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Smart Grid–Integration Of Conventional And Distributed Generation

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Abstract : In this paper, a general smart grid simulation model is developed in the MATLAB/Simulink environment, which integrates renewable energy resources, voltage monitoring, frequency monitoring and control capability. In this present scenario of power system network, conventional and distributed generation are used together to control the power flow in order to get a highly stable network. This smart grid model includes Thermal power plant (conventional generation) and PV plant (distributed generation). The load analysis has been done on the designed smart grid to check the stability in terms of active power flow and frequency deviation.

Frequency remains constant when the active power generated is equal to active power demand. Sufficient amount of active power is injected into the system with PV plant. This helps in maintaining the stability of the system and the frequency remains constant before and after integration of the PV plant.

Keywords : Simulink, smart grid, frequency deviation, active power.

1. INTRODUCTION

The term smart grid is coined by Amin in 2005 [1]. Smart grid is a type of electrical grid which attempts to predict and intelligently respond to the behavior and actions of all electric power users connected to it — suppliers, consumers and those that do both — in order to efficiently deliver reliable, economic, and sustainable electricity services [2]. Smart Grid has three economic goals: to enhance the reliability, to reduce peak demand and to reduce total energy consumption. To achieve these goals, various technologies have been developed and integrated in the electrical network. It is not intended to replace the current power grid system but only to improve it. A Smart Grid integrates advanced sensing technologies, control methods and integrated communications into current electricity grid both in transmission and distribution levels [3, 4]. Frequency and Active power are the main parameters to show the stability of any power system network like conventional power grid, micro grid or any virtual power plant [5]. The goal is to make power grids more efficient by integrating renewable energies and taking advantages of information and communication technologies. They possess the ability to be integrated with renewable energy sources on a large level which leads to sharing of load and reduction of load on large scale [6]. In this project a renewable energy source (PV plant) is integrated with the conventional thermal plant. After integration frequency deviations of the system remains constant with increase in active power flow. A lot of difficulty is faced in the integration of two conventional plants due to absence of continuous monitoring in case of traditional grid [7]. Due to this reason and keeping in mind the need of renewable energy, integrating the distributed generation with smart grid has become feasible due to the presence of continuous monitoring [8].

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2. BLOCK DIAGRAM OF PROPOSED SMART GRID

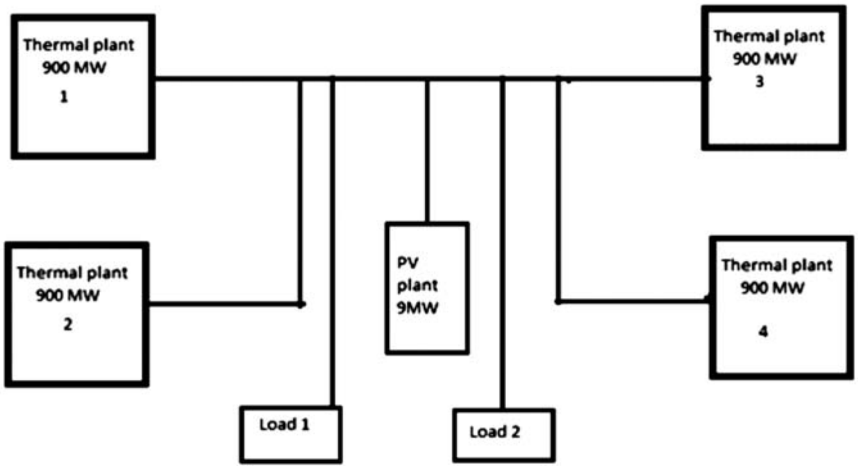

Fig. 1. Block diagram of proposed smart grid model.

