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Dump Power Control Technique In Microgrid For Islanded Mode

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Abstract: This paper proposes a hybrid power generation system by applying dump load control technique. Four power generation sources are taken into consideration wind, solar, battery storage and diesel generator which is load connected. Considerable efforts were put on the condition when there is surplus generation takes place in dump load. By generating feedback loop with battery storage system, battery overcharging has been prevented. Special attention was also given to design of PLL controller and voltage source inverter to control phase synchronization and to control power. Results were calculated and analyses in MATLAB/SIMULINK. It is anticipated that this hybrid power generation system will contribute to global environment protection in rural location without any dependency on commercial power generation system.

Keywords: *Hybrid power generation system, storage battery, dump load, and dump load power control.*

I. INTRODUCTION

In 24th century power generated from commercial means is not sufficient to meet growing needs of man. In order to satisfy the needs the demand for reliable power generation has been increased. This leads to the development in the distributed power generation system. The microgrid concept has being found boom to the society. It is a combination of various distributed sources with main grid. Microgrids are alone sufficient to supply power to the local load even if it is disconnected from main grid [1].

Microgrids are integrated with main grid at point of common coupling (PCC). A microgrid can be synchronize with utility only when there frequency, phase angle and voltages are within specific limits [2]. Std IEEE 1547-2003 helps to integrate the grid connection to distributed power generation system [3].

In microgrid, various renewable energy sources required power electronics interfacing for grid connection. Hence focus was given to study of different modes of operation and control in microgrid [4]. A various controlled strategies have been studied for both grids connected and islanded mode [5].Main focus was given to the prevention of battery over charging state when surplus of generation took place in dump load for island mode. As for grid connected mode hybrid power generation system consisting of wind solar and battery, in this case dumb power can be easily controlled by transferring dump power to utility grid [6].

The hybrid power generation system has been develop. Individual wind power and solar power generation system each, integrated with boost converter and inverter at load side. Diesel generator is also connected to power line which together given to a load side at same time; A dumb load is also mounted on same power line [7-8]. Surplus of power generation condition at dump load was been focused. In this case, battery over charging state occurs hence prevention of it has been necessary. Several different methods to prevent battery over charging are being used. One of the methods for battery over charging prevention is making use of hydrogen generator for a fuel battery instead of storage battery when hydrogen tank is totally filled; dump load is activated [9]. In this paper to overcome this problem the technique of dump load power control is build which is used to eliminate the dump load and use to increases the battery life .The rest of this paper is organized as follows: The microgrid structure is

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presented in section II. Operation of microgrid in section III. Section IV describes the modeling of sources of microgrid. Section V gives the result in MATLAB/SIMULINK. Finally conclusions are drawn in section VI.

II. PROPOSED ARCHITECTURE OF MICROGRID

The PV array, wind, battery and diesel generator are the given inputs to proposed architecture. These sources are connected to Boost Converter .The DC output voltage from solar and wind of boost converter is given to VSI (Voltage source Inverter) ,to achieve desired magnitude of AC voltage, the AC voltage output from VSI's is then step up to required voltage using transformer and fed to load and grid side.

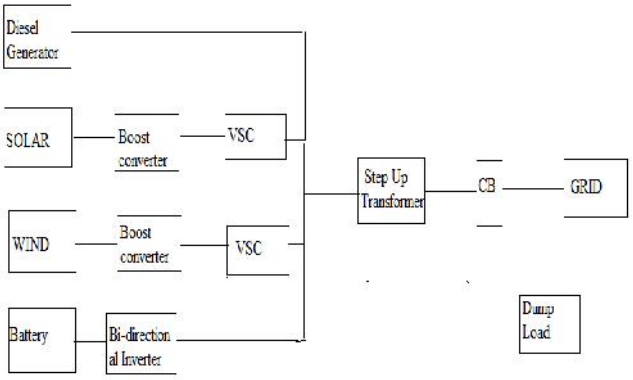

Figure 1: Proposed system of Microgrid

Battery is mounted along with bidirectional inverter (Inverter controller) which used to boost the DC voltage to AC voltage and it is also used to prevent battery overcharging state. The inverter is provided with PLL and PWM control mechanism use to generate active power to the utility grid with minimum reactive power.

