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MODELING AND CONTROL OF MICROGRID

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Abstract : This paper presents the modeling and control of Microgrid. Microgrids are quickly becoming the de facto standard for future power systems. Power converters are now frequently used in renewable energy power. Solar, wind, and hydropower are examples of renewable energies. They have different voltage and frequency, thus we can't connect them to the utilities directly. Inverters are used as an interface between the utility and the main grid to solve these problems. For the inverter to successfully coordinate between them, there are numerous controls. We employed the "estimated droop control technique" for the inverter in this work. The system that is the subject of this research is made up of two parallel inverters that are powered by a PV array and a wind turbine. These inverters are linked in parallel to create a microgrid in order to share the same loads. When the microgrid was operating in the islanded mode, interfaced parallel inverter control employing a P-F/Q-V droop control was examined. The PV array and the wind turbine are variable nonlinear DC sources and hence the control system should achieve good power sharing even with this imperfections. The proportional load sharing is derived from each individual inverter and the droop control for parallel inverters is put into practise. The inverter droop control should maintain voltage and frequency stability while in islanding mode. Using Matlab/Simulink to simulate the droop regulation of an inverter, the findings show that it significantly affects the voltage magnitude, frequency, and power sharing balance.

***keywords* - Photovoltaic Array, Wind Turbine, Parallel inverter, Droop Control, Microgrid.**

1. INTRODUCTION

A Microgrid is a developing type of power infrastructure. The environmental issues associated with fossil fuels and the continuously rising energy demands have made renewable energy sources one of the most practical substitutes for the massive, centralised fossil-fueled power plants. Recently distributed energy sources, such as fuel cells, wind turbines and photovoltaic cells are integrated to form a Microgrid. A system of parallel inverters that can be connected to the grid is known as a microgrid. To share the loads, distributed power sources in microgrid must run concurrently. Wind and photovoltaic systems are two of the more scalable and manageable renewable energy sources in microgrid, making them appropriate for integration as generators. It has been established that PV/Wind Microgrid is one of the grid's potential future evolutions. A PV and Wind Microgrid is shown in Figure.1

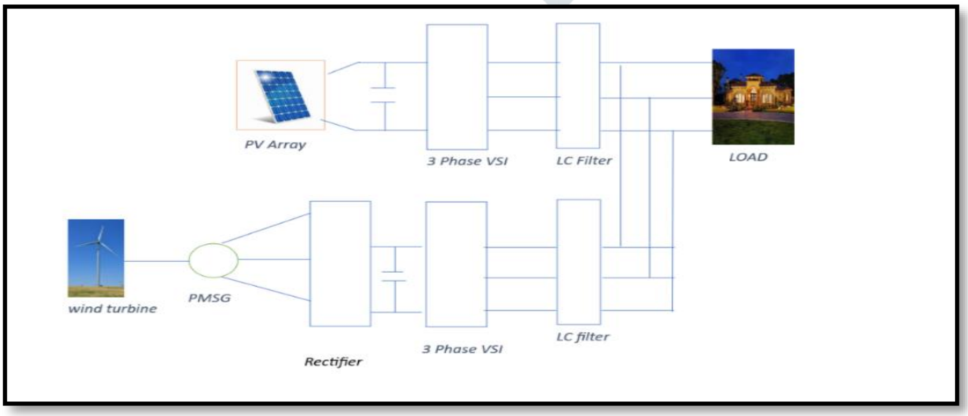

figure 1A system of two parallel inverter

PV modules are connected in series and parallel to form the PV source. There are several ways to connect PV modules to the grid, including central, string, and multistring. The centralized design, where the PV array is connected to a central inverter, is preferred for big installations due to its low cost and simplicity. The wind turbine is connected to the rectifier through a permanent magnetic synchronous generator. The wind turbine can be connected to numerous devices. The induction generator is the most popular choice for large wind farms. Because there is no need to excite current from the grid, isolated systems like the PMSG are used. Permanent magnet synchronous machines are also more effective and produce more energy. A three - phase voltage source inverter connects the PV array and wind energy system. The PV array and wind energy system are connected via a three-phase voltage source inverter. Additionally, predetermined ranges must be maintained for the voltage, phase, and frequency. There are numerous studies of inverter-based MGs' control techniques. There are four categories of control strategies: centralized, distributed, master-slave, and decentralized. Decentralised control was introduced to address the issues brought on by the interactions of the controller. Only local information is utilized by the decentralized controller in decentralized control. Droop control is one of the often employed decentralized control techniques. The inverters do not need to be connected by signal lines for droop control, which is a non-contact, signal line independent control method. Because grid power utility support is absent during islanding operations, microgrids must rely on their own capabilities to maintain voltage and frequency regulation. There is no need for inter-inverter communication when employing PF/Q-V for droop control. In order to provide proportional load sharing, droop control for parallel inverters in the microgrid is implemented in this study.

