ANALYSIS OF AC-SHUNTED GRID INTERFACED HYBRID PHOTOVOLTAIC/WIND ENERGY SYSTEM USING DYNAMIC SIMULATION MODEL

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Abstract: *In recent year there has been major development in solar photovoltaic (PV) and wind power technology. The increase in penetration levels of PV and wind power on power systems, several researches has been done on various fields in power systems involving system modeling, planning, control and dynamic studies. Due to the technological advancement and the mass production of the equipments like wind turbine generators, photovoltaic cell and power electronic devices, etc. The wind and photovoltaic generating systems have become cost effective for installation and operation. Because of the inherent nature of the wind energy system and the photovoltaic energy systems, the electric power generations from these systems are complementary. Therefore, the hybrid PV/wind power system has higher reliability to deliver continuous power. In case of hybrid isolated systems, the battery banks are necessary to feed the load. Usage of battery banks is not environment friendly as it is bulky in size, has higher costs, limited life cycles, and causes chemical pollution. So the best way to utilize this renewable power is in the grid connected mode of operation. The advantages of grid connected mode of operation are battery banks are not required and the generated power can be utilized locally and excess power can be fed to the grid [7].*

The objective of this paper is to create model and simulate ac-shunted grid-connected hybrid Photovoltaic/Wind power system interfaced through power electronic models using MATLAB/Simulink. The power conditioning system is implemented to control the power and feed the generated power to the local load and the grid. The performance is evaluated for different input variables and load variations by using simulate model.

Key words: *Renewable energy systems, wind model, PV model, DC/DC Boost converter, voltage source inverter (VSI), LC Filters, PQ controller, AC shunted system and MATLAB/Simulink.*

1. INTRODUCTION

Small-scale renewable energy systems are becoming more popular due to the recent development of small-scale energy technologies and global increasing of the energy demand [9]. Due to the increase in population and standard of living, the energy demand has increased [3]. The conventional power plants are providing the energy but fuel sources are at the verge of diminishing. Therefore renewable sources like wind, PV, fuel cell, micro turbine, wave and tidal energy, the power can be generated to meet load demand. In renewable energy sources the major contribution is from PV and wind energy systems. Due to mass production of the equipments like PV array, wind turbine generators, power electronics interface devices and the technological advancement in energy production from these sources are becoming reliable and economical day by day.

Among the renewable energy generation systems, the hybrid energy system (HES) generation is highly preferred. The hybrid energy system commonly consists of two or more non conventional or conventional energy sources. In hybrid energy systems, majorly two topologies are in use. One is hybrid wind power with fuel cell which can avoid the disadvantage of wind power intermittency, since fuel cell can act as an energy barrier and adjust the power output effectively. Another one is PV and

wind energy systems which are used because of their inherent nature. Due to the inherent nature of PV and wind energy systems, the hybrid PV and wind energy system is the best option to produce the reliable power [13].
In hybrid energy systems, the PV system gives DC output whereas a wind energy system gives AC output. For grid-connection of these two sources, the different power electronic interfaces are required. The AC-shunted grid-connected hybrid PV/wind power system is discussed below:

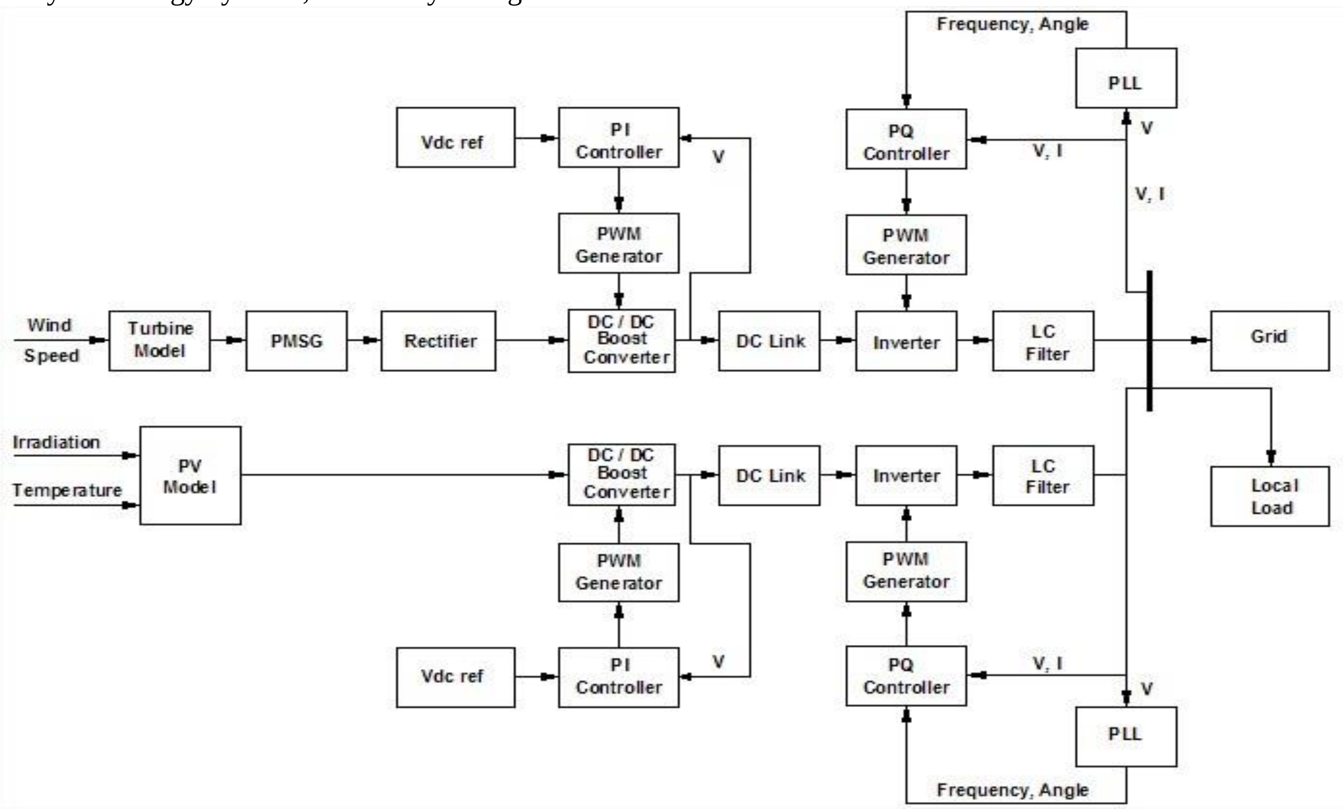

Fig. 1. Block diagram of simulated AC shunted hybrid PV and wind energy system

The Fig. 1. shows the block diagram of AC shunted PV and Wind hybrid energy system. Here the model of wind turbine is connected to Permanent magnet synchronous generator (PMSG). The AC output of PMSG is rectified by using uncontrolled rectifier. The rectified output is controlled by DC/DC boost converter. Output of DC/DC boost converter is connected to VSI through DC link. The VSI is connected to grid through LC filter and it is controlled by PQ controller.
The DC output of modeled photovoltaic array is connected to DC/DC boost converter to control the DC voltage. Then it is connected to VSI through DC link. The VSI is connected to grid through LC filter and it is controlled by separate PQ controller as shown in Fig 1.

2. POWER CONDITIONING SYSTEM FOR WIND AND PV HYBRID ENERGY SYSTEM

2.1 THE DC/DC BOOST CONVERTER

The boost converter is used to get regulated DC output from unregulated DC sources from PV and wind energy systems. The block diagram and design are as shown in Fig. 2:

