

Modelling and Synchronization of Wind/PV Hybrid System with the Grid Using PLL

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ABSTRACT: In earlier days, fossil fuel was considered as the main source for the production of electricity. Since it has adverse effect on the environment this fossil fuel has been replaced by renewable energy systems. Renewable energy sources offers clean and efficient energy obtained from sun, wind and some other sources. In this paper, a new model of hybrid PV/WIND system is developed. The synchronization of hybrid system with the grid is done by using DSOGI PLL. Hybridizing solar and wind power produces constant power. It provides power to remote location. The modelling and simulation is done in MATLAB/SIMULINK software. The performance characteristics of hybrid system and synchronization to the grid are also presented.

KEYWORDS: wind power, solar power, DSOGI PLL, synchronization, MATLAB.

I. INTRODUCTION

The availability of fossil fuel for the electric power generation has limited nowadays. This has led to the urgent search of other alternative sources. Renewable energy sources are those resources that can be used again even after harnessing the energy. The main renewable sources of energy are solar, wind, hydro, biomass etc. The most recently used renewable sources are wind and solar. Wind energy and solar energy are non-polluting and site dependant source of energy. Hybrid power system is a combination of two or more energy sources. The power can be provided even to the remote locations. Hybrid system is very much useful for continuous power generation. The wind energy conversion system converts the input wind to AC power which is directly fed to the grid. The PV system converts the input solar radiation into DC power. The combination of these two sources makes it a hybrid system. The hybrid system is synchronized to the power grid using PLL. Combined wind and solar systems are becoming more popular for power generation applications, due to advances in renewable energy technologies [1].

PLL stands for 'Phase-Locked Loop'. It is a closed loop frequency control system, which functioning is based on the phase sensitive detection of phase difference between the input and output signals of the controlled oscillator (CO). The Phase Locked Loop method of frequency synthesis is now the most commonly used method of producing high frequency oscillations in modern communications equipment.. The frequency and the phase angle of the input system should match with that of the grid requirements. The synchronization process is done by PLL. It matches the frequency of the input system with that of the grid. Thus, it reduces the error and improves the efficiency. The use of Phase Locked Loops (PLLs) for grid synchronization provides better response and it has been discussed in [2-3].

In this paper, modelling of wind and solar power sources and synchronization with grid is proposed. The PV system and the wind system are modelled. It is then combined to form a hybrid system. This hybrid system is synchronized with the grid using PLL. The DSOGI-PLL is modelled and it is connected with the hybrid system for synchronization with the grid. The voltage magnitude and frequency of the system is analysed. The modelling is done by using MATLAB/SIMULINK software.

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II SYSTEM CONFIGURATION

The configuration of proposed wind-PV hybrid system is shown in Fig.1. The hybrid system is constituted by a wind power generation branch and a PV power generation branch. The wind turbine is composed of permanent magnet synchronous generator and the PV system is composed of PV panels. The wind-PV hybrid generation system can not only harness more energy from nature but also allow the wind power and the PV power to complement one another to some extent between day and night while compared with an individual generation system (the wind power or the PV power) [4]. The grid interconnection converts the variable frequency and magnitude outputs from the hybrid wind/PV system to the synchronous frequency of the utility grid. These variable frequency and magnitude of the output voltages are converted to the DC voltage using DC link. The converter connected to the grid converts these developed DC voltage to the synchronous voltage of the grid [5].

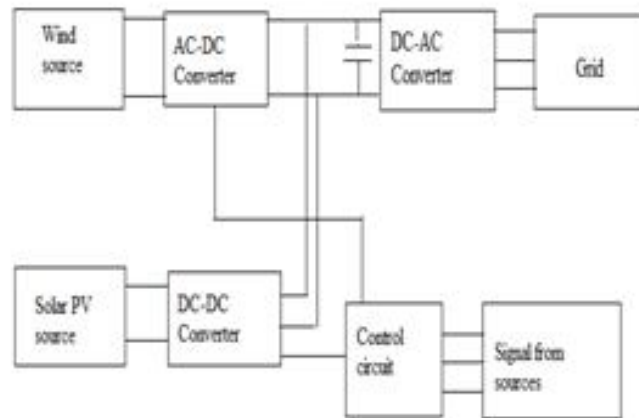


Fig.1. Block diagram of the proposed system

III MODELLING OF HYBRID SYSTEM

A) MODELING OF SOLAR (PV) SYSTEM

A PV system consists of group of solar cells, connections, supports etc. The solar cells are made up of semiconductor material with positive on one side and negative on the other side which is exposed to the sun. When the solar energy i.e., photons hit the solar cells, electrons are emitted from the semiconductor material and electron-hole pair is formed. If electrical conductors are attached to the positive and negative sides, then electrical circuit is formed and electrons are captured in the form of photo current [6]. The model of equivalent circuit of the solar cell is shown in Fig.2.