1.1 Mathematical Model of Photovoltaic Array

The photoelectric effect is used by PV solar cells to produce energy. The p-n junction in Figure 2 is the fundamental component of a PV cell. The characteristics of the PV cell are comparable to those of a regular diode in the dark. Electrons in the cell become free when sunlight with energy above the semiconductor energy gap strikes them, and a sizable current flows in the external circuit. PV cells are combined into modules, encased from the front, and supported by a metallic panel for safety because they are brittle and have low voltage.

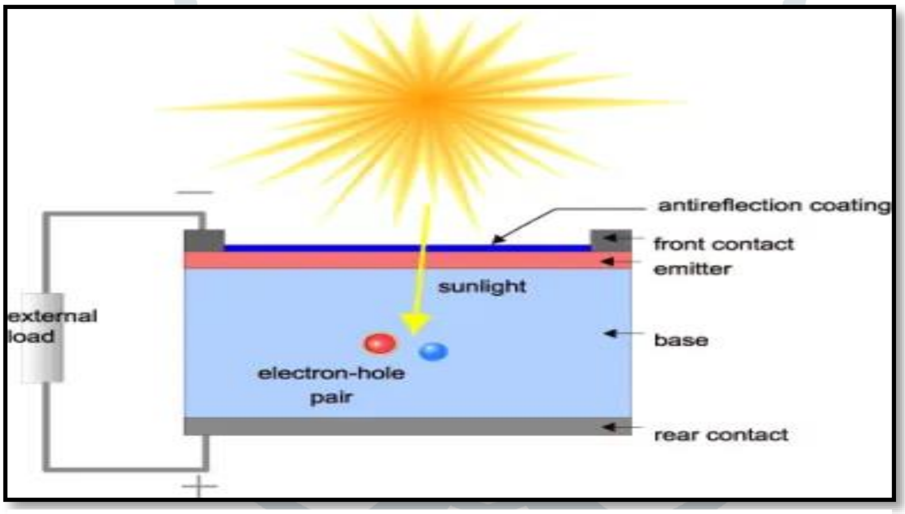

figure 2. p-n junction silicon solar cell

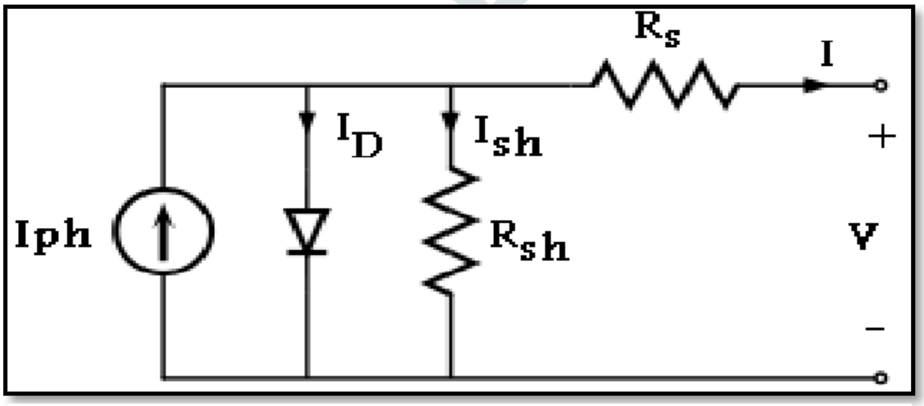

figure 3. circuit model of solar cell

The electrical circuit model is shown in Figure 3. The inclusion of I_0, I_{ph} and V_{OC} 's temperature dependency results in a model of medium complexity. Additionally, consideration is given to the temperature dependency of the parasitic resistances R_s and R_{sh}. The parasitic resistances R_s and R_{sh} 's temperature dependence is also taken into account. The mathematical model of a solar cell based on the single diode model is given as:

$$I(T,G,V) = I_{ph} - I_o \left(e^{\frac{V+IR_s}{nV_{th}}} - 1\right) - (V + I\,.R_s)/R_{sh}$$

$$= I_{ph} - I_D - I_{sh}$$

$$I_{ph} = I_{ph0} \cdot \frac{G}{G_{nom}}$$

$$I_{ph}(T) = I_{ph} + K_0 \,(\mathrm{T} - T_{meas})$$

$$K_0 = (I_{ph}(T_2) - I_{ph}(T_1)) / (T_2 - T_1)$$

$$I_0 = I_{SC(T_1)} \,.\, (T/T_1)^{3/n} \,.\, \exp (- E_g / V_s(1 / \mathrm{T} - 1/ T_1))$$

$$I_0 (T_1) = I_{SC(T_1)} / (\exp (\mathrm{q}\, I_{OC(T_1)} / \mathrm{nk}\, T_1) - 1)$$

$$R_s (T) = - dV/dI_{V_{OC}} - 1/ (I_{0_{T(1)}} \,.\, \mathrm{q} / \mathrm{nk}\, T_1 \,.\, e^{qV_{OC(T_1)}/\mathrm{nK}T_1})$$

$$R_{sh} = V_{oc} / (I_{ph} - I_o [\exp(qV_{OC} / \mathrm{nk}\, T_{meas} -1)])$$

$$R_{sh} (T) = R_{sh} \,.\, (\mathrm{T} / T_{meas})^a$$

The model's parameters are briefly given. I_{ph} is the photo generated current in Amperes. The photogenerated current at the nominal radiation is denoted by I_{ph0}. I_0 is the dark saturation current for diodes. Diode dark current is known as I_D. The shunt current is I_{sh}. The series resistance in Rs. Shunt resistance is denoted by R_{sh}. The solar flux, G, is measured in W/m2. The radiation that the PV module is calibrated at is known as the G_{nom}. The ideality parameter is n. The charge of an electron is e. Boltzmann's constant is k. The semiconductor energy gap is denoted by Vg. The short-circuit current temperature coefficient is known as K_0. The thermal voltage is V_{th}. The manufacturer provides the following: N_p : the number of consecutive cells, N_p : the quantity of parallel cells, Short circuit current (ISC) V_{OC} : the voltage of an open circuit. To generate the necessary voltage and power, the PV modules are linked in series and parallel. Our energy source is nonlinear, so the controller's objective is to provide AC power. in order to achieve power sharing amongst the various inverters in the microgrid with the specified voltage shape characteristics.

1.2 Mathematical Model of Wind Turbine

The wind turbine's mechanical power is provided

$$P_m = 0.5\ \rho A C_p\ V_w^3$$

where vw is the wind speed (m/s), A is the swept area (m2), Cp is the turbine's power coefficient, and Pm is the mechanical power in watts. The conversion effectiveness of the turbine is represented by the power coefficient. Cp is function of the tip speed, λ, of the turbine and is given by [1]:

$$C_p(\lambda) = c_1(\frac{c_2}{\lambda} - c_4)e^{-c_5/\lambda} + c_6\lambda$$

where λ=ωR/vw, ω is the rotational speed (rad/s), R is the radius of the blades. When cp=0.48 and λ=8.1, the turbine may produce its maximum amount of power. c1 = 0.5176, c2 = 116, c3 = 0.4, c4 = 5, c5 = 21, and c6 = 0.0068 are the coefficients from c1 to c6. The wind turbine utilised in the simulation is described as having a 20 kW power rating, a 12 m/s rated wind speed, 5 and 25 m/s cut-in and cut-out speeds, respectively, and a 10 m blade diameter. Figure 4 displays the mechanical power of the wind turbine in relation to the generator speed at various wind speeds.