As shown in figure all the four sources are connected in parallel with each other and interconnected to load. The system operation flow is shown. Wind and solar act together at that condition battery is in charging state. If surplus of generation happens at load side dump load get activated and feedback the access power to battery by bidirectional invertor. This bidirectional inverter then controls the battery charging and discharging state accordingly the invertor converts DC voltages to regulated AC voltage with suitable amplitude and frequency. The output of voltage and frequency can be easily controllable because grid does not exist in this mode the pulse with modulation (PWM) technique is used to generate the switching pulse. PLL technique is given importance in development of dump load control technique.

III. Dump Power Control Technique

Dump load which function as the storage system for excess power generation is connected at AC load side. In dump power control technique we develop current and voltage of storage battery is to be stable. For this use method in which dump load is removed by proving feedback in system

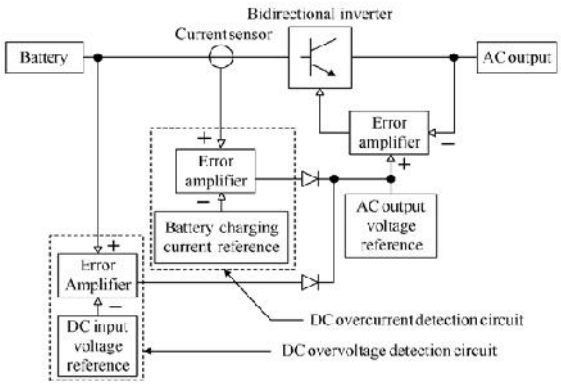

Figure 2: Block diagram of bidirectional inverter

As shows in fig 2 When larger amount of DC current is detected in the system and DC overvoltage in the circuit exceeds into AC O/P voltage reference the diode is turn on, which is related to error amplifier with larger output. Therefore DC current and voltage value is acted to AC output voltage references. In this system when AC overvoltage is detected in circuit diode turn on and added AC voltage in DC input voltage thus inverter acts.

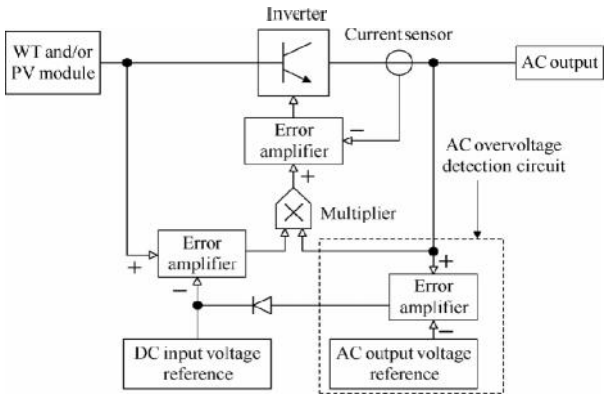

Figure 3: Block diagram of WT and PV inverters

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In fig 3 When dump power condition occurs its excess starts flowing in the battery through bidirectional inverter voltage flowing into battery is detected by voltage source converter and when battery voltage is found more than charging voltage reference diode acts and AC O/P reform voltage is increase the O/P voltage of bidirectional inverter found the O/P voltage of solar and wind will also get increase through reactive power control.

IV. Modeling of sources of microgrid

1. Modeling of Photovoltaic Array

Solar light is converted into electricity by photovoltaic cell. Materials used in solar cells are Crystalline or polycrystalline. Each PV cells generate about 0.5 V .The cell are group together to form modules. The photovoltaic array is series and parallel combination of photovoltaic modules. Its input parameter is solar irradiation and temperature. Figure 5.2 shows one diode equivalent circuit model for a PV cell. The current equation is given as follow

