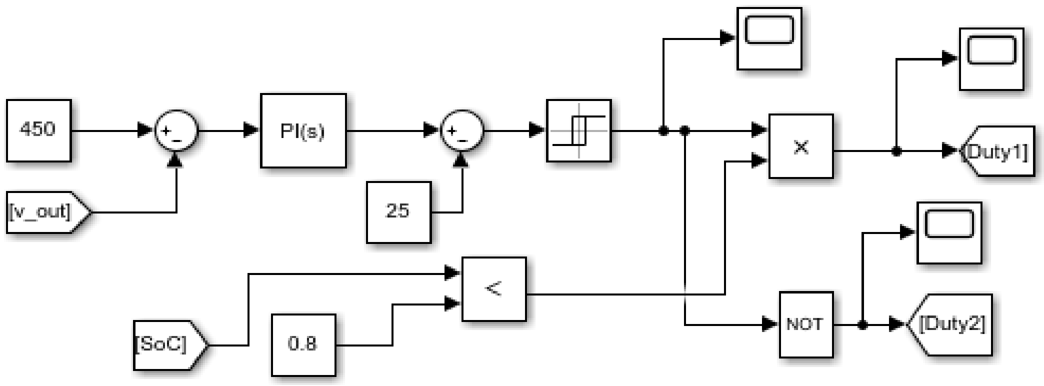


Figure.8 Control block of BESS

3.2 Switch positions of BESS in standby and grid connected modes

The Charging and discharging mode of BESS shown in figure.7 is decided by the following conditions.

V_{dc}	SoC	Duty 1	Duty 2
<450 (True)	< 0.8 (True)	1	0
True	False	0	1
False	True	1	0
False	False	0	1

VI. Control strategy employed for load management during standalone/prolonged islanding condition

To prevent the collapse of the DC link Voltage of DC MG, priority-based load shedding is done. The flowchart of the proposed load management scheme is provided here.

Priority based Load Shedding Algorithm:

```
function [x,y] = fcn(Pg,Pl,Pfc,Pb,SoC,Vdc)
Pd=Pg-Pl;
Vref=660;
w=0.97*Vref;
z=Pg+Pfc+Pb;
if  (Pd>0 || Pd==0)
     x=1;
      y=1;
    if (SoC>0.8 || z>Pl)
       x=1;
       y=1;
    else
       y=1;
       x=0;
    end
  else
  If (SoC>0.8)
         x=1;
         y=1;
      else if (Vdc<w)
              y=1;
              x=0;
           else
              x=1;
              y=1;
           end
     end
  end
  end
```

VII. SPWM based Bi-directional rectifier

In practice, the grid-side Voltage Source Converter(VSC) operates for maintaining the DC-link voltage and grid-side inverter voltage within their acceptable limits both ranges during the grid-connected and islanding mode of operation. In this work, the sinusoidal pulse width modulation (SPWM) technique is employed for controlling the VSC. The varying magnitude and phase angle of sinusoidal modulating signals are controlled by generating the modulation index (m).

