Stabilized DC Link Voltage with Hybrid Wind Turbine and PV Generation System

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Abstract—The renewable energy based DG system is attainment more consideration towards the power industries due to their plentiful accessibility which is cost free and eco-friendly, they are intermittent in nature too, hence the power prediction from one source is dependent. Thus, a hybrid DG system involving wind and solar energies can increase the power prediction over an individual. This paper presents, the stabilized DC link voltage connected with hybrid wind and solar based DG system along with power electronics interfacing. The system consists of PMSG as a wind generator, solar array, dc-dc converter and grid interface inverter. Power control strategy is used to extract the maximum power. Maximum power point tracking (MPPT) control is essential to ensure the output of photovoltaic power generation system at the maximum power output as possible. The DC link connected model of wind and PV system is presented in Matlab/Simulink environment. The simulation results show the controller performance and dynamic behavior of the hybrid wind-PV system for different loads.

Index Terms—Hybrid DG System, Power Converters, Wind Generators, Solar Photovoltaic, Distributed Generation

I. INTRODUCTION

Currently the distributed generators (DG) with the grid and standalone application is an emerging approach, mainly its control and operation. Interconnection of these DG source to distribution system will offer a number of assistances such as enhanced reliability, quality of power and improvement of system limits along with the ecological assistances [1]. Due to the increasing momentum towards renewable energy advances with these benefits, it is anticipated that a huge number of DG systems will be connecting to the utility grid in the coming years [2]. Interconnecting these small rating DG systems with diverse characteristics to low voltage network causes many problems. Thus the hybrid configuration with clean, efficient and sustainable energy technologies such as wind and PV will be dominant in the future power supply network. The grid integration of hybrid DG systems is expected to play a vital role in the future electrical power system. Multisource hybrid renewable power sources to some extent overcome the uncertainty, intermittency and low availability of single-source renewable energy systems, which has made the power supply more reliable [3]. And hence, hybrid power systems have caught worldwide research attention. To build a hybrid power system, there are different combinations of renewable energy sources. The grid connected performance of fuel cell and PV based hybrid DG system is reported in [4]. In [5], a grid integrated hybrid wind/PV/fuel cell system with an optimal design for distributed energy production is presented. The detailed performance study of the hybrid power system with PV, wind and wave sources is reported in [6]. In [7], the design and economic analysis of grid connected hybrid PV/wind systems for the intermittent production of hydrogen. For performance of a grid integrated hybrid PV and fuel cell power plant with controller is maximized in [8]. From these listed hybrid power systems, it is observed that the main alternative energy sources employed are wind and PV power. This study concentrates towards small-scale grid integrated wind/PV hybrid system under grid connected mode. The primary power sources for the system chosen are wind and photovoltaic power to take complete benefits of renewable energy available around us. The hybrid system can supply power both to the utility grid and to local loads for a grid connected application. For grid connected operation mode of hybrid system, the utility grid behaves as backup energy source. The suitable power electronic converters are required to operate hybrid in grid connected mode of operation. The more power converter usage produces more losses. Some of the loads like battery, electronic equipment, DC drives require DC power which can be supplied from DC voltage directly from DC bus with proper dc-dc converter. A grid integrated hybrid system with wind and PV as the energy resources which can reduce the multiple conversion stages is implemented. The hybrid power system can supply both DC and three phase AC loads. In this paper, the utility interactive performance analysis of hybrid wind/PV system is presented through simulation study under grid disturbance conditions. In this mode of operation of hybrid system, each DG will generate its maximum power and the grid will supply extra load demand requirements. The DC link voltage (VDC) is regulated through inverter controller. In this study, the balanced voltage dip, polluted grid voltages and unbalanced grid voltages are considered as the grid perturbation conditions. The block diagram of hybrid wind/PV system for its grid connection is presented in Fig 1.