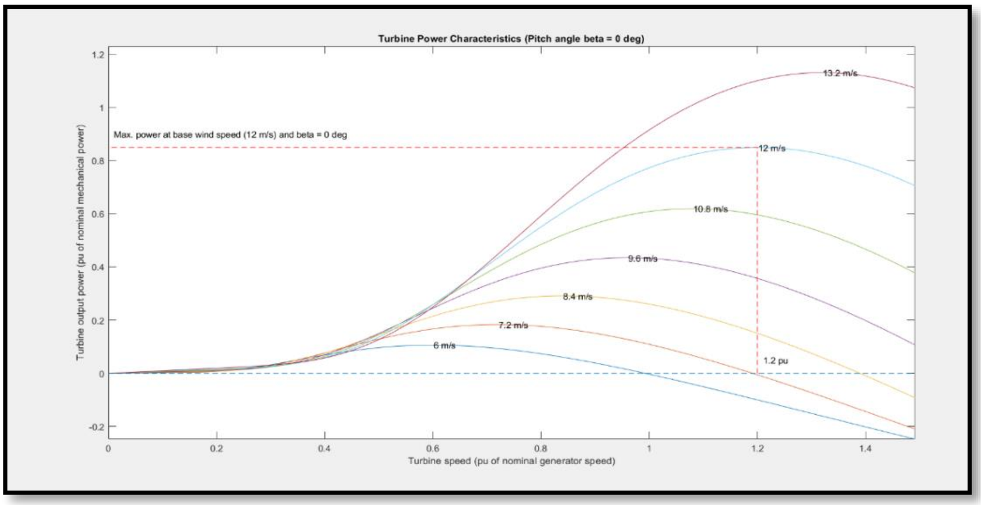

figure 4.comparing mechanical power and turbine speed

2. RESEARCH METHODOLOGY

Droop Control

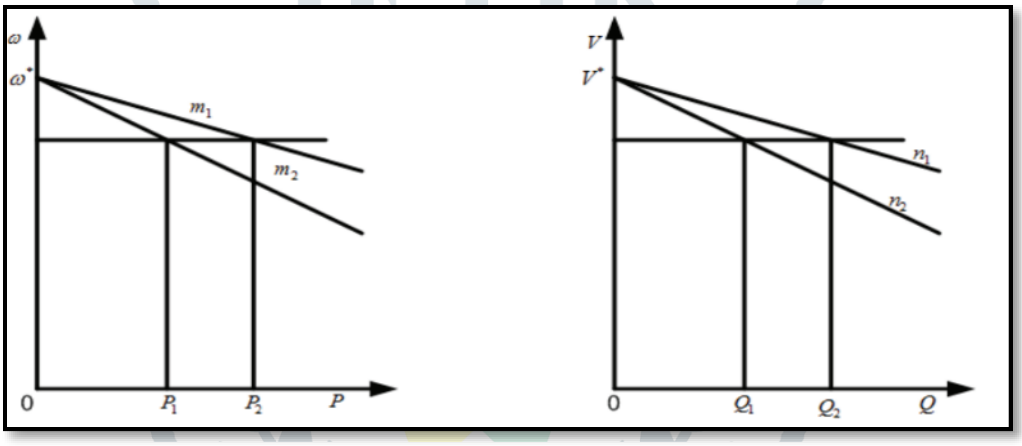

figure 5. droop control curve

The DG unit output power is:

$$P + jQ = \bar{S} = V\bar{I}^* = V\left(\frac{Ee^{j\theta} - V}{Ze^{j\theta}}\right)^*$$

Output current is:

$$\bar{I} = \frac{Ee^{j(\delta-\theta)} - Ve^{-j\theta}}{Z}$$

DG unit output of active power:

$$P = \frac{V}{R^2+X^2}[\ R\ (E\cos\delta - V) + XE\sin\delta$$

DG unit output of reactive power:

$$Q = \frac{V}{R^2+X^2}[\ X\ (E\cos\delta - V) + RE\sin\delta$$

Suppose the resistive component of the inverter output impedance is insignificant,The inverter output voltage and ac bus voltage are extremely low, namely $\theta = 90^0$, δ is very small, thus $\sin\delta = \delta$, $\cos\delta = 1$

The out power is:

$$\omega = \omega^* - m (P - P^*)$$

$$V = V^* - n (Q - Q^*)$$

The no-load output voltage amplitude and frequency of an inverter are $= V^*$, ω^*. m, n are the active and reactive droop co-efficients. The rated active and reactive power of the inverter are P^*, Q^*.