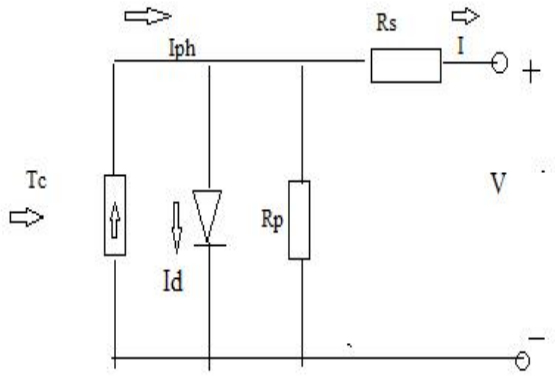

Figure 4: Equivalent circuit for Solar cell with single diode

$$I = I_{pv} - I_0 \left[\exp\left(\frac{qV}{\alpha KT} - 1\right)\right]$$

$$I = I_{pv} - I_0 \left[\exp\left(\frac{V+R_s}{V_t \alpha}\right)\right] - V + \frac{IR_s}{R_p} \quad \ldots\ldots\ldots (1)$$

Where, I_{pv} is current generated by incident light, q is charge of electron 1.6×10−19, K is Boltzmann constant 1.38×10−23 (J/K),

I_o is Reverse saturation current, T is cell temperature (K), Rp is parallel resistance, R_s is series resistance, V_t is terminal voltage of the array. The current-voltage and power-voltage characteristics of a solar PV module operating at a standard irradiance of 1000W/m^2 and different solar temperature are shown in Fig.7

PARAMETERS	VALUES
1)Parallel strings	66
2)Series connected module/string	5
3)Module type	Sun Power SPR-305E-WHT-D
4)Maximum voltage at MPP(Vmpp)	54.7V
5)Cells per module	96
6)PWM switching frequency	5000Hz
7)Maximum current at MPP(Impp)	5.58A
8)Maximum power	3.5 kW
9)Open circuit voltage(Voc)	64.2V
10)Short circuit current(Isc)	4.49A
11)Series resistance (Rs)	0.37Ω

Table 1

Parameters for PV Array

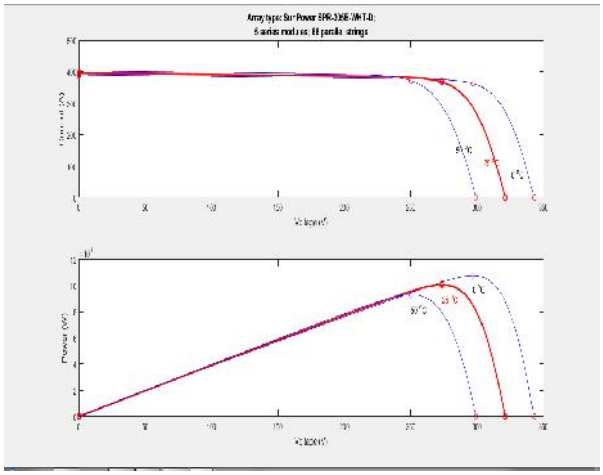

Figure 5: Shows the P-V and V-I charactertics of PV array at different temperatures.

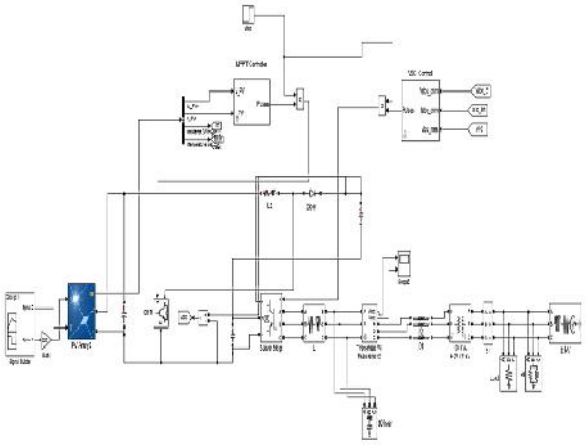

Figure 6: Modeling of PV array in MATLAB\SIMULINK

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2. Modeling of Wind System

Winds converts its kinetic energy into electric energy .A rotor in wind turbines extracts its kinetic energy .wind turbines consist of two or more blades mechanically connected to an electrical generator. The mechanical power of wind turbine can be given as

$$P_m = 0.5\, A\, C_p(\lambda,\beta) V^3 \ldots (2)$$

Where, A is wind turbine rotor swept area, Cp (λ, β) is power coefficient of wind turbine which is the function of tip speed ration λ and pitch angle β,V is wind speed, P is air density, λ is Tip speed ratio of the rotor blade tip speed to wind speed, β is Blade pitch angle.