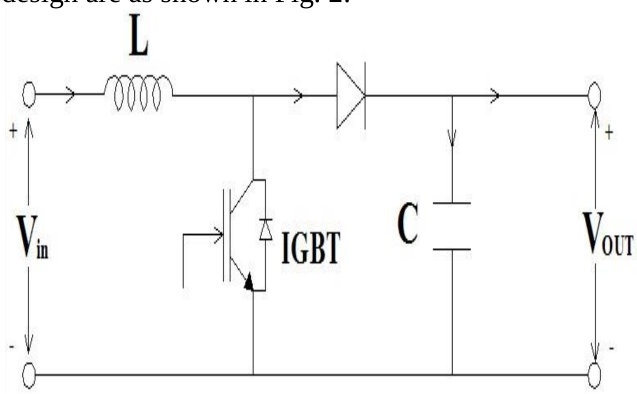

Fig. 2. Block diagram of DC/DC boost converter

The main components parameters of DC-DC boost converter are calculated by using the following equations: [1]

$$D = 1 - \frac{V_{in}}{V_{out}} \quad (1)$$

$$R = \frac{{V_{out}}^2}{P_{in}} \quad (2)$$

$$L = \frac{D(1-D)^2 R}{2 * f_s} \quad (3)$$

$$C \geq \frac{V_{out} * D}{R * f_s * \Delta V_{out}} \quad (4)$$

Where, D is Duty cycle, V_{in} is Input voltage, out is Output voltage, R is Load resistance and fs is Switching frequency. The converter is tuned using PI controller [5].

2.2 THREE PHASE INVERTER

The inverter is of typical three phase six switch pulse width modulation (PWM) voltage source inverter. The voltage source inverter (VSI) converts the power from the dc voltage source to three phase ac outputs with 120^o phase displacement. PWM is modulation technique used to control and shape of the VSI output voltage. VSI can be typically controlled by two ways. The active and reactive power control scheme (PQ control), when the inverter is operated to meet grid connected operation and active power and voltage scheme (PV control), when the inverter is operated to meet isolated operation [10 & 12]. Here PQ control scheme is implemented using park transformation in Simulink.

2.3 DESIGN LC FILTER

The waveform quality of the sensitive load is improved by putting an LC filter at the output of VSI.

According to thumb rule of control theory, if fundamental frequency is 50Hz, resonant frequency is 500Hz and the switching frequency is 5000Hz [8].

The resonance frequency is given by,

$$\omega_r = \frac{1}{\sqrt{L_f * C_f}} \quad (5)$$

Where, ω_r is Resonance frequency, L_f is Filter inductance and C_f is Filter capacitance.

3. RESULTS

Using simulated model the following performance study has been done:

3.1 STEADY STATE

In this case the inputs like irradiation, temperature, wind speed and load are kept constant for simulation. The irradiation $1000W/m^2$, temperature 25^0C, wind seed 12m/s and load parameters as 125kW active power, 41.08kVAR reactive power are given for simulation. The results are as follows:

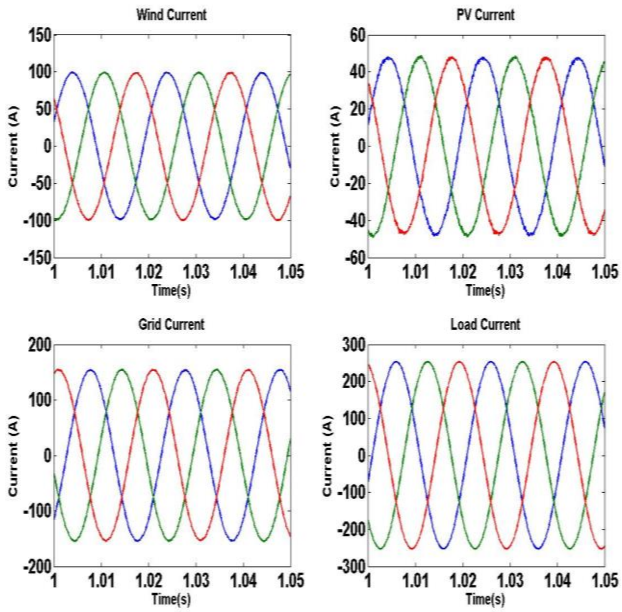

Fig. 3. 1. Inverter output currents

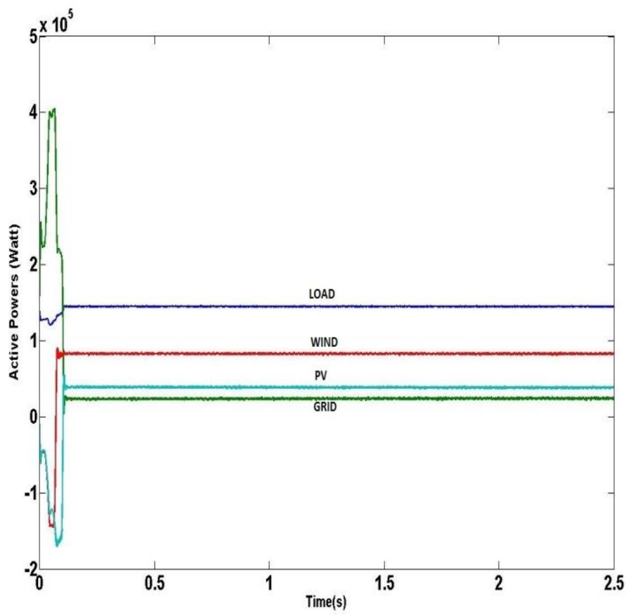

Fig. 3. 2. Active powers

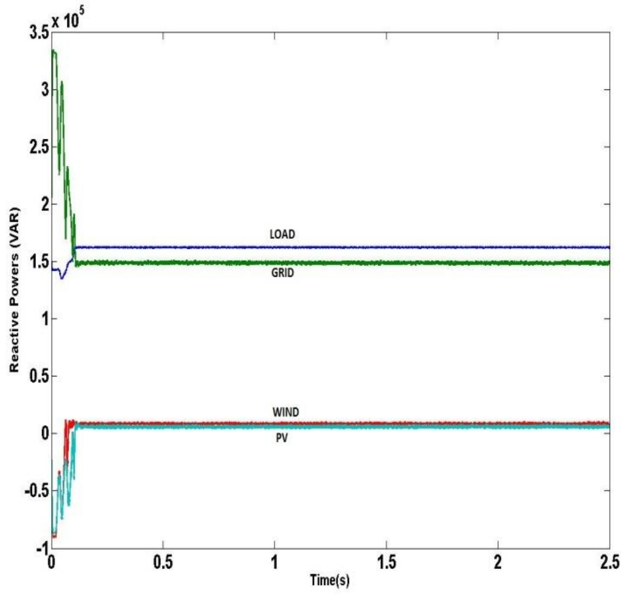

Fig. 3. 3. Reactive powers

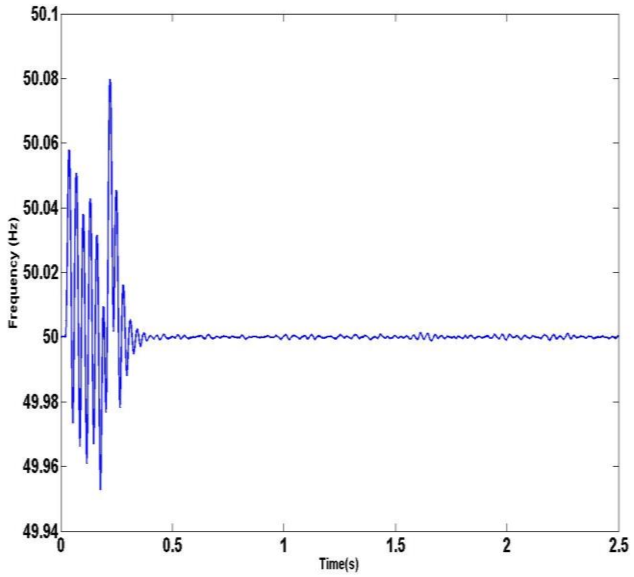

Fig. 3. 4. Frequency response

From the Fig. 3.1. – Fig. 3.4, all currents, active powers and reactive powers are constant. In frequency response, frequency is within the limit of synchronization parameter as mentioned in (IEEE 1547 2008) i.e; (49.3-50.5)Hz for >30kW rated energy systems [4].

