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Simulation and Performance Study of Grid-connected Wind and Photovoltaic Hybrid Energy System

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Hybrid energy system (HES) includes several (two or more) energy sources with appropriate energy conversion technologies connected together to feed power to local load/grid. HES allows a wide variety of primary energy sources, frequently generated from renewable sources as the stand alone system for rural electrification and also for grid extension. The objective of this work is to model photovoltaic (PV) & wind grid connected HES using Matlab/Simulink. The model is useful for simulation of PV & wind grid connected HES. Blocks like wind model, PV model, energy conversion system and loads are implemented and the results of simulation model are also presented.

Keywords: *PV model, Wind model, Hybrid energy conversion system, PQ control and LC filter.*

1.0 INTRODUCTION

HES are inter-connected from wind, photovoltaic and fuel cell to generate power to local load and connecting to grid/micro grids. Because of the inherent nature of the solar energy and the wind energy, the electric power generations of the PV array and the wind turbine are complementary. The hybrid PV & wind power system has higher reliability to deliver continuous power than individual source. In order to draw maximum power from PV arrays or wind turbines and to deliver stable power to the load, a substantial battery bank is needed. However, the usage of battery is not an environmental friendly and there are some disadvantages like, heavy weights, bulky size, high costs, limited life cycles, and chemical pollution. Therefore one of the ways to utilize the electric energy produced by the PV array and wind turbine systems is by directly connecting them to the grid [2-9]

2.0 INTEGRATION OF PV & WIND HES TO GRID

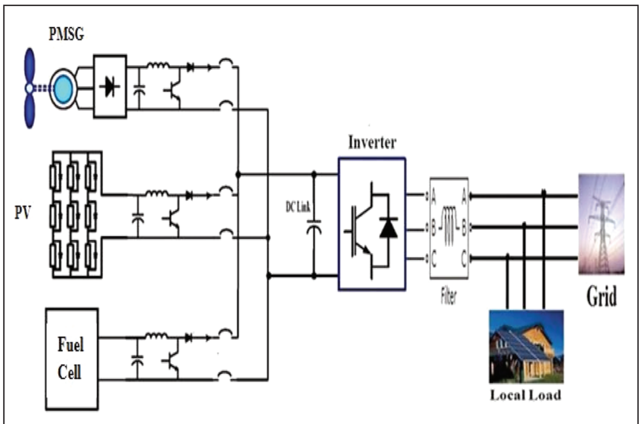

FIG. 1 CONFIGURATION OF HES

The configuration of hybrid energy system is shown in Figure 1, it contains wind, photovoltaic and fuel cell power system connected to the grid. But in general case hybrid energy system can be a combination of different renewable/non renewable energy systems.

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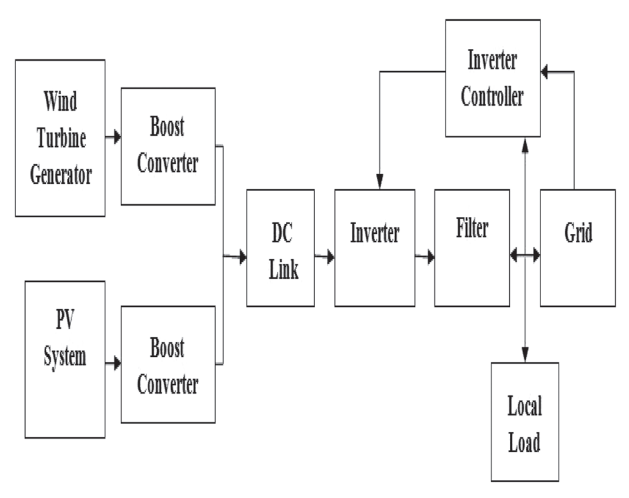

FIG. 2 BLOCK DIAGRAM OF MODELED GRID CONNECTED PV & WIND HES [9]

The Block diagram of modeled grid connected PV & wind HES consists of PV model with boost converter, wind model with boost converter connected to the grid with power electronic interface (Figure 2). Power electronic interface consists of DC link connected to voltage source inverter (VSI), VSI output is connected through LC filter. The inverter is controlled by PQ control.