3. SIMULATION MODEL

3.1 Model of Microgrid

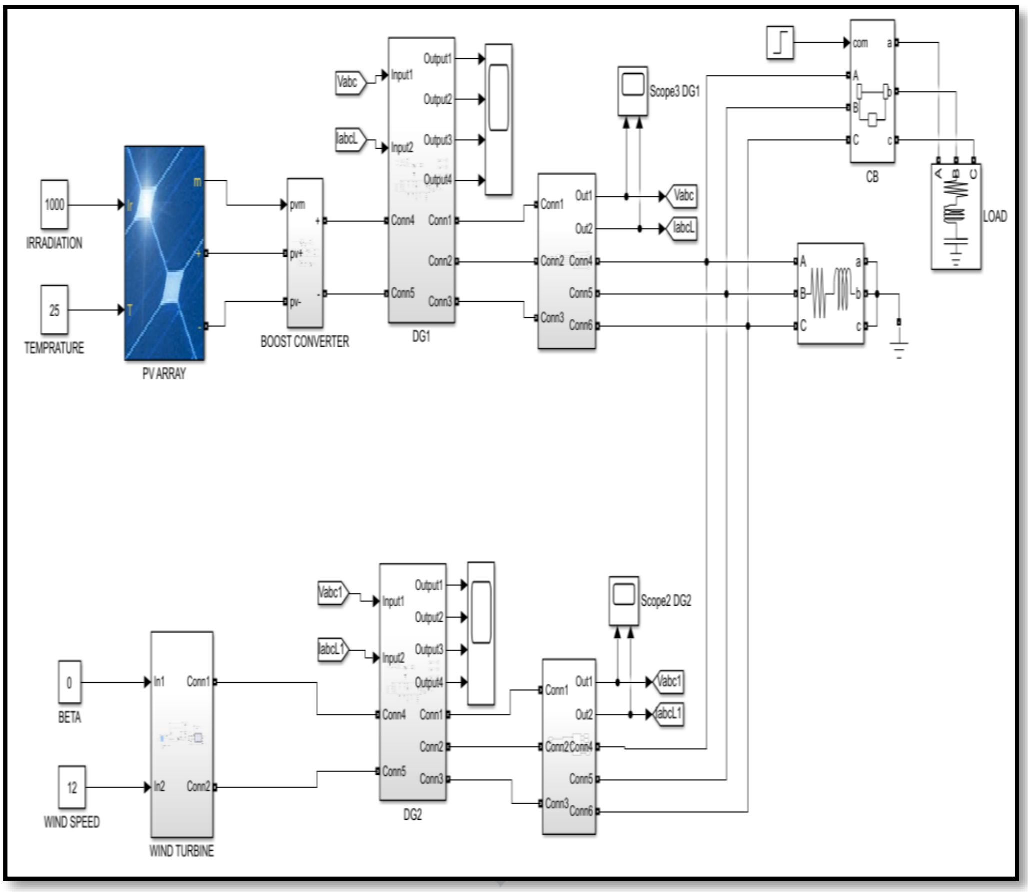

figure 6. microgrid system

Microgrid system show in fig 6. A small power supply network for residential areas known as a low voltage microgrid system has been created. Microgrid system consist of two different micro source. DG1 and DG2 are connect in parallel. To better understand the principles of load sharing, the structure has two micro sources.