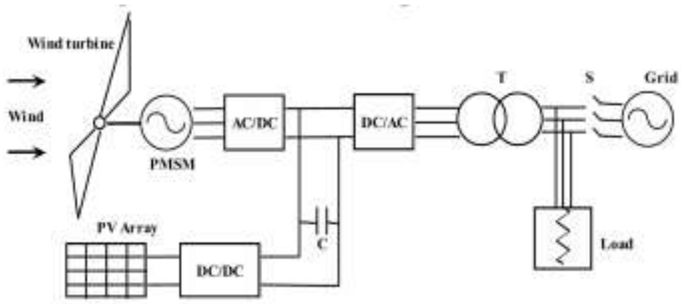

Fig. 1. Block diagram of wind and PV hybrid system

The wind power system with PMSG with uncontrolled rectifier and dc-dc boost converter is connected to a DC bus. To connect the PV arrays are connected to DC bus, a dc-dc boost converter is used. The wind and photovoltaic generators are controlled locally to obtain the maximum power extraction. For the analysis of the grid connected hybrid system, both DC and AC loads are considered. The DC load is connected through a dc-dc buck converter to the DC bus. The rated voltages for DC load and AC load. In grid tied operation mode, the grid side inverter is responsible for stable DC bus voltage and injects only active power to the grid with zero reactive power.

II. MODELING OF HYBRID WIND AND PHOTOVOLTAIC SYSTEM

The model of hybrid wind and PV system consist of each components individually in the succeeding paragraphs as

A. Modelling of PV system

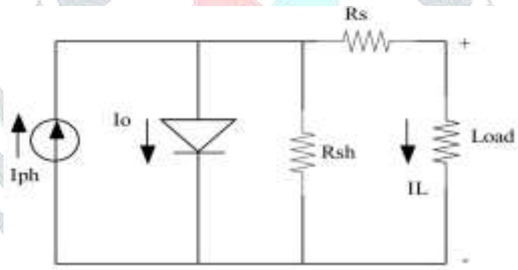

Fig. 2. Circuit diagram of single PV cell

PV array are formed by combine no of solar cell in series and in parallel. A simple solar cell equivalent circuit model is shown in Fig. 2. To enhance the performance or rating no of cell are combine. Solar cell are connected in series to provide greater output voltage and combined in parallel to increase the current. Hence a particular PV array is the combination of several PV module connected in series and parallel. A module is the combination of no of solar cells connected in series and parallel. Photo-current of the module: Photo current is the function of solar irradiation and cell temperature is given by an expression

$$I_{pv} = \frac{[I_{scr} + k_i(T - 298)] \times \lambda}{1000} \qquad (1)$$

The reverser saturation current of the module of PV system can be represented by an expression

$$I_{rs} = I_{scr} / [\exp(qV_{oc} / N_s KAT) - 1] \qquad (2)$$

Saturation current of the module: Saturation current varies with cell temperature is given by an expression

$$I_o = I_{rs}\left[\frac{T^2}{T_R^{\ 2}}\right]\exp\left[\left[q \times E_{go} / BK\left(\frac{1}{T_r} - \frac{1}{T}\right)\right]\right] \qquad (3)$$

The current output module and power output of solar panels is approximately proportional to the sun's intensity.

$$I_{pv} = N_p \times I_{pv} - N_p \times I_0 \frac{\left[\exp\left(q \times V_{pv} + I_{pv} \times R_s\right)\right]}{N_s AKT} - 1 \qquad (4)$$

B. Modelling of Wind turbine generation

From the swept region of the blades a current of air turbine extract kinetic force is given by the equation

$$P = \frac{1}{2}\rho A V^3{}_w \qquad (5)$$

The above equation is for power accessible in the wind but it is dissimilar as of power transferred beginning the wind turbine. Wind power is expressed by the equation.

$$P = \frac{1}{2}\rho A C_p V^3{}_w \qquad (6)$$

Tip speed ratio of wind turbine can be defend as

$$P = \frac{1}{2}\rho A C_p V^3{}_w \qquad (7)$$

$$\lambda = \frac{2\pi RN}{V_w} \qquad (8)$$

The power coefficient is differ from the wind turbine because there are losses in the mechanical transmission and electrical generationhas no dimension and can be used to describe the preference of the size of the rotor. The mechanical power transfer to the shaft is given by an expression

$$P_m = 0.5_\rho A C_p V_w^{\ 3} \qquad (9)$$

Where power coefficient is a function of pitch angle β and tip speed ratio λ. the relationship between torque and power is given as,

$$T_m = \frac{P_m}{\omega} \qquad (10)$$

Using optimum value of Cp the torque change into

$$T_{\max} = 0.5 C_{p-opt}\pi\left(\frac{R_5}{\lambda^2{}_{out}}\right)\omega^2 \qquad (11)$$