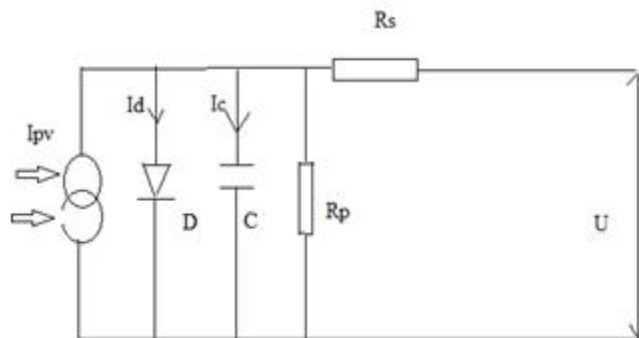


Fig.2 Equivalent circuit diagram of a solar cell

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The diode is the one which determines the current voltage characteristic of the cell. The output of the current source is directly proportional to the light falling on the cell. The system is modelled using MATLAB software. The solar system model consists of three simulink blocks: solar model block, PV model block and energy conversion block.

B) MODELLING OF WIND ENERGY SYSTEM

The wind energy system consists of wind turbine and generator. The generator can be either induction or synchronous. The most commonly used generator in the wind energy conversion system nowadays is permanent magnet synchronous generator. The PMSG can produce efficient power when compared to other machines. The three inputs are the generator speed in pu of the nominal speed of the generator, the pitch angle in degrees and the wind speed in m/s. The tip speed ratio λ in pu of λ_{nom} is obtained by the division of the rotational speed in pu of the base rotational speed and the wind speed in pu of the base wind speed. The output is the torque applied to the generator shaft. The power extracted from the wind is given by,

$$P = \frac{1}{2} \rho A V^3 C_p$$

Where, C_p is called power coefficient of the rotor or rotor efficiency. The value of C_p is between 0.4 and 0.5 for high-speed, two blade turbines and between 0.2 and 0.4 for low-speed turbines with more blades.

c) MODELING OF SOLAR-WIND HYBRID SYSTEM

The solar-wind hybrid system has been modelled by combining the two individual models of solar and wind system. It increases the efficiency of the system and the power output can also be increased. The circuit diagram of the proposed system is shown in Fig.3.

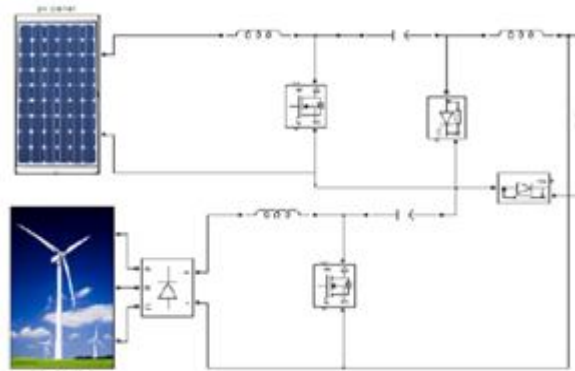


Fig.3. Circuit diagram of hybrid system

The hybrid system is then synchronized with the grid using phase locked loop (PLL) technique. In this paper, double second order generalized integrator (DSOGI) PLL is used for the synchronization.

IV PHASE LOCKED LOOP

PLL stands for 'Phase-Locked Loop'. It is a closed loop frequency control system, which functioning is based on the phase sensitive detection of phase difference between the input and output signals of the controlled oscillator (CO). The Phase Locked Loop method of frequency synthesis is now the most commonly used method of producing high frequency oscillations in modern communications equipment.. The frequency and the phase angle of the input system should match with that of the grid requirements. The synchronization process is done by PLL. It matches the frequency of the input system with that of the grid. Thus, it reduces the error and improves the efficiency.

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A PLL is a feedback system that includes a VCO, phase detector, and low pass filter within its loop. Its purpose is to force the VCO to replicate and track the frequency and phase at the input when in lock. The PLL is a control system allowing one oscillator to track with another. It is possible to have a phase offset between input and output, but when locked, the frequencies must exactly track. The PLL output can be taken from either V_{cont} , the filtered (almost DC) VCO control voltage, or from the output of the VCO depending on the application. The VCO output can be used as a local oscillator or to generate a clock signal for a digital system. Either phase or frequency can be used as the input or output variables. The Phase-locked loop (PLL) is the most common method for determination of the grid voltage phase angle and frequency. However, there are still serious limitations of reported PLL algorithms in real grid voltage conditions (unbalance and distortion). The basic block diagram of PLL is shown in Fig. 4.