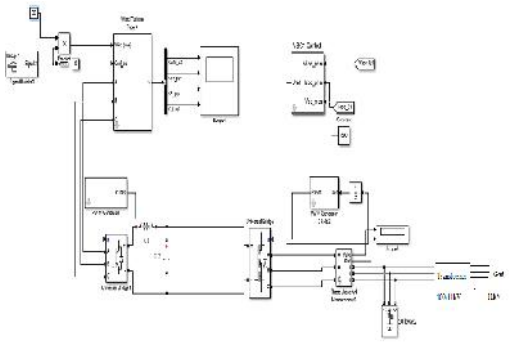

Figure 7: Modeling of wind system in MATLAB\SIMULINK

Table 2

Parameters of wind turbine

PARAMETERS	VALUES
1) 1) Induction generator	3.5KVA
2) Frequency	50Hz
3) series Resistance	0.006Ω pu
4) Inverter voltage	330V
5) Rated nominal power	3.5Kw
6) No of wind Turbines	1
7)Line-Line voltage	100V
8)Wind seed	0-12m/sec
9) pitch angle	0 deg
10) J Rotor Inertia Constant	0.62s

Fig 7 shows the modeling of wind in hybrid system .Input to wind is velocity and speed in (miles/sec) is mounted with boost converter. Then to inverter to convert DC power to AC power. Further to AC load.

3. Modeling of Diesel Generator

It is a combination of diesel engine with alternator to generate electricity energy. Diesel engine is run by using fuel oil, liquid fuel or natural gas. These generators are useful when power fails and discontinuity in supply is found. It is composed of diesel engine, AC synchronous generator and control panel.

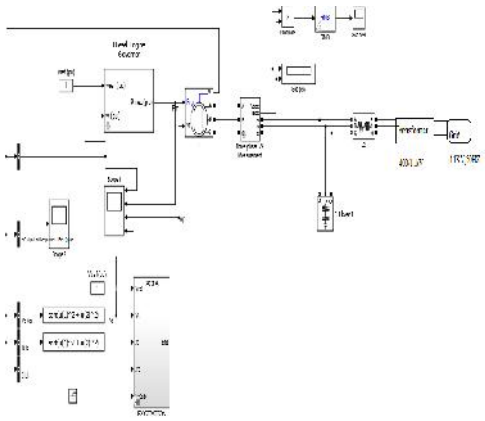

Figure 8: Modeling of diesel generator in MATLAB/SIMULINK

The system is designed in MATLAB/SIMULINK as shown figure .Speed reference is input provided of the engine then to the synchronous generator .Excitation system is provide to synchronous generator to provided to starting.

Table 3

3 Parameters of Diesel Generator

PARAMETERS	VALUES
1) Rated power	8.1KVA
2) Frequency	50Hz
3) Stator Resistance (Rs)	0.0082Ω pu
4)Line-Line voltage	330V
5)Armature Time Constant(Ta)	0.332 Ω pu
6)Rotor type	Salient pole
7) Pairs of poles	2 Ω pu
8) Unsaturated Reactance(Xd)	1.8 Ω pu
9) Unsaturated Transient Reactance(Xd')	0.184 Ω pu
10) Unsaturated Transient Reactance(Xd")	0.115 Ω pu
11)Unsaturated Reactance(Xq)	0.892 Ω pu
12) Unsaturated Transient Reactance(Xq')	0.207 Ω pu
13)Inertia Coefficient (J)	0.142s

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4. Battery Storage System with Bi-Directional Inverter

Battery converts electric energy into chemical energy for storing energy purpose .The conversion of AC to DC is done by battery energy storage system (BESS), it has batteries and power electronics devices control system. By using DC power batteries and charge or discharge. Bi-directional power devices use to regulate power flow between batteries and energy system. There are various types of battery available like lithium ion, lead acid, nickel cadmium, nickel metal hydride are some among them. Among all lithium ion has highest energy density, low cost, different sizes availability. It is used in cellular phones computer etc.