III. PMSG

A PMSG is an appealing result which depends on variable rate operation. The variable velocity wind turbine with full scale recurrence converter is an appealing answer for exploration on appropriated power era frameworks. The benefits of PMSG over impelling machines are the high productivity and unwavering quality, since there is no requirement for outside excitation littler in size and simple to control. The generator is specifically associated with the framework through a full scale consecutive power converter. The force converter couples the generator to the network. Generator converter is utilized to control the torque and rate and network side converter is utilized to control the force stream with a specific end goal to keep the DC join voltage steady. The two converters are associated by a DC join capacitor keeping in mind the end goal to have a different control for every converter.

IV. MAXIMUM POWER POINT TECHANIQUE

Maximum Power Point of a solar module varies with the variation of irradiation and temperature So MPPT algorithms are necessary in PV applications because by the use of MPPT algorithms it obtain the peak power from the solar panel. Previously there are different methods to find the MPPT have been developed. According many aspects these techniques differ such as required sensors, complexity, range of effectiveness, according to speed, cost, if there is change in irradiation and temperature than also the effectiveness of tracking, requirement of hardware and its implementation. 19 different MPPT algorithms are there among these techniques, the Incremental conductance algorithms and the P&O algorithms are generally used.

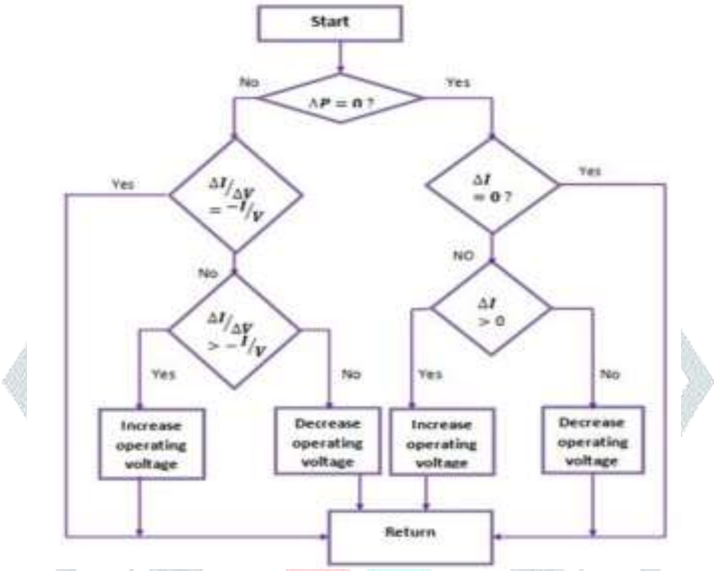

Fig. 3. Flow chart of incremental conductance method

This is easy to use and simple in operation and required less hardware as compare to other. When there is more than one MPP other MPPT technique are used and it appeared generally when the PV array is partially shaded. This is also a common Maximum Power Point Tracking algorithm. According to this method from the P-V characteristic curve there is a single peak value and the maximum power point exist. The flow chart for incremental conductance is shown in Fig.3.

