The Journal of CPRI,
Vol. 10, No. 3, September 2014 pp. 525-530

Performance study of grid-connected wind and photovoltaic hybrid energy system under variation of generation

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The aim of this work is to analyze typical configuration of grid connected wind and photovoltaic hybrid energy system. Nowadays hybrid energy systems (HES) are widely used because of inherent problems with solar energy. HES includes several (two or more) energy sources with appropriate energy conversion technologies connected together to feed power to local load/grid. These allowa wide variety of primary energy sources, frequently generated from renewable sources as the stand alone system for rural electrification and also for grid extension. Mainly the work presents the system response under generation variation of HES with grid interface. Application represents a useful tool in research activity and also in teaching.

Keywords: *Renewable energy systems,Photovoltaic(PV) systems, Wind energy system and grid connected energy system.*

1.0 INTRODUCTION

Presently more renewable energy systems have been implemented in power generation sector due to the environmental protection regulations and the shortage of conventional energy sources. PV generation is the technique which uses photovoltaic cell to convert solar energy to electric energy. Photovoltaic energy is important as a renewable energy source because of its distinctive advantages, such as simple configuration, no fuel cost, and low maintenance cost, etc. However, the disadvantage is that photovoltaic generation inherently depends upon weather conditions. Thus, energy storage element is necessary to help get stable and reliable power from PV system to meet regular loads. To improve both steady and dynamic behaviors of the whole generation system, the concept of grid connected HES comes into picture.

HES are inter-connected renewable and non renewable energy sources like wind, photovoltaic, fuel cell and diesel generators to feed 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. HES are necessary in order to draw maximum power from PV arrays or wind turbines and to deliver stable power to the load. The PV with fuel cell generation system is another preferable option in hybrid energy generation.

To avoid battery requirement to store energy in renewable energy generation system, grid connected system is the best possible solution.

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The advantages of grid connected systems are it is environmental friendly due to absence of battery bank and uninterrupted supply can be given from the grid even in the absence of renewable energy generation.

The objective of this paper is to discuss about grid-connected wind and photovoltaic HES and to present performance of the modeled system under variation of generation condition.

2.0 LITERATURE REVIEW

Modeling of permanent magnet synchronous generator (PMSG) has implemented in MATLAB/Simulink for variable-speed directly-driven wind turbine power generation architecture in [1]. For variable speed wind turbine usage of PMSG is good option it gives a wide range of speed variation and it offers better performance due to higher efficiency and less maintenance and it does not need rotor supply. PMSG can be used without a gearbox, which implies a reduction of the weight of the nacelle and reduction of costs.

Basics of electrical and power electronic aspects involved with modern wind generation systems, including modern power electronics and converters, electric generation and conversion systems for both fixed speed and variable speed systems are discussed in [2]. A broad discussion regarding control techniques for wind turbines, configurations of wind farms, and the issues of integrating wind turbines into power systems has done.

The IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems has been discussed by Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage [3]. Mainly the required parameters are discussed for grid interactive renewable energy sources implementation.

Modeling of a photovoltaic and wind hybrid system has done using Matlab/Simulink in [4]. The model is useful for simulation of a hybrid photovoltaic and wind energy systems connected to a grid. Blocks like wind model, photovoltaic model, energy conversion and load are implemented and the results of simulation are presented.

Design and analysis of an experimental study on Digital Signal Processor (DSP) controlled single-phase Pulse Width Modulation (PWM) inverter are presented in [5]. The waveform quality of the sensitive load is improved by putting an LC filter at the output of the PWM inverter. The design of LC filter according to the thumb rule of control theory is discussed.

Modeling of photovoltaic arrays has implemented in [6]. The method is used to obtain the parameters of the array model using information from the data sheet. The photovoltaic array model can be simulated with any circuit simulator. The equations of the model are presented in details and the model is validated with experimental data and simulation examples are presented.

Modeling, simulation and experimental study of a fuel cell power plant suitable for standalone application as well as micro-grid/grid interface has implemented in [7]. A single stage PWM inverter is selected as power electronic interface between fuel cell and grid. The LC filter design has discussed in this paper. Over all simulation model is developed in MATLAB.

The control strategy of power converters for micro grids (MG) has implemented in [8]. The renewable sources and the storage system are connected on DC-bus which is interconnected with a main grid trough VSI. The attention focuses on the control technique of the VSI during grid connected. Renewable energy sources with MG have been investigated on simulation using a MATLAB/Simulink model.

