Power Management Strategy between PV-Wind Hybrid System Using Cuckoo MPPT Techniques

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ABSTRACT

The main theme of this paper is to maintain a power management strategy in grid interfaced hybrid system. Here, the PV and Wind Energy Systems considered hybrid connection systems. Wind and PV systems are more efficient DG systems, as freely available in nature. The DFIG based wind system is designed to generate 16kW and Solar system is designed for rating of 20kW power generation. In addition with battery management system also used for back-up purpose. An MPPT based DC-DC converters are proposed for both PV and Wind systems to improve the reliability and effective power management between the systems under different load conditions. This proposed system is verified in MATLAB simulink environment.

Key Words: Wind Energy System, PV Panel, MPPT Technique, Power-management, DC-DC Converter.

INTRODUCTION

In the last decade, the plants related to fossil fuels such as coal, gas and petroleum plays a key role to meet the load demand. But the major concern with these plants is that, these plants may cause global warming, pollution and releases carbon di-oxide which is harmful to humans and plants. Renewable energy systems has the solution in power plants to overcome these problems. The most reliable DG systems are PV and wind as freely available in nature, high efficient and economical.

The renewable energies present in this paper as solar, wind and fuel cell system. Solar system converts irradiance and temperature into electrical energy. And also to maintain constant dc from the solar system an MPPT based dc-dc converter is implemented. As per literature, there are approximately 26 MPPT techniques available. Out

of these the basic perturb & observe technique is considered.

Generation of electrical energy from wind energy is obtained with the help of wind turbine system. The wind turbine consists of blades, hub, gear mechanism used to change low speed shaft to high speed shaft and generator. From the literature point the available generators are synchronous generator, induction generator.

There are two types in induction generator i.e SCIG and DFIG. In dfig the rotor is recycled and regulated by using two back-back converters and fed to stator. The output from the wind system is converted to dc voltage with the help of rectifier.

And also this paper mainly concentrate on fuel energy based renewable system. In this, the fuel energy is converted to electrical energy by electrolyte process. The proton exchange membrane type fuel system is considered in this

paper. In this case the hydrogen fuel is reacted with oxidant to generate electrons. The output of fuel cell is applied to a conventional Dc-Dc converter to improve the voltage levels to meet the requirements. A combined voltage from the Dc bus is applied to inverter to synchronize with grid system. And with these combination, this paper proposes the concept to meet the load demand under various conditions.

PROPOSED HYBRID ENERGY SYSTEM:

Figure 1: Configuration of Hybrid Energy System

The above figure 1, shows the structure of hybrid system with grid interfaced system. This hybrid system is a combination of wind, solar and fuel cell system. Here, this three systems are connected at DC bus. The energy from PV and FC is DC side, the energy of wind system is converter to DC with the help of rectifier. This Common DC bus is applied to Inverter to achieve AC side and connected to grid. The synchronization between hybrid system and grid is maintained with PWM controller.

PV System:

In this, the solar radiation is converted to electrical energy with the help of photon effect. The initial energy from the solar panel is electric current and converted to dc voltage with the help of electrical equivalent circuit. The main problem with solar system, the output is not constant because of variations in solar irradiance. In order to maintain solar output as constant, this paper is implemented with MPPT based DC-DC converter.

Figure 2: Architecture of PV System

The mathematical analysis of PV system is expressed as,

$$I = I_{ph} - I_D - I_{sh}$$

$$I = I_{ph} - I_o \left[e^{\left(\frac{qV_D}{nKT} \right)} \right] - \left(\frac{V_D}{R_s} \right)$$

Figure 3: P-V & I-V Characteristics of Solar system

MPPT Technique:

The purpose of MPPT technique is to design a suitable reference signal required for PWM of DC - DC converter this MPPT technique increases the efficiency of DG system and battery charging controllers. This paper proposes MPPT controller and compare the performances of each MPPT the chosen MPPT techniques are (a) Petrob and observe.

WIND Energy System:

In wind system the energy conversion can be done in two stages, in first stage the wind speed is converted to mechanical power with the help of wind turbine and later with help of generator it converted to electrical energy. Generally, there are two types of generators available in market i.e synchronous generator and induction generator. DFIG generator is proposed in this paper.

The mathematical analysis for wind energy system is expressed as below. The mechanical output power from the wind turbine as

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

Figure 4: Tip Speed Ratio Vs Coefficient of Power

MODELLING AND DESIGN OF DFIG:

Figure 5: Back-back Converters with DFIG

The structure of doubly fed induction generator with two back-back converters are shown in figure 5. Here, the purpose of two converters is to control and regulate the rotor power. These converters acts as rectifier and inverter combination called as rotor side and grid side converters. The control diagrams for these two converters are implemented with reference signals of stator and rotor parameters. The mathematical analysis for dfig system is obtained with induction generator equivalent circuit as shown in figure 6.