V. THREE PHASE VOLTAGE SOURCE INVERTER

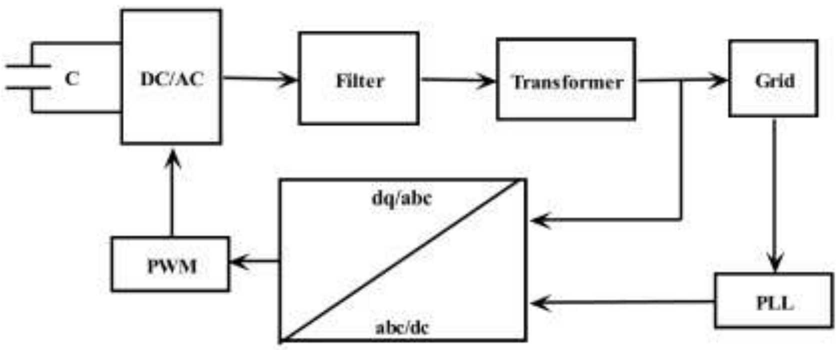

Fig. 4. Block diagram of VSI

The block diagram for voltage source inverter (VS) is shown in Fig. 4. The distribution power generation system three phase VSI are used to interfere between DC & AC system for the control of active and reactive power along with constant DC link voltage. Different control technique are used to the three phase grid connected voltage source Inverter. Power electronics converter is widely employed in all the application due to the switches non linearity occurs in the system so the power stage must be linearized. In this project a three phase grid connected VSI with LC filter has been measured for modeling. It is quite difficult to design a controller for three phase ac system. So first three phase Ac system (abc) is transferred into synchronous rotating reference frame (dq) which is known as parks for simple operation.

VI. RESULTS AND DISCUSSIONS

The performance of hybrid system with in connected to grid has been presented Matlab/Simulink environment for the block diagram shown in Fig.1. The components of each individual source are depleted and simulation study is obtained for the duration of 1.5sec. The DC link voltage connected between PV cell and wind turbine is shown in Fig.5. In this, the level of voltage is maintained by the two source is 780V DC supply. The simulation parameter for the presented model is given in Table I.

TABLE I

SIMULATION PARAMETERS OF HYBRID SYSTEM

Sl No	Parameter	Values
1.	Wind turbines	Blade radius: 3.7m, Air density: 1.225kg/m^2, Number of Blades: 3, C_{pmax}=0.47.
2.	Permanent Magnet Sync, Generator, magnetic induction	Stator resistance Rs:0.1764ohm, Rotor inertia:0.00065kg/m2, L_d=L_q=4.245mH: Torque constant =13.91Nm, Pole Pairs:18, Isc:3.8A, G=1000W/m^2, Pout=40kW
3.	Photovoltaic array	k:1.38e-23, q:1.6e-19, n:1.2,Vg:1.12, Pm:60kW, Ns:32, Np:21, Voc:21.1V, Isc:3.8A, G:1000W/m2, Pout:40kW.
4.	DC link voltage	720V, DC link capacitor :5000mF
5.	Load	Resistive load of 15kW, 480Vrms
6.	Filter	R=3e-3Ohm, L=250e-0H