Efficient power electronic interface for wind energy generation system has discussed in [9]. This paper is containing the typical Cp curve for a wind turbine, power-wind speed characteristics for a wind turbine and generator systems for wind turbines like fixed-speed wind turbines and variable-speed wind turbines. The different turbine generator configuration for wind energy system has discussed.

3.0 INTEGRATION OF PV & WIND HES TO GRID

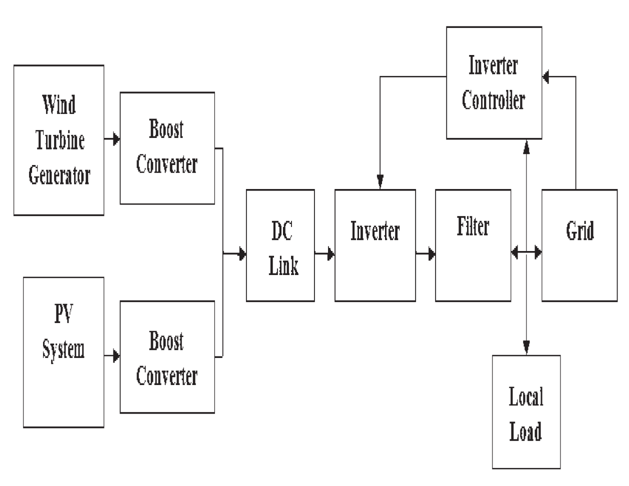

FIG. 1 BLOCK DIAGRAM OF MODELED GRID CONNECTED PV & WIND HES

The Block diagram of modeled grid connected PV & wind HES (Figure 1) consists of PV model with boost converter, wind model with boost converter connected to the grid with power electronic interface. 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.

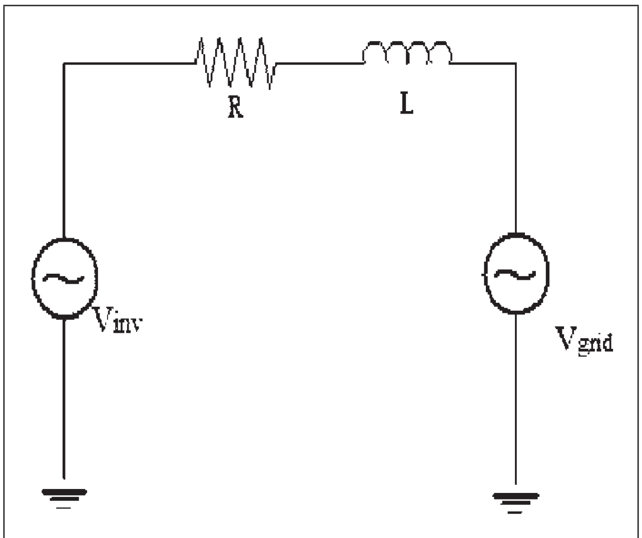

FIG. 2 POWER FLOW BETWEEN A VSI AND GRID [9]

Where,

Vi_{nv} = Inverter voltage.

V_{grid}= Grid voltage.

R = Resistance of filter, transformers and transmission line.

L = Inductance of filter, transformers and transmission line.

The Figure 2 shows power flow between a VSI and grid, where the impedance represents the combined filter, transformer and transmission line inductance. The active and reactive power flows from the converter are controlled by magnitude and phase of the converter output voltages relative with grid parameters. The active power flow is controlled by varying the phase difference and reactive power flow is by varying the magnitude of inverter output. The phase difference and amplitude are varied with reference of constant grid voltage. The control of modulation index controls amplitude, and synchronization and phase angle control of modulating sine wave controls the phase variation. The real and reactive power delivered to the utility is given by following relations,

$$P = \frac{E * V_S}{Z} * \cos(\theta_Z - \delta) - \frac{E^2}{Z}\cos(\theta_Z) \quad ....(1)$$

$$Q = \frac{E * V_S}{Z} * \sin(\theta_Z - \delta) - \frac{E^2}{Z}\sin(\theta_Z) \quad ....(2)$$

Where,

$$Z = \sqrt{R^2 + X^2}$$

$$\theta_Z = tan^{-1}\frac{X}{R}$$

Inverter can be controlled typically 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. In this work the PQ control method is used to control the inverter.