This mathematical analysis for RSC and GSC as shown in figure 6 is obtained by writing KVL and KCL equations.

Figure 6: DFIG Equivalent Circuit

From KVL in figure-6,

$$V_{st} = j\omega_1 L_m (I_r + I_s + I_{mr}) + j\omega_1 L_{st} I_{ts} + R_{st} I_{st}$$

$$V_r / s = j\omega_1 L_m (I_r + I_s + I_{mr}) + j\omega_1 L_{tr} I_{ts} + R_r / s * I_r$$

$$0 = j\omega_1 L_m (I_r + I_s + I_{mr}) + R_m I_{mr}$$

The expression for electromagnetic torque is shown as

$$T_e = 3n I_m \psi_r I_r^*$$

The stator and rotor powers are shown as

$$P_s = 3R_s I_s^2 + 3R_{mr} I_{mr}^2 + 3\omega_1 I_m [\psi_m I_r^*]$$

$$P_r = 3R_{mr} I_{mr}^2 - 3\omega_1 I_m [\psi_m I_r^*]$$

Control Diagram for RSC & GSC Converters:

The reference signals required for two converters of DFIG is implemented with active and reactive powers in dq-axis of DFIG.

$$\bar{V}_r = \bar{I}_r R_r + \frac{d\psi_r}{dt}$$

$$\bar{\psi}_r = \bar{I}_r L_r + s e^{-j\epsilon} M \bar{I}_r$$

Substituting the value of $\bar{\psi}_r$ in above equation e get

$$\bar{V}_r = \bar{I}_r R_r + \frac{d}{dt} (L_r \bar{I}_r - \frac{M^2}{L_s} \bar{I}_r + \frac{M}{L_s} \bar{\psi}_s e^{-j\epsilon})$$

Figure 7, shows the control diagram for rotor and grid side converters of DFIG system. Here, the system active powers are compared with reference powers to generate dq-reference currents in inner loop. And in the outer loop these dq-reference currents are compared with grid currents and applied to PWM generators for RSC and GSC.

Figure 7: DFIG Converters Control Diagram

SIMULATION RESULTS:

The complete grid connected hybrid system is given in figure 9. The PV system consists of two PV arrays with two PV module in series mode and boost converter. The ratings of PV, Wind energy and battery energy system are 16kW and 20KW respectively for 11 kV, 50MW power grid connection with load connected to the system.

Figure 5: The Simulation Diagram for The Hybrid Wind-PV System

SIMULATED GRAPHS:

Fig. 6 shows the simulation result for the proposed system to show the power management strategies. Here, the load sharing is chosen between PV, battery and wind system according to their generations. The solar system generates 10kW during 0s to 2s and 8kw between 2s to 6s. And the wind system generates 9.8kW between 0s to 4s and 6kW during 4s to 6s. The demand for load to this system is approximately 47kW and it is changed to 38kW during the period 3s to 6s.

Fig. 6 Simulation Result for (a) Load Demand, (b) Solar Power, (c) Wind Power and (d) Battery Power

Fig. 7. Power Factors for Inverter Load Current

Fig. 7 shows the simulation results for power factors of phase-a, phase-b and phase-c of load voltage and current. Here in this case, the load is taken as linear balanced load, so that the power factor is almost reaches to unity. Fig. 8 shows the simulation results for load voltage and current.

Fig. 8 Simulation result for Load Voltage and Current

Fig. 9 shows the simulation result for the proposed system to show the power management strategies implemented with PO MPPT controller. Here, the load sharing is chosen between PV, battery and grid system according to their generations. The irradiance to solar system is considered in variable mode i.e during 0s to 4s the irradiance is 1000w/m², 800 w/m² applied during 4s to 5s and later it changed to 900 w/m². Based on these conditions, the output from the solar system like 10kW during 0s to 4s and 8.2kw between 4s to 5s and again it raised to 9kW after 5s. The wind energy system generates 4.8kW between 0s to 4s with wind speed of 9m/s, it generates 3.6kW during 4s to 5s with wind speed of 7m/s again after 5s the wind speed is changed to 9m/s and generates 4.8kW. The demand for load to this system is approximately 14kW and it is changed to 45kW during the period 4s to 5s.

Fig. 9. Simulation Result for (a) Load Demand, (b) Battery Power, (c) Solar Power and (d) Wind Power with PO Controller

CONCLUSION

The hybrid solar, wind and fuel cell based grid connected system is implemented in this paper. A MPPT technique is used to improve the reliability of PV system, and the generator for wind system is implemented with back-back converters with DFIG system, proton exchange membrane type fuel cell system based hybrid system is designed in this paper. This system is tested for different load demand conditions. To improve the reliability and efficiency, the proposed hybrid system is implemented with MPPT techniques such as PO techniques. The results for hybrid system with different MPPT techniques is analyzed under different load levels. This proposed system is tested in Matlab and verified the results.

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