3.2 Model of Distributed Generation 1 and Distributed Generation 2

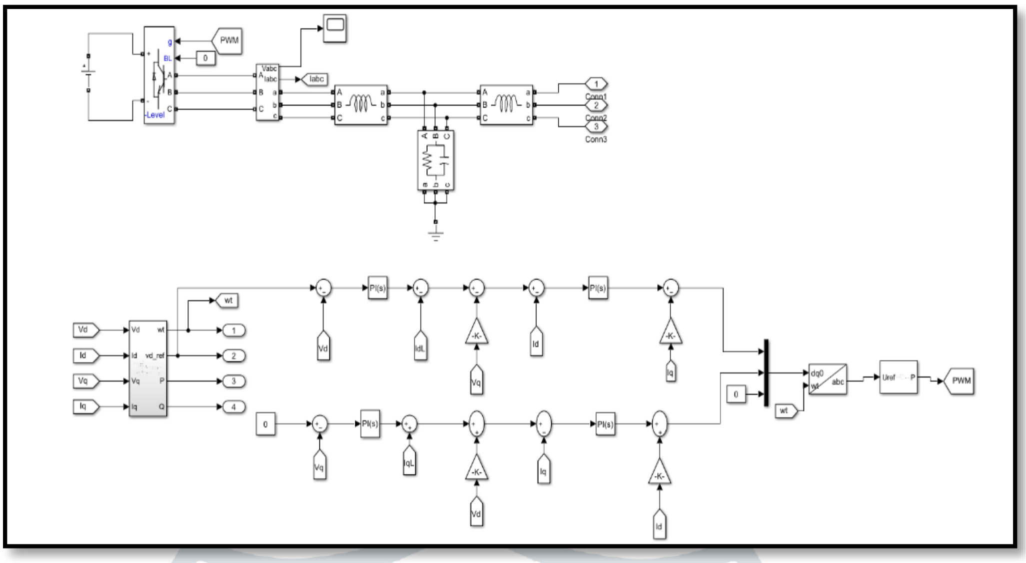

figure 7. distributed generation 1

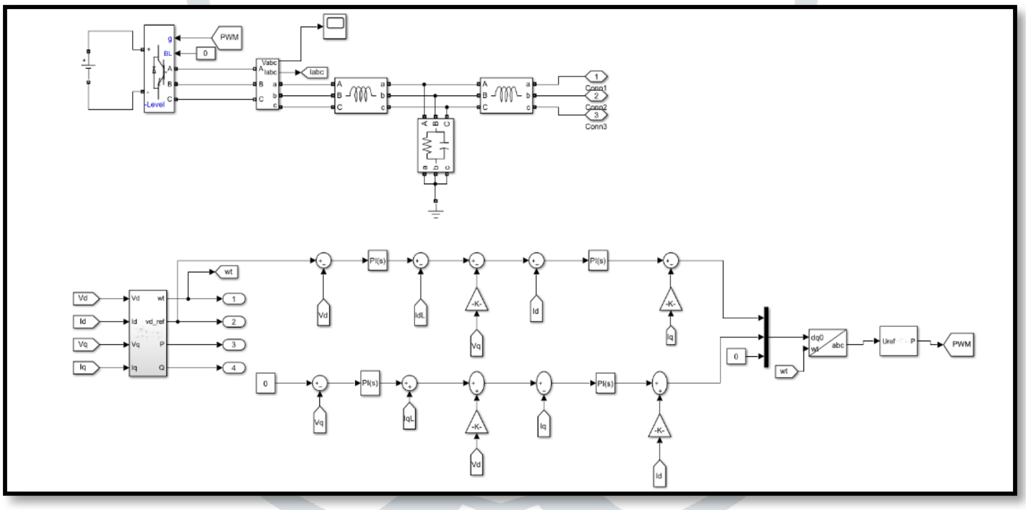

figure 8. distributed generation 2

Consider the reference voltage to be constant. Using the droop controller, produce the reference voltage. Grid side voltage is first sensed and converted into dq coordinates. The dq parameter, use for power calculation from the droop controller. The output is a applied to the PI controller. In this voltage control loop into the current control loop and then convert the dq coordinate to the abc and then applied to the PWM for generation of switching signal for inverter.

3.3 Simulation of Active and Reactive Power Droop Controller

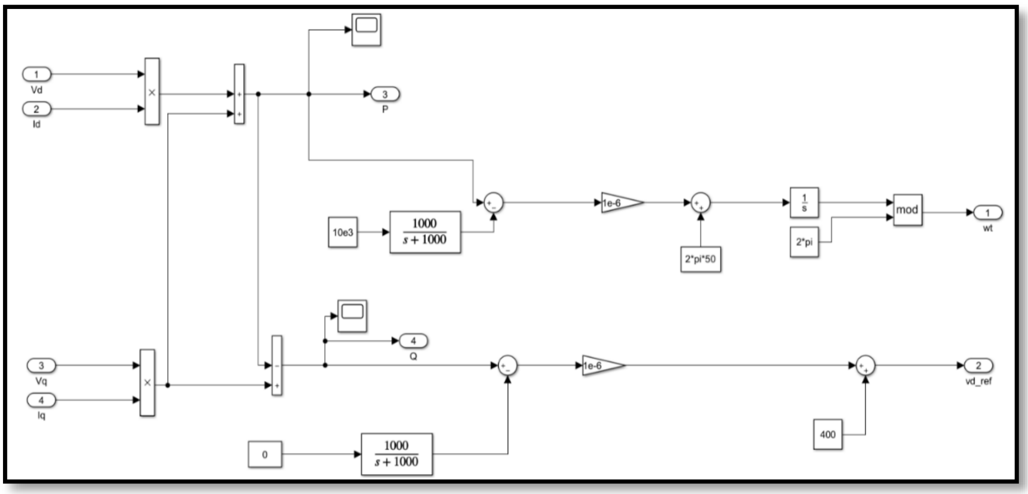

figure 9.active and reactive power control loop

Droop control is a simple way to control the active and reactive power of a synchronous generator. In droop control technique to obtain the maximum benefit such as increase power and reduce cost. Droop control technique is implement in parallel to achieve power sharing.