3.0 SIMULATION STUDY

HES is implemented using MATLAB/Simulink and three simulation cases are studied, namely:

a. Steady operation.

b. Variation of Load.

c. Single-Line Fault.

a. Steady operation

When the system is in steady state, solar irradiation, temperature, wind speed and load are kept constant. The solar irradiation 1000 W/m^2, temperature 25^{0}C, wind seed 12 m/s and load parameters 100 kW active power, 60 kVAR reactive power are given as inputs to the simulated model and 415 Vr.m.s, 50 Hz is taken for grid parameter. The results are as follows:

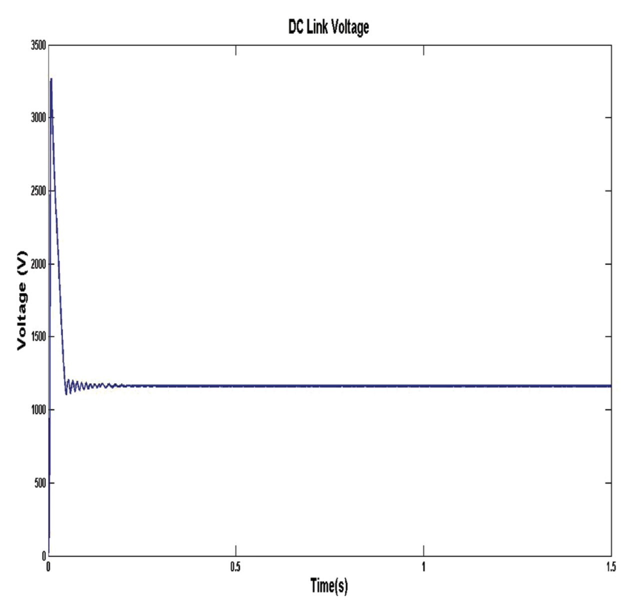

FIG. 3(A) DC LINK VOLTAGE

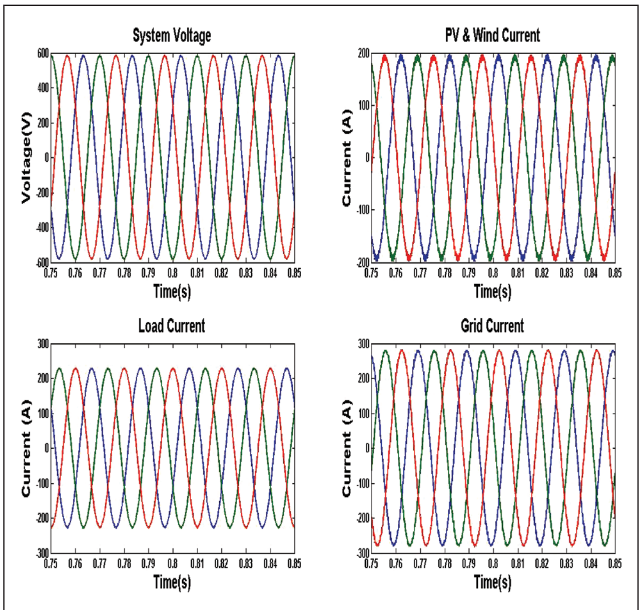

FIG. 3(B) VOLTAGE & CURRENTS AT AC BUS

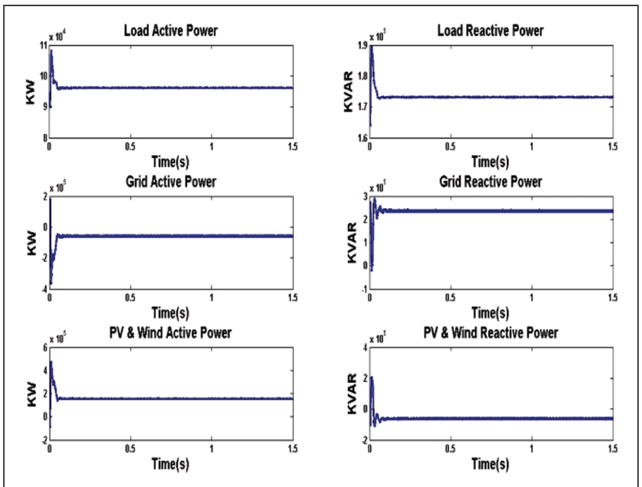

FIG. 3(C) ACTIVE & REACTIVE POWERS

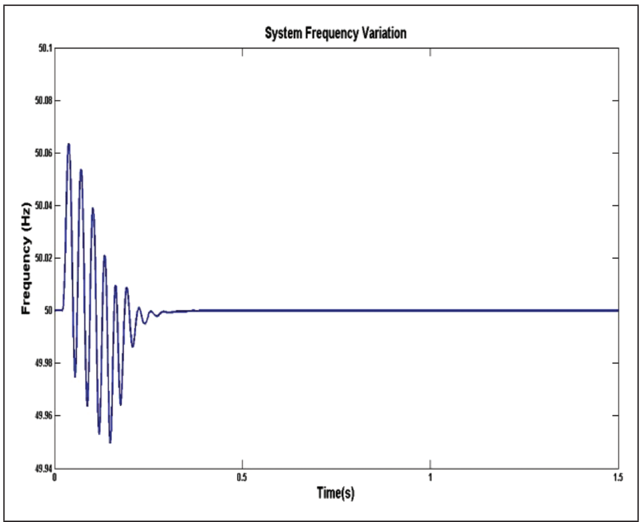

FIG. 3(D) FREQUENCY VARIATION

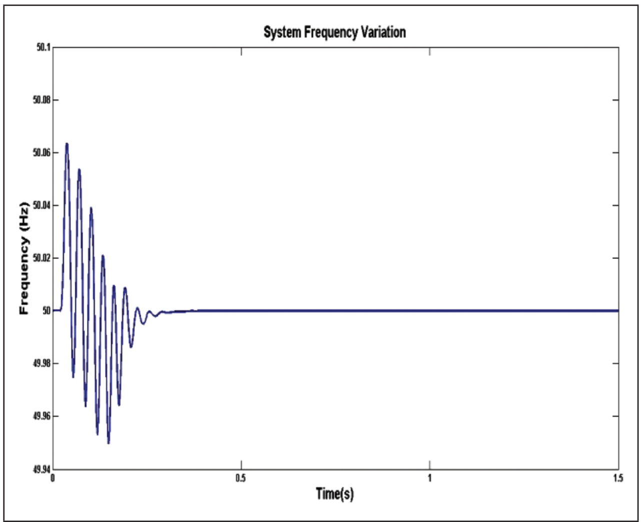

FIG. 4(A) DC LINK VOLTAGE