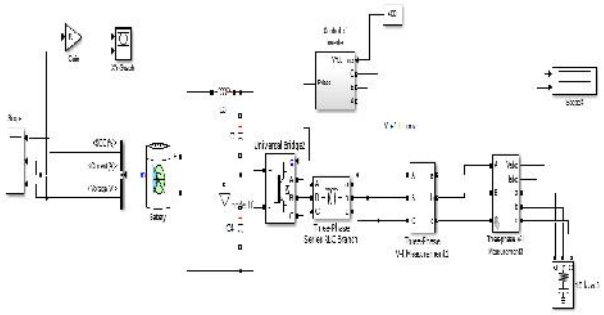

Figure 9: .Modeling of battery storage system

Table 4

Parameters of Battery Storage System

1)Battery Type	Lithium Ion
2)Nominal Voltage	288V
3)Rated capacity	48 Ah
4)Initial state of charge	100%
5)Fully charge voltage	335.22V
6)Nominal discharge current	20.86A
7)Internal Resistance	0.064Ω
8)Capacity (Ah) at nominal voltage	43.40Ah

5. PHASE LOCKED LOOP (PLL)

A PLL is an electronic circuit to an voltage oscillator that constantly adjusts to match frequency of an input signal. PLL is use to generate, stabilize, modulate, filter or reduce noise. PLL takes input as voltage and finds its angle and frequency.

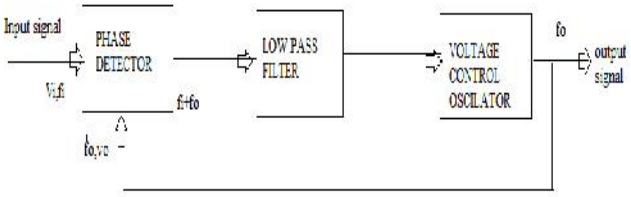

Figure 10: The block diagram of the PLL

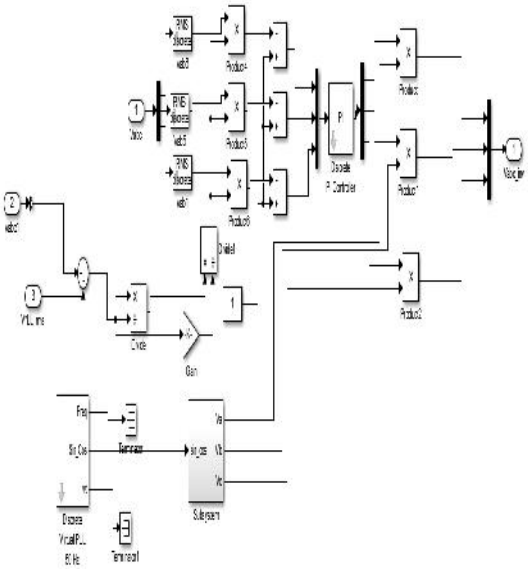

Figure 11:Modeling of PLL in MATLAB/SIMULINK

6. MODELING OF CONVERTERS

6.1Boost converter

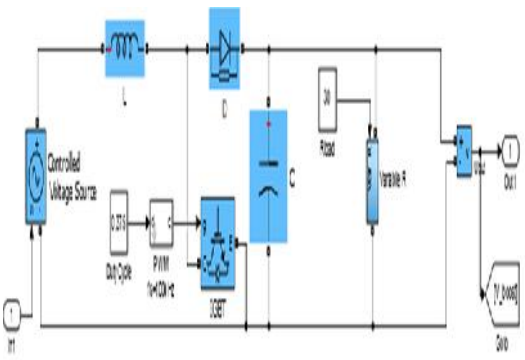

Figure 12: Simulink model of boost converter

Boost converter is used to boost the voltages .as show in fig 12 Inductor is used to storage energy .The ideal PWM and transistor acts as a switching controller and as switching element. The diode is used as rectifier and the capacitor is used for filtering purpose.