4.0 SIMULATION STUDY

HES are implemented using MATLAB/Simulink and performance study has been presented under variation of HES generation with change of solar irradiation, temperature and wind speed. The load value is kept constant. The wind speed is changed from 12 m/s to 14 m/s at 0.7s, temperature is changed from 250C to 300C at 0.9s, solar irradiation is changed from 1000 W/m^2 to 1800 W/m2 at 1.25s, and load parameters 100 kW active power, 60 kVAR reactive power are given as inputs to the simulated model and 415 V, 50 Hz is taken for grid parameter. The results are as follows:

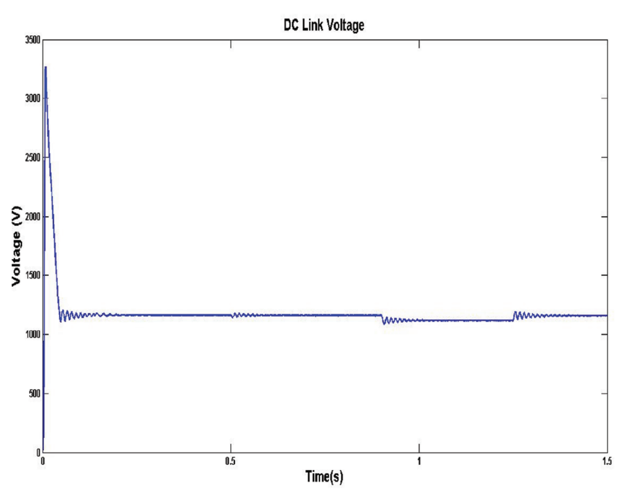

FIG. 3(A) DC LINK VOLTAGE

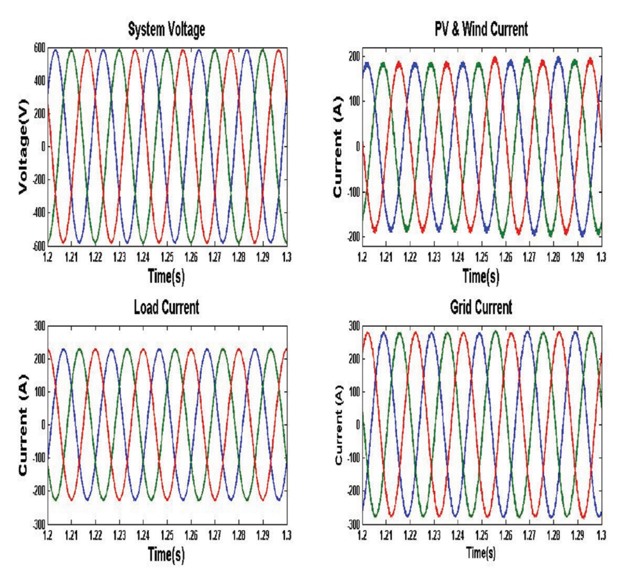

FIG. 3(B) VOLTAGE & CURRENTS AT AC BUS

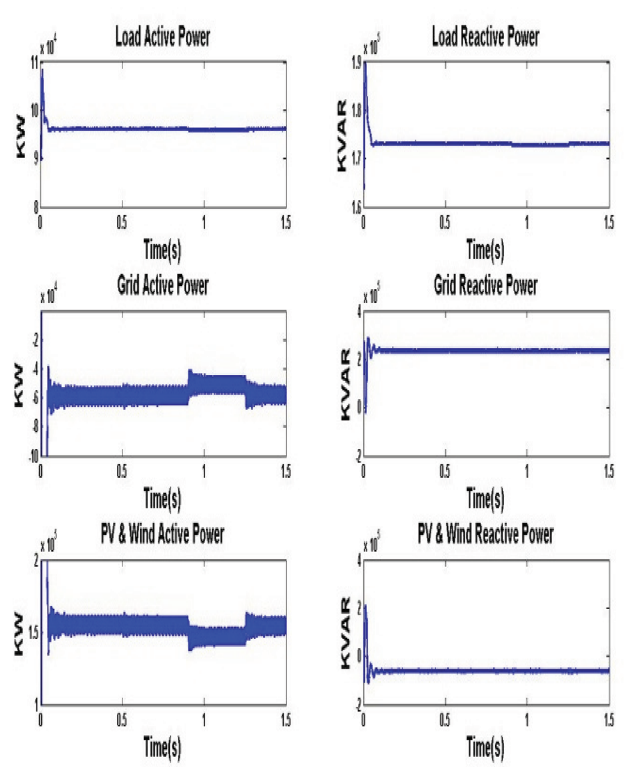

FIG. 3(C) ACTIVE & REACTIVE POWERS

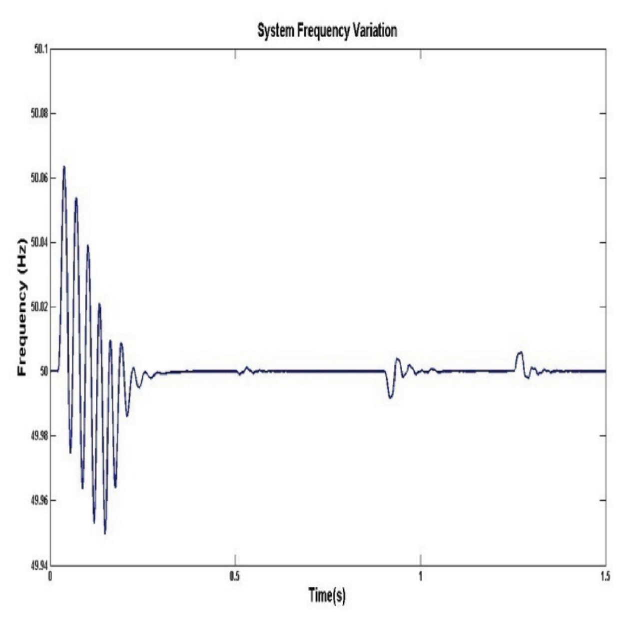

FIG. 3(D) FREQUENCY VARIATION

From the Figure [3(a)–3(d)], the variation of HES generation of PV & wind HES is studied. From Figure 3(a) it can be realized that, the variation in DC Link voltage is with in tolerable limit after it reaches steady state value. In Figure 3(b), load current & system voltages are constant, the increase in PV & wind current due to increase in irradiation at 1.25s, is shared to grid as shown.

In Figure 3(c), PV & wind reactive power is decreased at 0.9s due to decrease in temperature &PV & wind active power is increased at 1.25s due to increase in irradiation. 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.

5.0 CONCLUSIONS

The performances of modeled system are meeting the RES grid interconnection requirements which are specified in IEEE 1547, under generation variation of HES with grid interface.