From Figure 3(a)–3(d), the steady state operation of PV & wind HES is studied. In steady state operation in Figure 3(a) (it is shown that, the DC Link voltage is constant throughout the operation after it reaches steady state value. In Figure 3(b), the voltage & currents values are constant throughout the simulation due to constant parameters. In Figure 3(c), the active & reactive powers are constant throughout operation after it reaches steady state. The Figure 3(d) shows the system frequency variation throughout the simulation time & it is within the limit of grid connection requirement, which is specified in the standard IEEE-1547 [4].

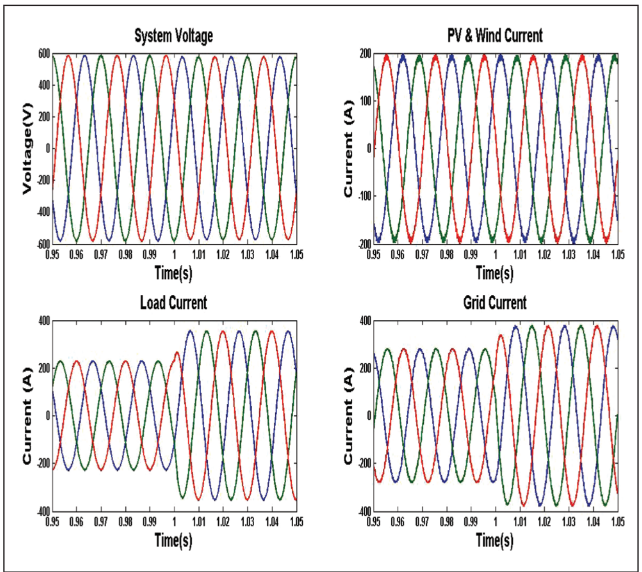

FIG. 4(B) VOLTAGE & CURRENTS AT AC BUS

b. Variation of Load

When the system is under load variation state, solar irradiation, temperature and wind speed are kept constant & load is changed at 1s. The solar irradiation 1000 W/m^2, temperature 25°C, wind seed 12 m/s and load parameters 100 kW active power, 60 kVAR reactive power (from 0s-1s), 150 kW active power, 90 kVAR reactive power (from 0s-1s), are given as inputs to the simulated model and 415 Vr.m.s, 50 Hz is taken for grid parameter. The results are as follows:

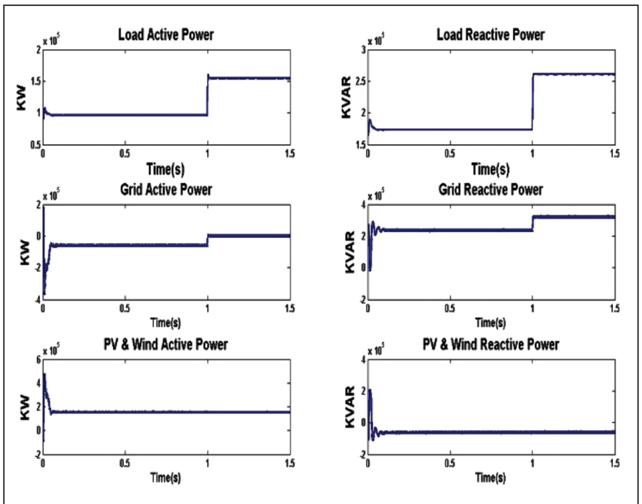

FIG. 4(C) ACTIVE & REACTIVE POWERS

From the Figure 4(a)–4(d), the load variation operation of PV & wind HES is studied. From Figure 4(a) it is shown that, the DC Link voltage is constant irrespective of system load variation.

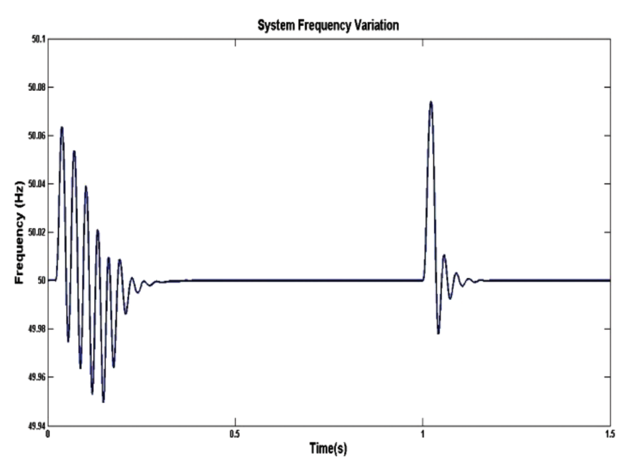

FIG. 4(D) FREQUENCY VARIATION

In Figure 4(b), PV & wind current & the system voltages are constant; the change in load current due to load variation is shared by the grid as shown. In Figure 4(c), load active & reactive powers change at 1s from 100 KW to 150 KW & 60 kVAR to 90 kVAR that increased demand is shared by grid as shown. The Figure 4(d) shows the system frequency variation throughout the simulation time & it is within the limit of grid connection requirement, which is specified in the standard IEEE-1547 [4].

c. Single- Line Fault:

In this case the single line to ground fault is applied to the system during 0.5 s to 0.55 s. 12 m/s wind speed, 1000 W/m^2 solar irradiation, 25°C temperature and the load value is kept constant, that is at 100 kW active power, 60 kVAR reactive power these values are given for simulation. 415 Vr.m.s, 50 Hz is taken for grid parameter. The results are as follows:

From the Figure 5(a)–5(d), the effect of fault occurrence for the system can be studied. In this operation from Figure 5(a) it can be realized that, the DC Link voltage is nearly constant throughout the simulation after it reaches steady state value irrespective of fault in the system. In Figure 5(b), However, during fault period, voltages and currents of the ac line are all changing: phase-a voltage reduces to zero, current value rises to very large. In Figure 5(c), active and reactive power values are changed due to occurrence of fault.