6.2 Voltage Source Inverter

VSI control loop consist of PLL block, DC voltage control loop, current control loop, reference voltage and PWM generator. VSI control loop in Matlab Simulink is shown in figure below.

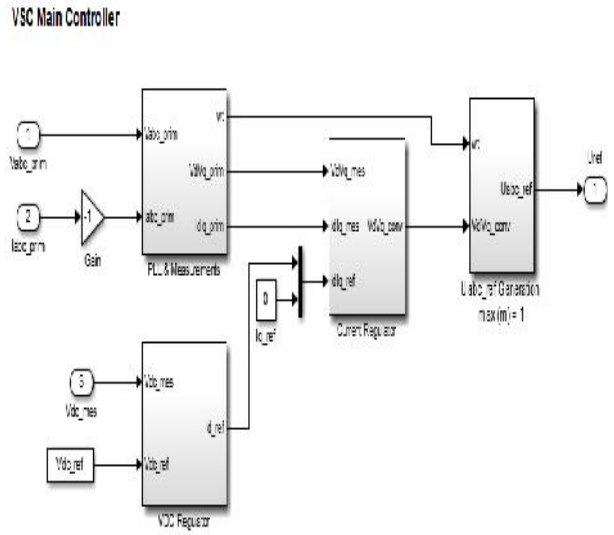

Figure 13: VSI controller modeling in MATLAB\SIMULINK

1) PLL block and modeling has been explained in above section. It converts voltage and current to per unit value. PLL take voltage as the input and finds its angle and frequency.

2) VDC Regulator (DC VOLTAGE CONTROL LOOP)

Voltage regulator loop help to generate the DC voltage in inverter at side. PI controller gains K_P and K_I are given by formulas as follows

$$K_p = \frac{3C}{20T_S} \ldots (3)$$

$$K_I = \frac{K_P}{20T_S} \ldots . (4)$$

Where, Kp is proportional constant and KI is integral gains and C is capacitor provided by boost converter and Ts is the switching period of the inverter. voltage regulator is shown in Figure.

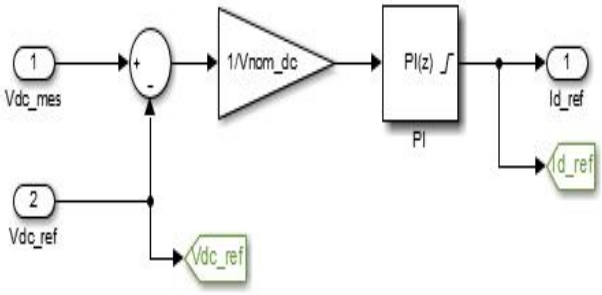

Figure 14: Voltage regulators modeling in MATLAB/SIMULINK

ii) Current Regulator (current control loop):

Current regulator helps to generates current in dq transformation system. The current regulator is shown in the Fig 15.

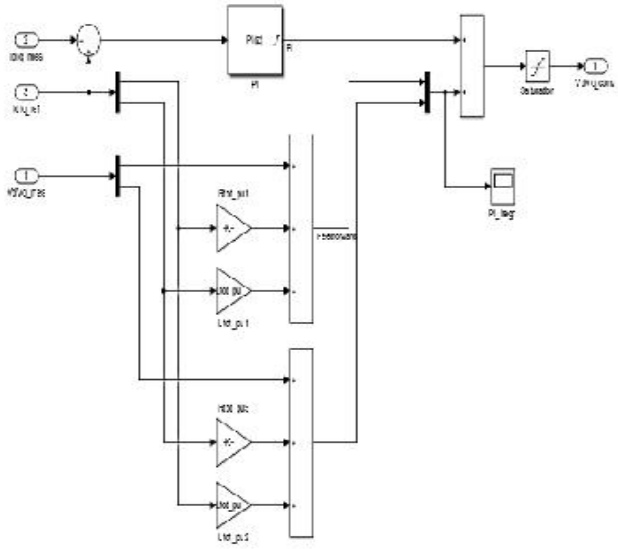

Figure15: Current control loop modeling in MATLAB\SIMULINK

Where PI controller gains KP and KI are given by formula as follows

$$K_p = \frac{2L}{T_S} \ldots\ldots\ldots (5)$$

$$K_I = \frac{K_P}{20T_S} \ldots\ldots . (6)$$

Where, L is LC inductor filter, Ts is Inverter switching period, τ is time constant given by L/R, R is Filter resistance (1 Ω).

iv) PWM generator.