3. SIMULATION OF THERMAL POWER PLANT

In a thermal power plant, the frequency deviations are maintained by the automatic load frequency control (ALFC) loop of synchronous generator. When loads are increasing or decreasing then frequency will decrease or increase accordingly [9]. For automatic frequency control, ALFC is used in both single and double area loop. When loads are increasing or decreasing then frequency will decrease or increase accordingly. For automatic frequency control, ALFC is used in both single and double area loop [10]. For a two area system, during normal operation the real power transferred over the tie line is given by

$$P_{12} = \frac{|E_1||E_2|}{X_{12}} \sin \delta_{12} \tag{1}$$

Where,

$$X_{12} = X_1 + X_{tie} + X_2 \tag{2}$$

$$\delta_{12} = \delta_1 - \delta_2 \tag{3}$$

In case of the simulation for the thermal plant, a six bus system is taken in which, four buses are generator buses with capacity 900 MW and two buses are load buses with certain inductive, resistive and capacitive loads. Loads are changed with capacitive load kept constant to observe the changes in system frequency.

4. GRID CONNECTED PV PLANT

PV modules are developed by grouping of cells. The modules are connected in series for more voltage rating and in parallel to meet the current specifications [11]. Series connection of modules is called string.

The output current from the PV cell can be found using the equation [12]:

Where

$$I_{PV} = [I_{SC} + K(T - T_{ref})]*\frac{G}{G_n} \tag{4}$$

$$I_o = I_{on} * \left[\frac{T}{T_{ref}}\right]^3 \left[\exp\left(\frac{qE_g}{aK}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right)\right] \tag{5}$$

$$I = I_{PV} - I_o\left\{\exp\left[\frac{q(V + R_S 1)}{nkT}\right] - 1\right\} - \frac{V + R_S I}{R_p} \tag{6}$$

I_{pv} : Light-generated current or photocurrent (A)
T : Cell's working temperature in °K
T_{ref} : Cell's reference temperature in °K
I_{on} : Nominal saturation current (A)
I_o : saturation current (A)
G : actual irradiation (W/ m^2)
Gn : nominal irradiation (usually 1000 W/ m^2)
Rp : is the shunt resistance. (Ω)
Rs : is the series resistance. (Ω)
K : is Boltzman constant = 1.3805×10^{-23} J/K
q : is Electron charge = 1.6×10^{-19}C
I : output current from the PV cell (A)
Eg : is the band gap energy of the semiconductor
a : is the ideality factor =1.6
V : Cell voltage

The characteristics of a 100KW PV module are as follows:

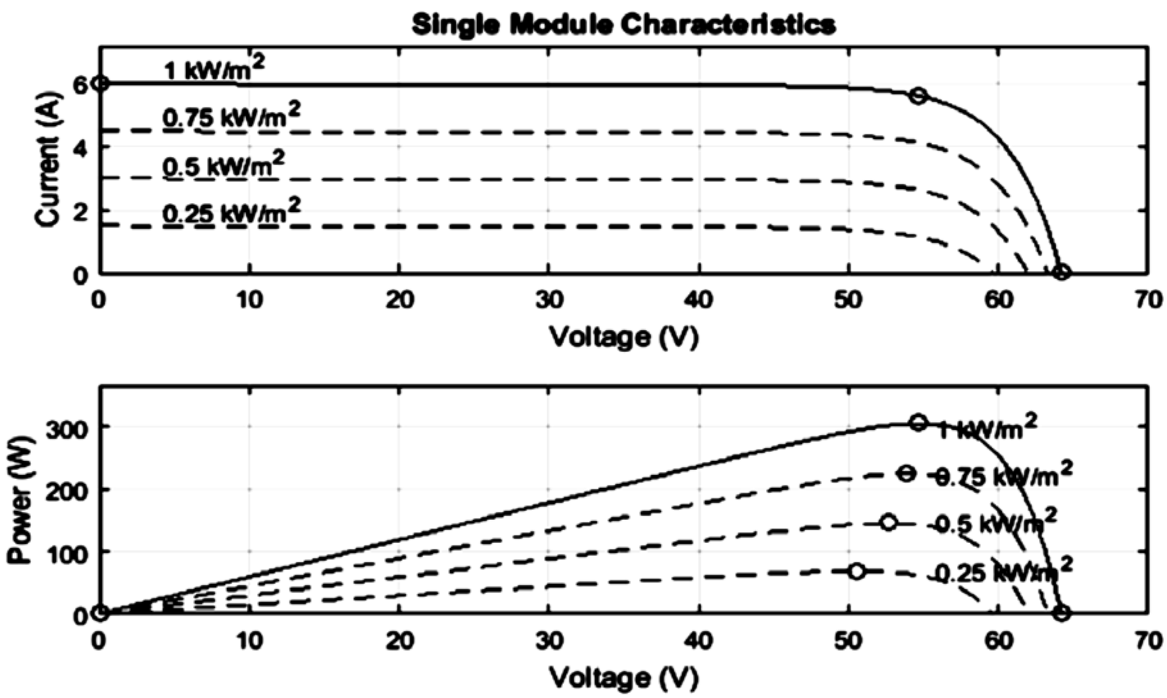

Fig. 2. Single module characteristics.

The output of the PV module is given to a buck-boost converter which can step up or down the voltage depending on the requirement. Since the Photovoltaic has a non-linearity characteristic, maximum power point controller allows operating the photovoltaic array at Maximum power point.

The MPPT adjust the pulse width of the DC/DC converter or DC/AC of the inverter. It adjusts the duty cycle to always give the maximum output [13]. The MPPT method used is the Perturb and Observe (P&O) method [14, 15]. The below is the algorithm of the Perturb and Observe (P&O) method.