Controlling of PID controller by fuzzy or ANN technique can be implemented to get constant DC link voltage irrespective of variation of generation.

REFERENCES

[1] Alejandro Rolan, Alvaro Luna, Gerardo Vazquez and Gustavo Azevedo, "Modeling of a Variable Speed Wind Turbine with a Permanent Magnet Synchronous Generator", IEEE International Symposium on Industrial Electronics, 2009.

[2] Frede Blaabjerg and Zhe Chen, "Power Electronics for Modern Wind Turbines", A Publication in the Morgan & Claypool Publishers' Series, 2006.

[3] IEEE 1547, "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems". IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage, 2008.

[4] Jitendra Kasera, Ankit Chaplot and Jai Kumar Maherchandani, "Modeling and Simulation of Wind-PV Hybrid Power System using Matlab/Simulink", IEEE Students' Conference on Electrical, Electronics and Computer Science, 2012.

[5] Mehmet TUMAY K Çagatay BAYINDIR Mehmet Ugraş CUMA and Ahmet TEKE, "Experimental Setup for a DSP Based Single-Phase PWM Inverter" IEEE, 2005.

[6] M G Villalva, J R Gazoli, E and Ruppert F, "Modeling and Circuit-Based Simulation of Photovoltaic Arrays", Brazilian Journal of Power Electronics Vol. 14, no. 1, pp. 35-45, 2009.

[7] Shailendra Jain, Jin Jiang, Xinhong Huang and Srdjan Stevandic, "Modeling of Fuel Cell Based Power Supply System for Grid Interface", IEEE, 2011.

[8] Santhosha Kumar A, "Modeling and simulation of fuel cell based distributed generation system", Project report submitted in electrical and electronics department at national institute of technology Karnataka, Chapter 3, 30-33, 2010.

[9] Zhe Chen, Frede Blaabjerg and Soeren Baekhoej Kjaer, "Power Electronics as Efficient Interface in Dispersed Power Generation Systems", IEEE Transactions on Power Electronics, vol. 19, no. 5, September, 2004.