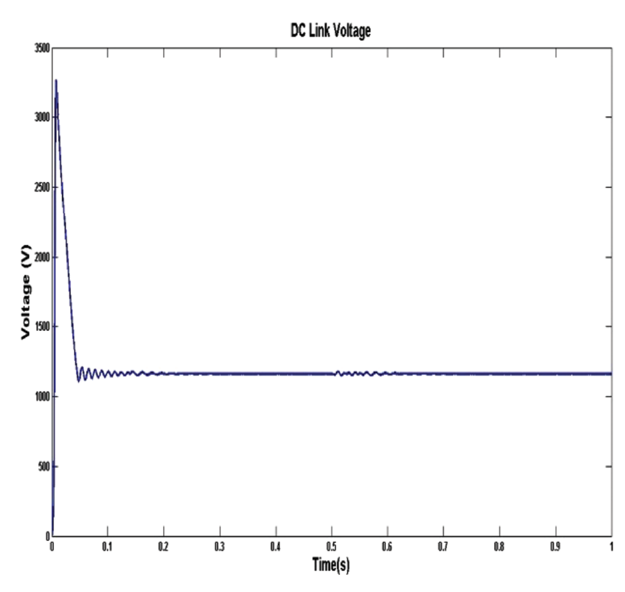

FIG. 5(A) DC LINK VOLTAGE

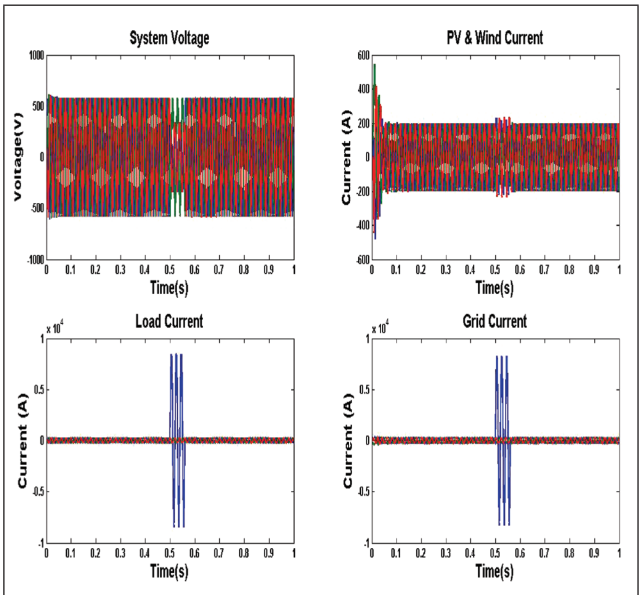

FIG. 5(B) VOLTAGE & CURRENTS AT AC BUS

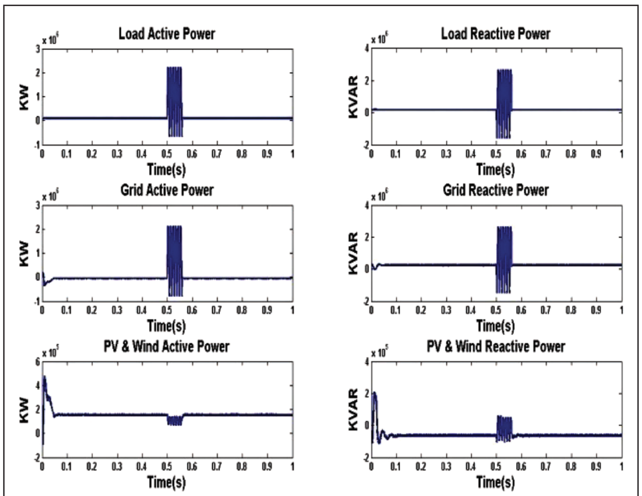

FIG. 5(C) ACTIVE & REACTIVE POWERS

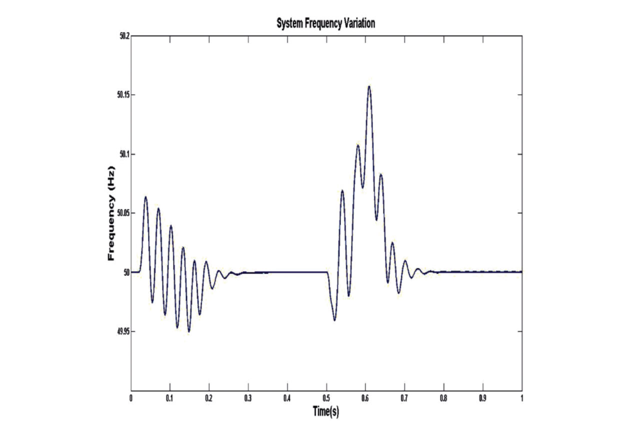

FIG. 5(D) FREQUENCY VARIATION

The Figure 5(d) shows the system frequency variation throughout the simulation time & it is within the limit of grid connection requirement, which is specified in the standard IEEE-1547 [4].

4.0 CONCLUSIONS

1. In this paper the model of PV & wind HES is done by using Matlab/Simulink.
2. The performance study is done for above modeled system.
3. The performances of modeled system are meeting the RES grid interconnection requirements which are specified in IEEE 1547.
4. It can be concluded that the grid connected HES topology is better than stand alone HES, because grid connected HES system requires no battery system and it can supply local load, the remaining power can be fed to the grid. So grid connected HES are eco-friendly systems and there will not be any power interruptions, like in standalone systems.

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