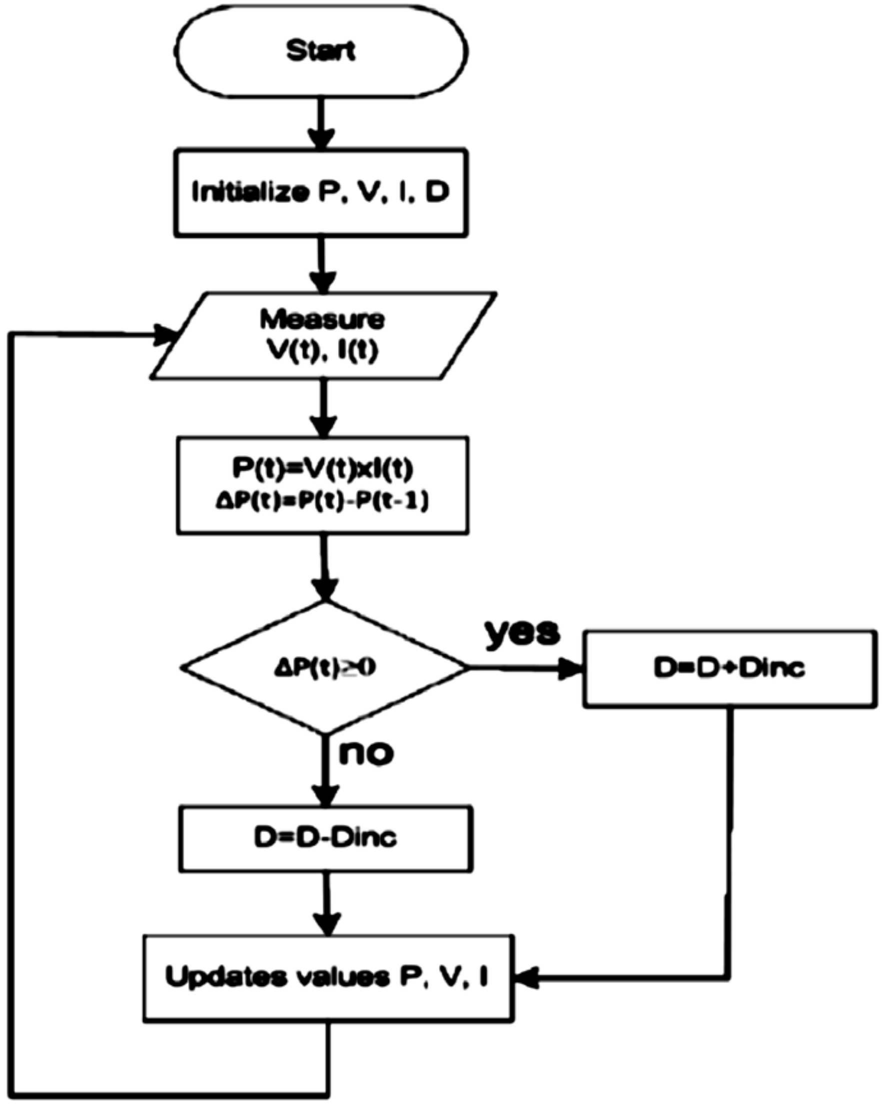

Fig. 3. Perturb and Observe flowchart.

The output of the converter is given to the inverter so the DC output is converted to AC for connecting it to grid used suitable inverter control [16]. 9MW PV plant is simulated in this project.

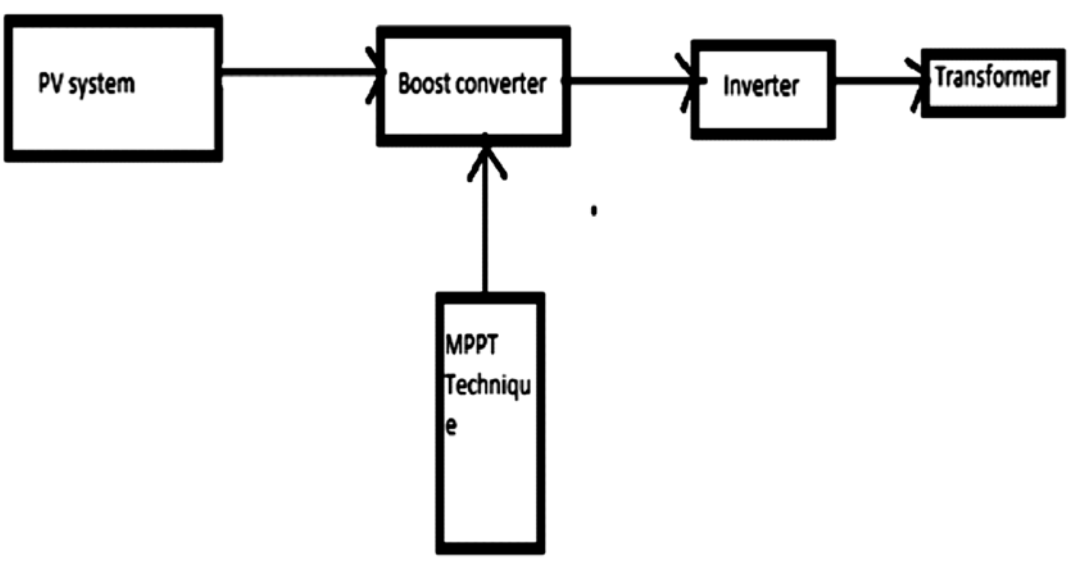

Fig. 4. Block diagram of PV plant.

5. RESULTS

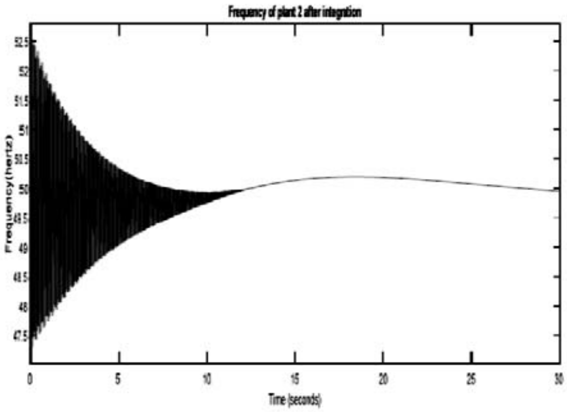

Fig. 5. Frequency of plant 1 before integration.