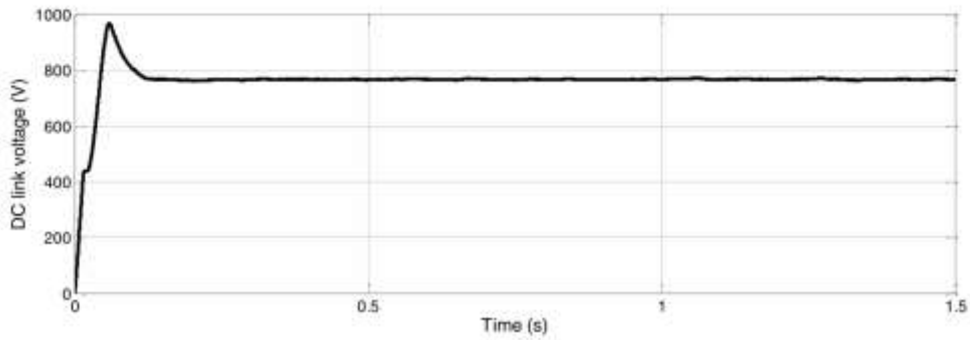

Fig .5 Common DC link voltage of the hybrid system

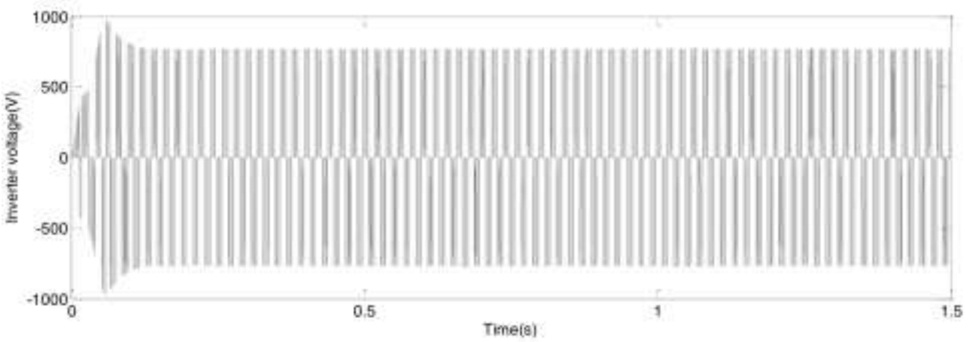

Fig. 6 Waveform of inverter output voltage

Fig. 5 show the constant DC link voltage and Fig. 6 shows the inverter output voltage which is seems to be a square before the filter terminals. Initially the level of voltage is increased due to the staring of wind turbine which is not considered in this work. The mechanical power required to drive the generation is shown in Fig.7. The rotational speed of the generation is shown in Fig.8. The turbine torque required to drive the PMSM is shown in Fig.8 the rotational speed is 18rpm, since the wind velocity is considered as low speed and is depicted in Fig. 9. The active and reactive power supplied by the hybrid DG system is shown in Fig. 10. In this, the reactive power supplied by the DG is restricted to zero by the inverter only. Hence, the reactive power is zero as shown through the simulation result. The three phase sinusoidal grid voltage is shown in Fig10. The root mean square value of the voltage shown in Fig.11. This it to show the grid voltage is sinusoidal at common point coupling. The load current is shown in Fig. 12.