Reference voltage and PWM generator is used to converts the voltage back into abc transformation

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from dq transformation. PWM generator produces PWM signals by comparing three phase signals and the triangular waveforms with the reference frequency. .

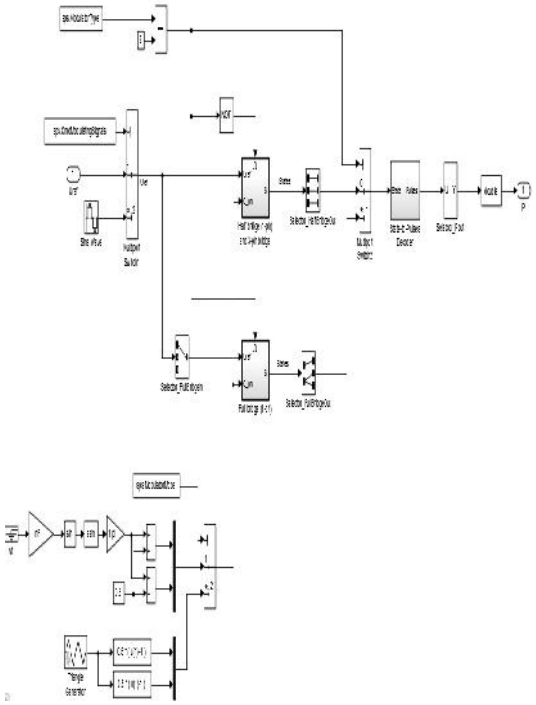

Figure 16: PWM Generator modeling in MATLAB/SIMULINK

V SIMULATION RESULTS

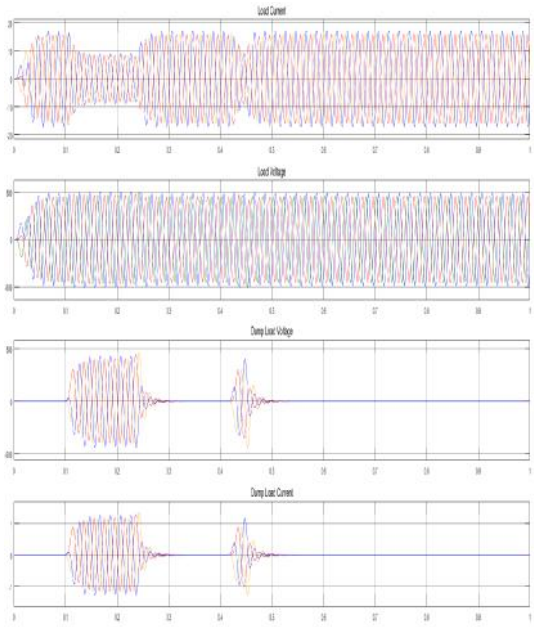

Figure 17: Simulation results during the synchronization of microgrid to utility grid

Figure 17 shows the Load and Dump load characteristics of Current and Voltage in Grid connected and Islanded connected mode. Here from this graphical representation it is observed that when there is excess power generation in Islanded mode, dump load gets activated. Here in the interval between (0.1 to 0.3) sec and (0.4 to 0.5) sec dump load is a