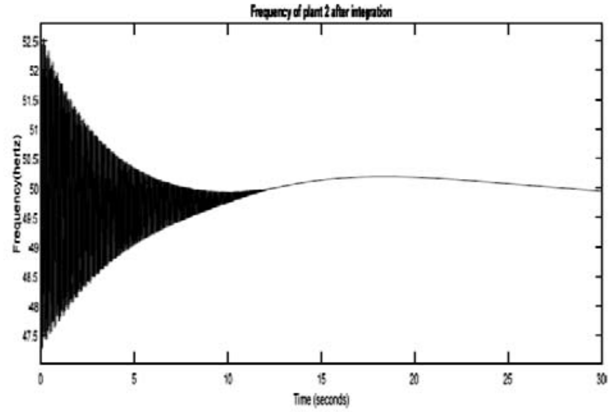

Fig. 6. Frequency of plant 2 before integration.

The following graphs show the frequency of plant 1 and plant 2 before integration. The frequency varies between 49.8 Hz to 50.2 Hz which is the ideal range of frequency deviations.

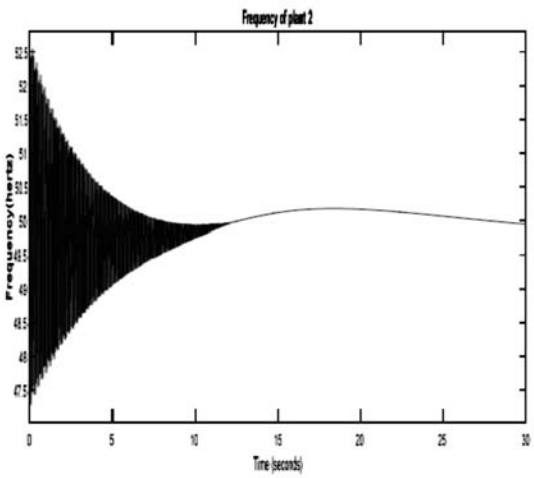

Fig. 7. Frequency of plant 1 after integration.

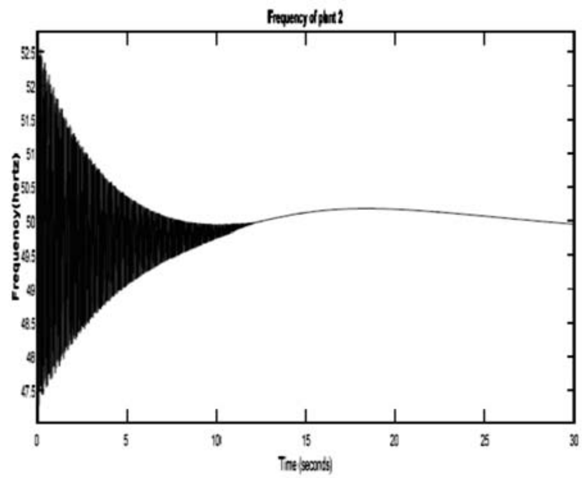

Fig. 8. Frequency of plant 2 after integration.

The following graphs show the frequency of plant 1 and plant 2 after integration. The frequency variation is ideal and also as in the same way as before integration. This is because during integration, only active power is being injected into the system which helps to maintain the frequency constant.

Table 1.Active powers before and after integration

Plant	*Active powers before integration(MW)*	*Active powers after integration(MW)*
1	125.4768	140.7534
2	103.3415	116.4978
3	113.1820	125.4305
4	124.4361	136.8343

6. CONCLUSION

In this paper, four thermal plants each of 900 MW capacities are simulated. The active power values and the frequency deviations are observed. Now, this is integrated with a 9 MW PV plant. Again, the active power values and the frequency deviations are observed. It is observed that the frequency deviations are constant before and after integration due to the injection of only active power into the grid and there is an increase in the active power in the grid. This proves the efficiency of the smart grid with PV integration.

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