4. SIMULATION RESULT

Matlab/Simulink is used to implement the microgrid in Figure 6. The parameters of the parallel inverters are as follows: C = 9.94μF, L =5.1mH and R = 5.37 ohm. The inverter is pushed to create 15 kW real power and 15 kVar reactive power under the control strategy. Figure 8. demonstrates that the parallel inverters' output three phase voltages remained constant at 800 V. In the simulation, the PV array's radiation is set to 1000 W/m2 and the temperature is set at 25 C. The wind speed is fixed at 12 m/s, and the pitch angle is set at zero. Figure 6 depicts the DC input voltages of the first and second inverters.

4.2 Result of DG1 and DG2

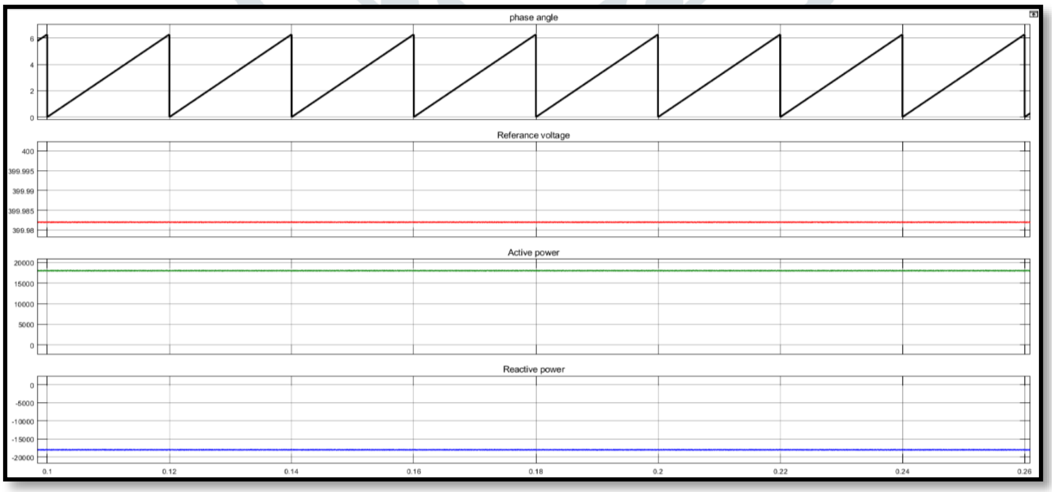

figure 10. phase angle ,reference voltage, active &reactive power of dg1

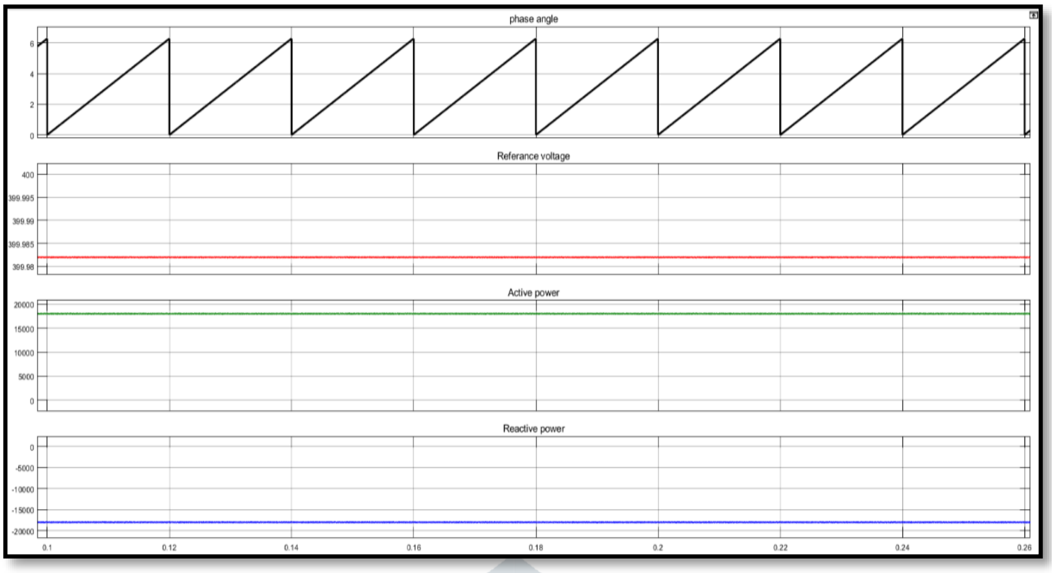

figure 11. phase angle ,reference voltage, active &reactive power of dg 2