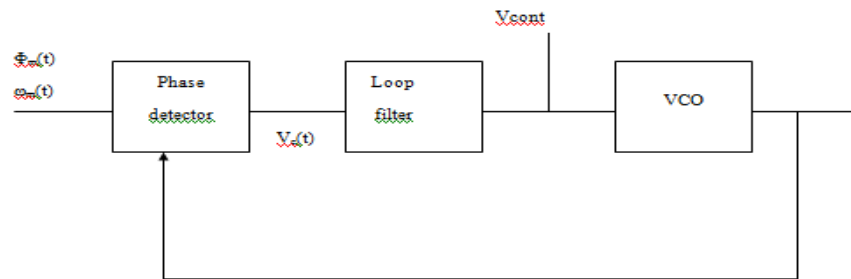


Fig.4 Block Diagram of PLL

V EXPERIMENTAL RESULTS

The system is modelled using MATLAB/SIMULINK software. The output waveform of the system is shown in Fig.5 (a).

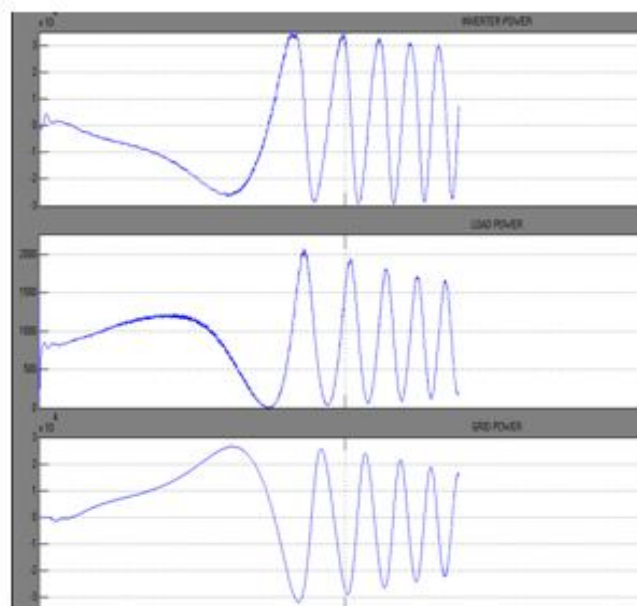


Fig.5 (a) Output waveform of hybrid system

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The phase angle characteristics of DSOGI PLL are shown in Fig.5 (b).

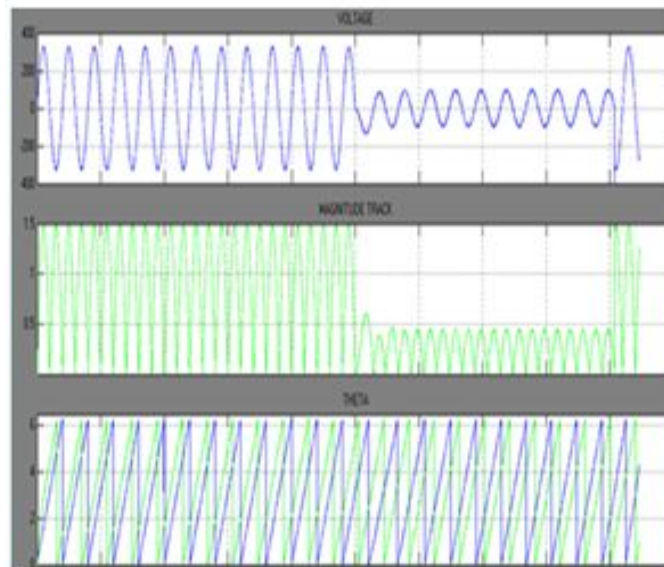


Fig.5 (b). Output waveform of DSOGI PLL

VI. CONCLUSION

Renewable energy sources also called non-conventional type of energy are continuously replenished by natural processes. Hybrid systems are the right solution for a clean energy production. Hybridizing solar and wind power sources provide a realistic form of power generation. Here, a hybrid wind and solar energy system is proposed. This system is synchronized with the grid using DSOGI PLL. The PLL can reduce the harmonics and match the frequency of the system with that of the grid during voltage unbalances. The hybrid system and the PLL are designed using MATLAB/SIMULINK software. The characteristics of the system and its effects to the grid are represented. The proposed system can increase the efficiency and provide continuous power.

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