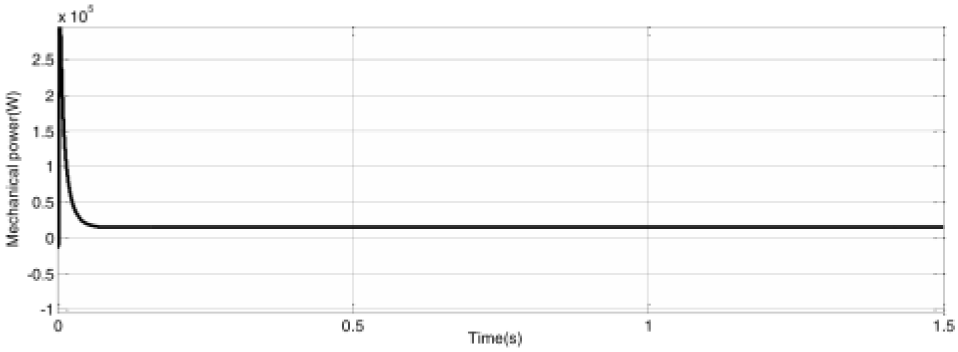

Fig.7 Wave from output power developed from the PMSG

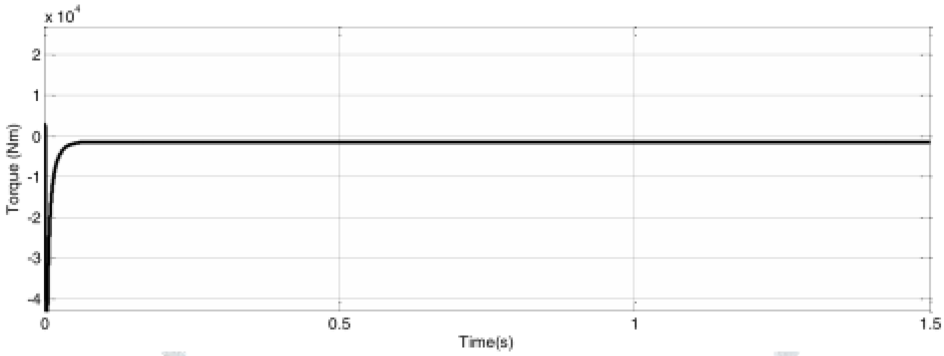

Fig. 8 Turbine torque

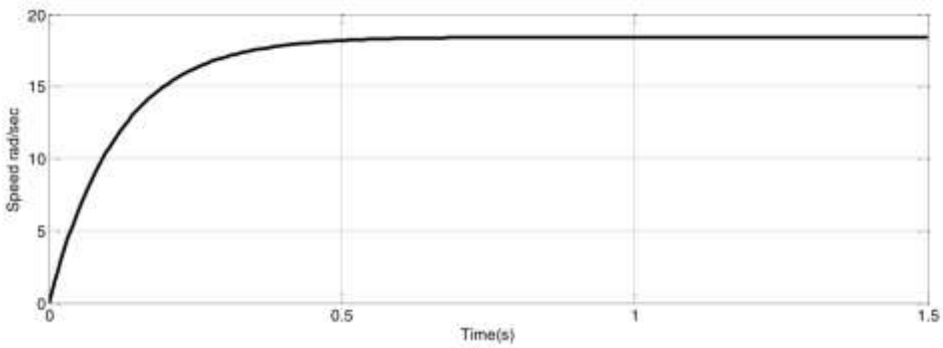

Fig.9 Turbine speed

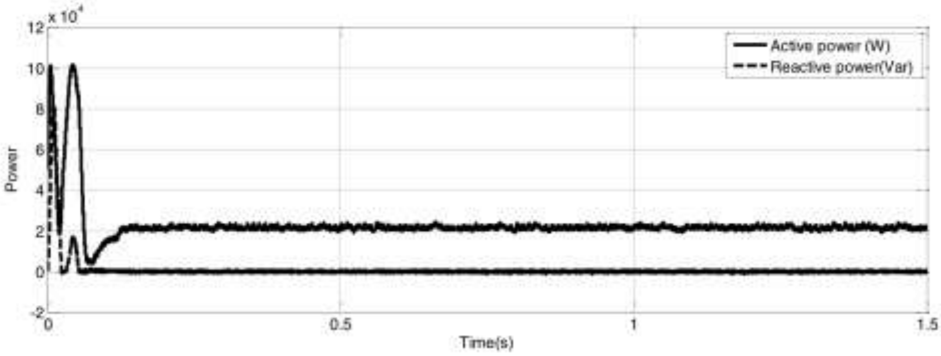

Fig.10 Active and reactive power

Fig. 11. Grid voltage

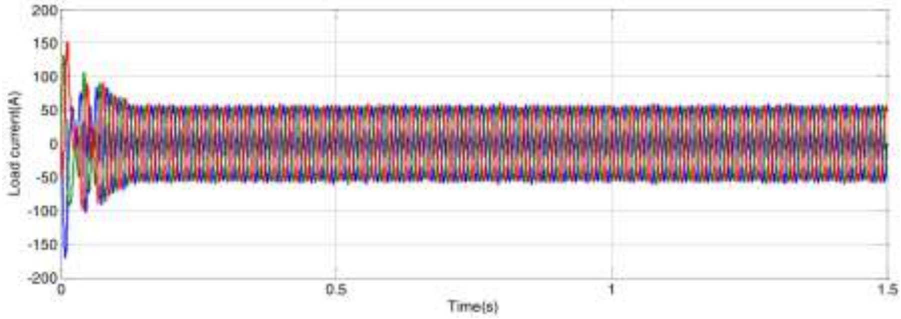

Fig. 12.Load current

VII. CONCLUSIONS

The hybrid wind and PV power system with constant DC link voltage configuration is described in MATLAB/SIMULINK atmosphere. The existing work includes the grid tied mode of operation of hybrid system. The models are developed for all the converters to maintain stable system under continuous load and also the control mechanism are studied. The dynamic performance of hybrid wind and PV power systems are studied for different system disturbances like load variation, wind speed variation and different solar irradiation and temperature inputs can be measured as future scope of this work. The simulation results demonstration that, using a VSI and PQ control approaches of grid connected hybrid energy system. The hybrid grid can deliver a reliable, high quality and more efficient power to consumer. The hybrid system with grid connected may be feasible for small isolated plants with both PV systems and wind turbine generator as the main power supply.

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