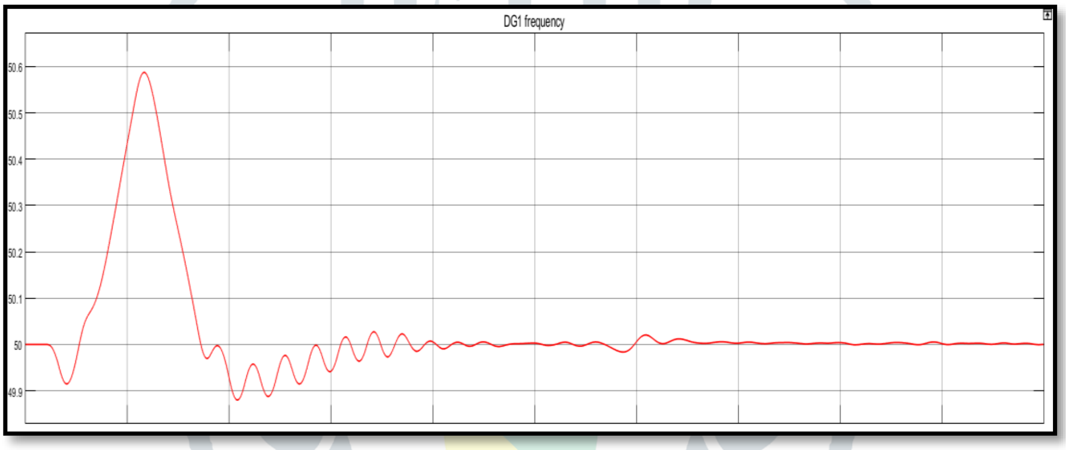

figure 12. output frequency of dg1

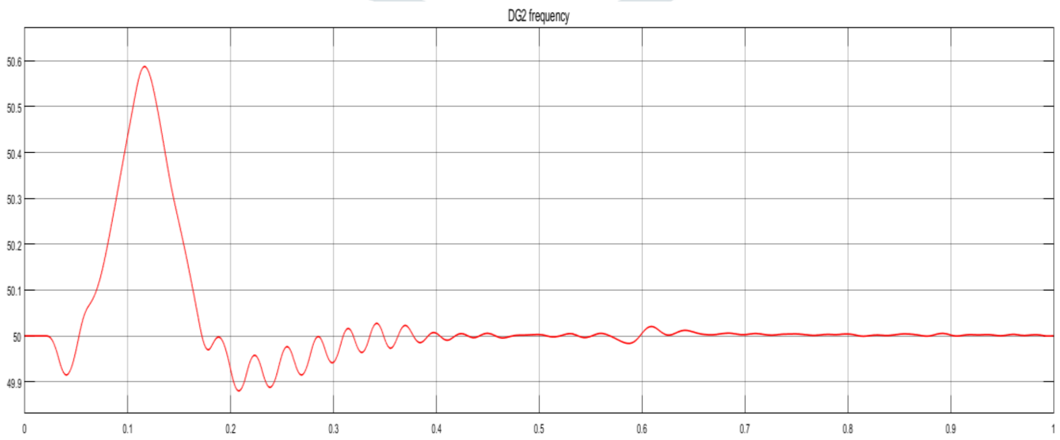

figure 13. output frequency of dg 2

4. CONCLUTION

The paper is about modelling and control of Microgrid. Simulink is used to create the PV array and wind energy system models. To stabilize the system while achieving load sharing, a distributed control method is adopted. The controller has been tested, and power sharing is possible even when the PV array and wind energy system output DC levels. Each inverter in a microgrid achieves proportional load sharing by employing droop control. The simulation results show that the droop control method can efficiently provide the required power to the load while keeping system voltage dips and frequency within a stable range.

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