7.1 SPWM based Bi-directional rectifier

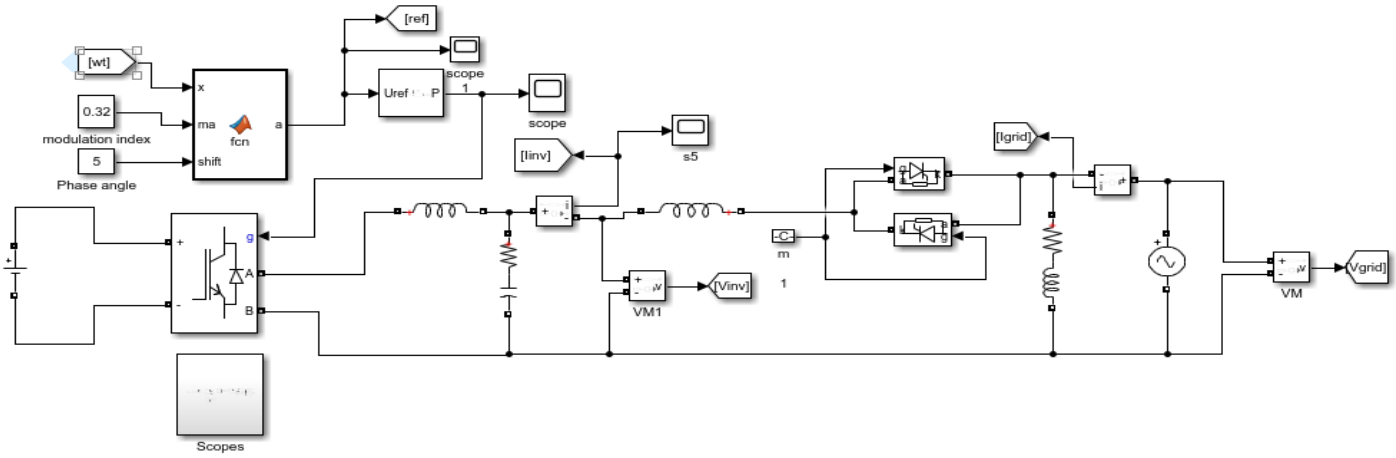
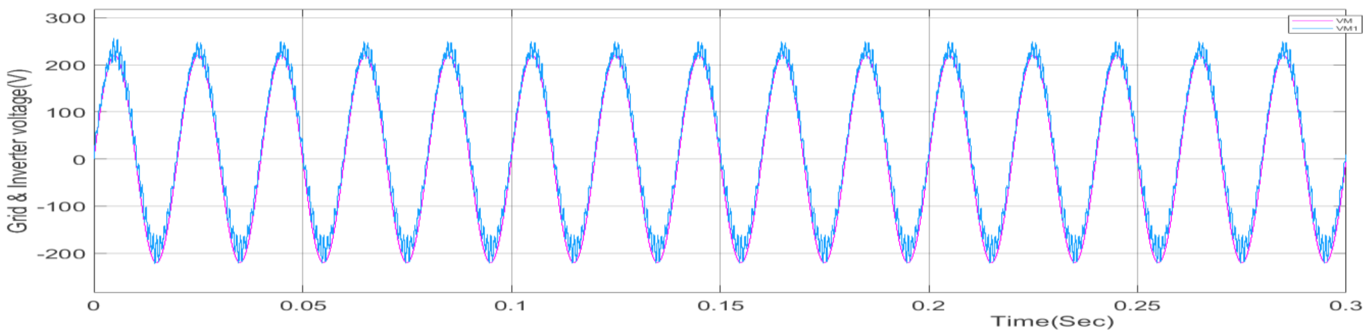


Figure 8. Grid interactive inverter

7.2) Synchronized Grid and Inverter voltages



VIII. Results and Discussions

The performance of the proposed DC Microgrid is evaluated for the different power system contingencies such as the change in irradiance and temperature of the PV cell, grid-connected, islanding and line fault scenario,etc. The objective of the present work is to maintain proper power management, DC-link voltage, and inverter-side line voltage of DC MG during the grid-connected mode of operation by using the coordinated control scheme During Grid connected mode, the total generation by the PV energy system is less than the demand. As a result, the fuel cell starts maintaining the DC link voltage and the battery is discharged/Charged by giving the excess energy to maintain the power balance in DC MG and at the same time, the utility grid is supplying the required power to the local load. At this operating condition, the DC-link voltage of the DC microgrid and the inverter-side root mean square (RMS) line voltage is maintained within their acceptable limits.

Conclusion

In this proposed work, an improved power management control strategy with a priority based load shedding algorithm is proposed for improving both the dynamic and steady-state performance of the DC-link voltage in the DC MG. The combination of both voltage and SoC-based control strategy of the battery, FC, Coordination between each source and load. The Fuzzy logic controller gains of the FC system are tuned adaptively by using the Mamdani-fuzzy control to get a better dynamic voltage response of the DC MG. The proposed priority-based load shedding algorithm maintains a proper power balance among different energy sources and storage devices during standalone or prolonged islanding mode of operation.

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