3.2 VARIABLE LOAD

In this case the load is increased during 1.7s. Remaining parameters are kept constant. The results are as follows:

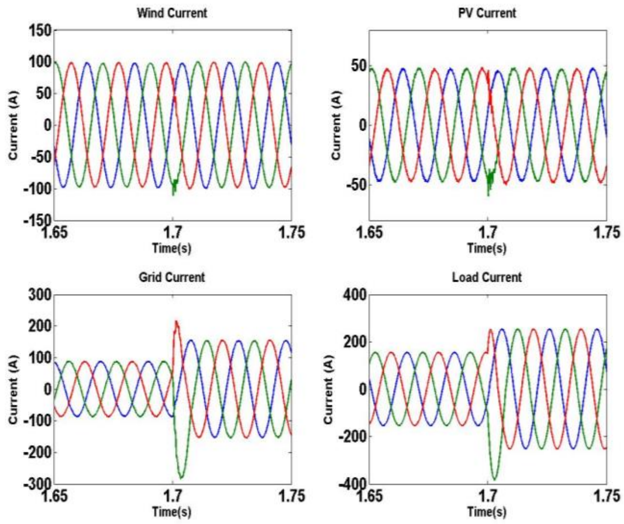

Fig. 4. 1. Inverter output currents

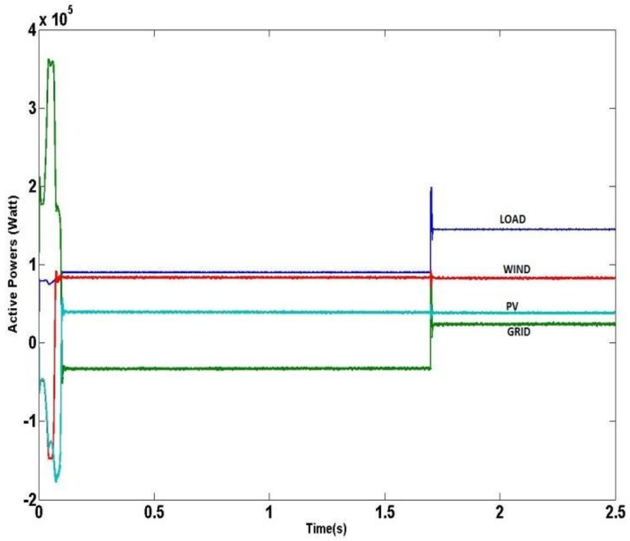

Fig. 4. 2. Active powers

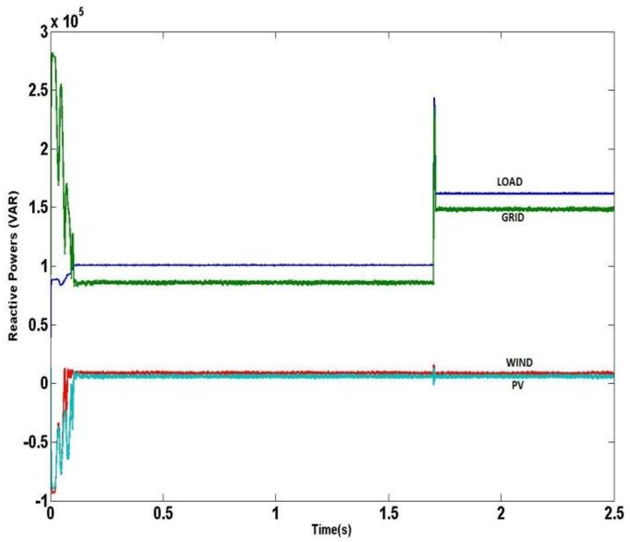

Fig. 4. 3. Reactive powers

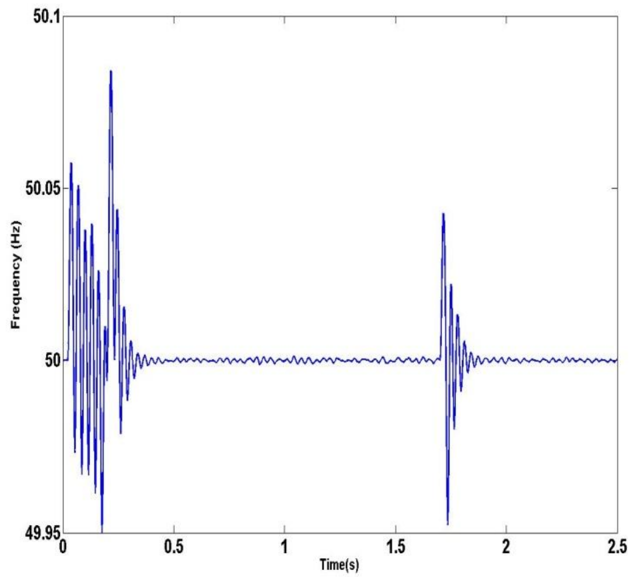

Fig. 4. 4. Frequency response

From the Fig. 4.1. – Fig. 4.4, the increase in load at 1.7s is shared by the grid can be seen in above currents, active power and Reactive power results. In frequency response, frequency is within the limit of synchronization parameter as mentioned in (IEEE 1547 2008) i.e; (49.3-50.5)Hz for >30kW rated energy systems [4].

3.3 VARIABLE GENERATION

3.3.1 WIND SPEED VARIATION

In this case wind seed 12 m/s during (0 - 0.8)s and 10m/s during (0.8 - 2.5)s are taken. The results are as follows:

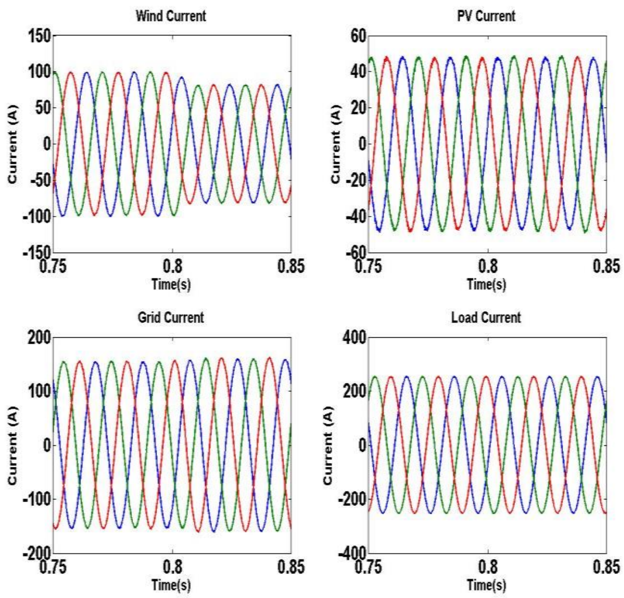

Fig. 5. 1. Inverter output currents

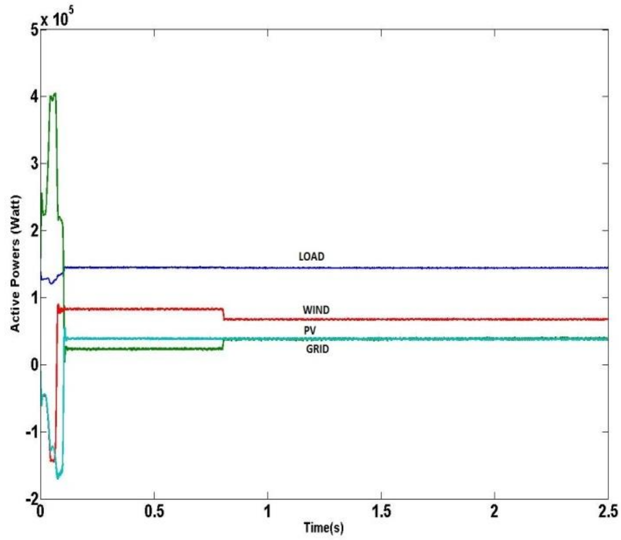

Fig. 5. 2. Active powers

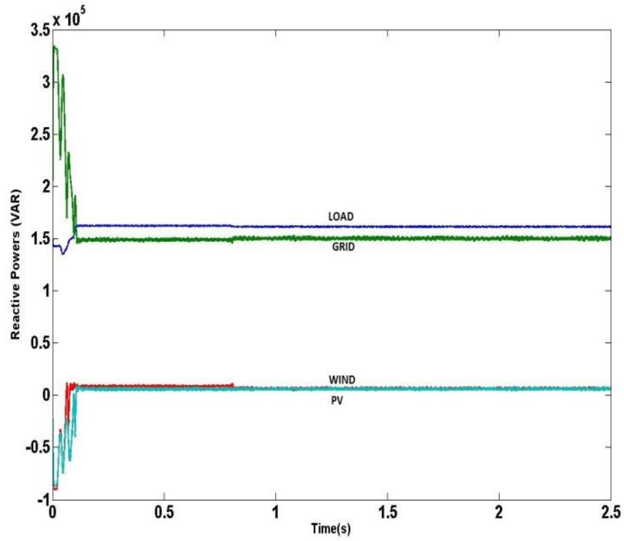

Fig. 5. 3. Reactive powers

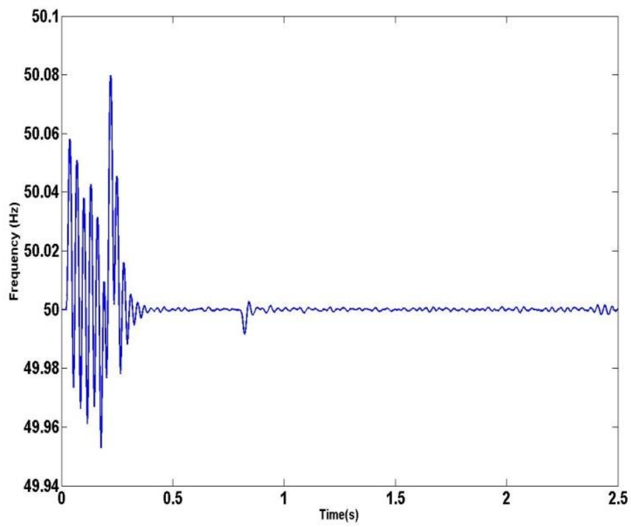

Fig. 5. 4. Frequency response

From the Fig. 5.1. – Fig. 5.4, the decrease in wind speed reduces the wind output and the same is shared by grid can be seen. In frequency response, frequency is within the limit of synchronization parameter as mentioned in (IEEE 1547 2008) i.e; (49.3-50.5)Hz for >30kW rated energy systems [4].

3.3.2 IRRADIATION VARIATION

In this case Irradiation 1000W/m^2 during (0 - 1.4)s and 1400W/m^2 during (1.4 - 2.5)s are given. The results are as follows:

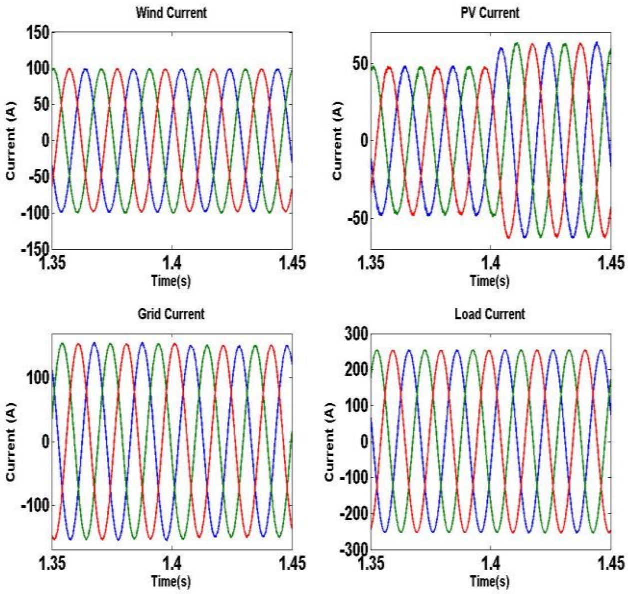

Fig. 6. 1. Inverter output currents

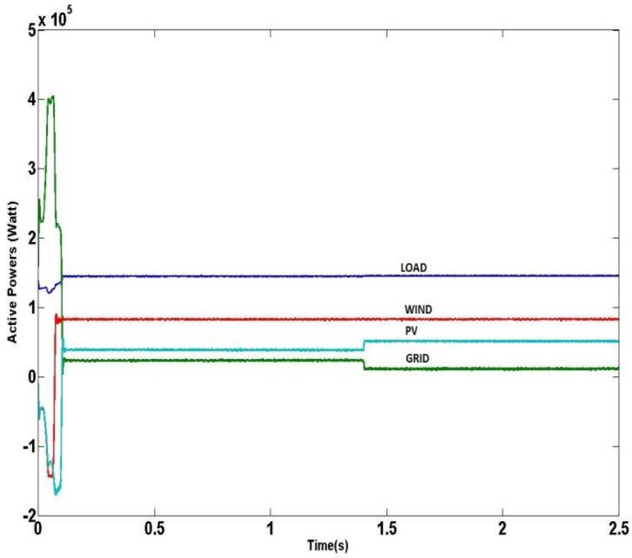

Fig**.** 6. 2. Active powers

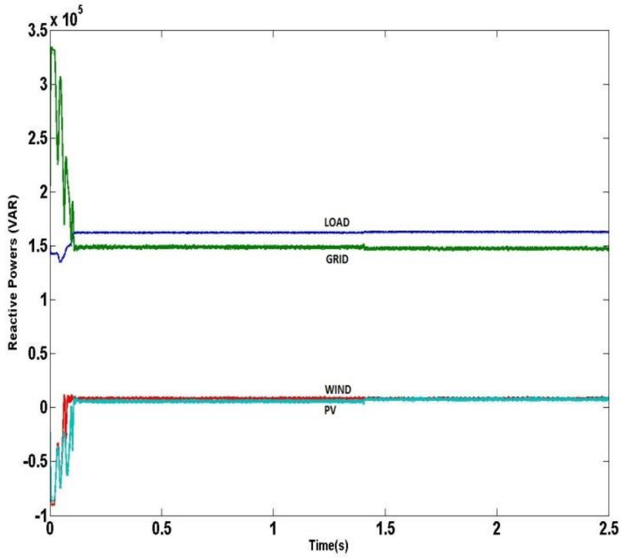

Fig**. 6**. 3. Reactive powers

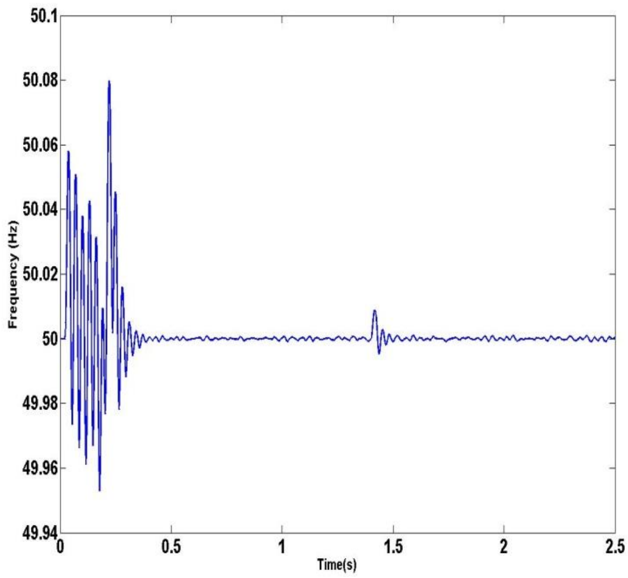

Fig. 6. 4. Frequency response

From the Fig. 6.1. – Fig. 6.4. The increase in irradiation increases PV output and the same is fed to the grid can be seen. In frequency response, frequency is within the limit of synchronization parameter as mentioned in (IEEE 1547 2008) i.e; (49.3-50.5)Hz for >30kW rated energy systems [4].

6. CONCLUSIONS

The simulation results shows that, using a VSI and PQ control strategies, it is possible to have a good response of grid-connected hybrid energy system.

The modeled AC shunted hybrid PV and wind energy systems meets the limit of synchronization parameter as mentioned in IEEE 1547-2008.

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