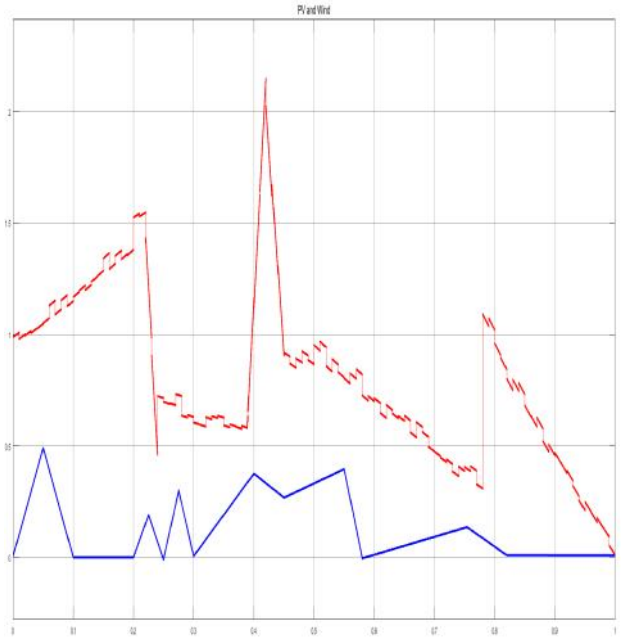

Figure18: Power output of the PV and Wind VS Time

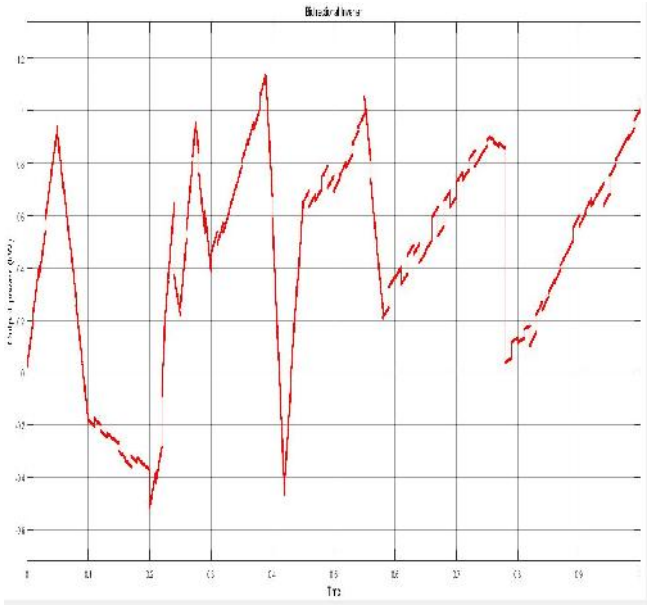

Figure 19: Power Output of Bidirectional inverter

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The Figure 18 shows the graphical representation of power output of the PV and Wind Turbine. Here in the representation it is observed that when battery is under charging condition dump load is not activated, and when battery is in discharging state bidirectional inverter gets activated and hence dump load also activates. As from the explanation of previous figure (6.7) we conclude that in the interval of 0.4 to 0.5 dump load is activated and hence at the same interval we are getting maximum power output delivery of PV array and Wind Turbine.

The Figure 19 shows the graphical representation of power output of the Bidirectional Inverter. In this case when output power is positive, battery is in discharging state and vice versa happens that us when battery is in charging state the power output is negative as observed from the above figure. It is also observed that in the interval of (0.4 to0.5) dump load is activated, bidirectional inverter carries negative output power and this shows that the battery is charged.

VI CONCULSION AND FUTURE SCOPE

A hybrid model consist of wind, solar, battery & diesel generator power generation system was been carried out in MATLAB /SIMULINK. Control issues when grid connected and islanded mode had been studied. And focused was given to power generated in islanded condition and analysis was done in MATLAB/SIMULINK. Excess generation is carried in dump load. 1. PLL control technique and 2. Dump control technique have been use to control battery overcharging and elimination of dump control load have been achieved by forming feedback loop in the system with bi-directional inverter. Due to this there is no requirement for the high speed line to transfer voltage and current data to storage battery. The effective use of excess power generate is made possible. Battery life expansion is made possible. The system is link with ac system, which will allow flexible expansion of system in future. The power generate through this system can be further be used in local area, for heating purpose etc. This system will also provide environmental protection. Since it can be work only on is located islands there will be on use of commercial power system to generate electricity

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