Permanent Magnet Synchronous Generator fed Wind Energy Conversion System with Boost converter and PI controller

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Abstract — This paper presents analysis of a wind energy conversion system (WECS) based on a Permanent magnet Synchronous generator (DFIG) connected to the electric standalone load. The aim of the work is to apply the dynamic performances of type of controllers (namely, classical PI) for the WECS in terms of tracking and robustness with respect to the wind fluctuation as well as the impact on the quality of the energy produced. A vector control with stator flux orientation of the DFIG, and further to achieve maximum wind energy capturing. To show the effectiveness of the control method performances analysis of the system are analyzed by simulation on MATLAB/SIMULINK.This paper introduces a proportional integral (PI) controller for the direct drive permanent magnet synchronous generator (PMSG) wind turbine system. This paper exhibits a passivity-based robust output voltage controller for DC/DC boost converters for wind power system applications.Simulation results are obtained by MATLAB/SIMULINK for 10 KW load conncted to a standalone PMSG based Wind Energy Conversion System.

I. Introduction : Energy is an essential ingredient of socio-economic development and economic growth. Renewable energy sources like wind energy is indigenous and can help in reducing the dependency on fossil fuels. Wind is the indirect form of solar energy and is always being replenished by the sun. Wind is caused by differential heating of the earth's surface by the sun. It has been estimated that roughly 10 million MW of energy are continuously available in the earth's wind. Wind energy provides a varied and environmentally friendly option and national energy security at a time when decreasing global reserves of fossil fuels threatens the long-term sustainability of global economy. This paper reviews the performance of PMSG based Wind energy conversion system model.

II.CHOICE OF GENERATORS FOR DIRECT DRIVE WIND ENERGY CONVERSION SYSTEM: Historically,the induction generator with squirrel cage rotor is a very popular machine because of its low price, mechanical simplicity, robust structure, resistance against disturbance and less vibration[1]. However, the induction generator requires bulky capacitors for its excitation.The synchronous generator and the induction generator are mainly designed for constant speed wind turbine operation and hence they are inefficient or even ill-suited for variable speed wind turbine operation (Ying Fan et al 2006). The squirrel cage induction generator and doubly fedinduction generator based Wind Energy Conversion System (WECS) have poor efficiency and moreover, they cannot track Maximum Power Point (MPP) as wind velocity changes [2].

The direct drive structure can operate without any reactive power consumption. The induction generator does not run efficiently during most of the time and draws large reactive power [7].The induction generator coupled with wind turbine in direct drive system is a highly nonlinear system and it requires a nonlinear control strategy to bring the system to its optimal operating point [6]. Looking at the improved characteristics, price reduction and availability of higher energy PM materials, the Permanent Magnet Sychronous Generator becomes more attractive for DDWECS.

The permanent magnet sychronous generator has the advantages of simplicity in construction, very compact in size, no necessity of additional power supply for magnetic field excitation, no need of bi-directional power flow controller and high reliability. Also the PMSG has an inherent brushless rotor construction. Hence, PMSG is more suitable for Wind Energy Conversion System (WECS) [3].The permanent magnet synchronous machines have power to weight ratio, good reliability and high efficiency than other electrically excited machines. Elimination of rotor excitation loss implies that very high efficiency can be achieved. Also recent advances in power electronic semi conductor devices make the PMSG more suitable for DDWECS.The gear box is removed and replaced by a multi pole permanent magnet synchronous generator. Both induction generator and external excited synchronous generator with large number of poles must have larger diameter for efficient operation in the typical speed range of 20 rpm to 120 rpm and are consequently very expensive [5]. Whereas PMG allows larger number of poles in its construction with small pole pitch and yields cost effective design [10].Multipole radial flux machines with PM excitation can be used as direct coupled generators in wind turbines and can be built to fit within the confined space of a nacelle. The low speed construction is superior to high speed construction, which means that multi-pole PM generators are preferred in small, gearless low speed wind energy systems[8]. Therefore, trends have been set to make direct drive PM wind generator system more attractive for wind turbine concepts [9].

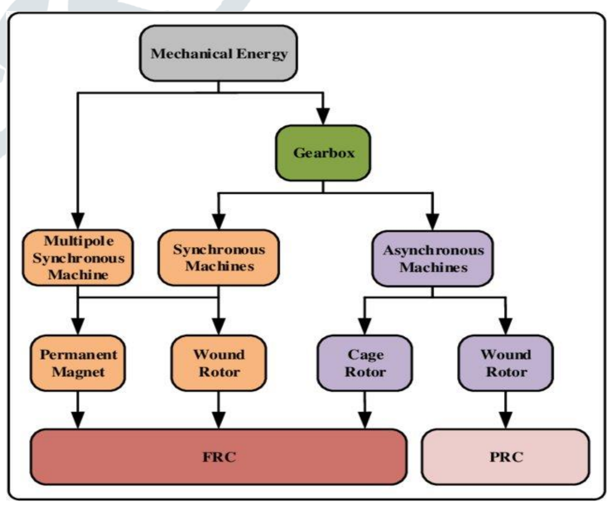

Fig 1. Wind energy conversion technology routes

FRC means Fully Rated Converters

PRC means Partially Rated Converters

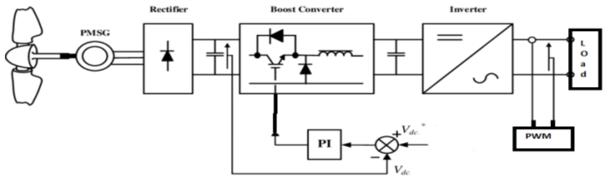

Fig 2 .Block Diagram of proposed system

A. Dynamic Modelling of Wind Turbine: The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture. Numerous wind turbines are installed at one site to build a wind farm of the desired power generation capacity. Obviously, sites with steady high wind produce more energy over the year.

The power extracted by the blades is customarily expressed as a fraction of the upstream wind power in watts

$$Po = \frac{1}{2} \rho A V^3 C_p \quad (1)$$

where, Po = mechanical power extracted by the rotor, i.e., the turbine output power, ρ = air density (Kg/m3), A = area swept by the rotor blades (m2), and V = velocity of the air (m/s), Cp= Power Coefficient The power coefficients Cp is the most important parameter in the case of power regulation. It is a non-linear function whose value is unique to each turbine type and is a function of wind speed that the turbine is operating. Each turbine manufacturer provides look up tables for Cp for operation purposes. Additional to the look up tables from the turbine manufactures, model for power coefficient have been developed. The Betz limit says that wind turbine can convert to above 27/ 16 (59.3%) of the kinetic energy of the wind into mechanical energy i.e. rotation of turbine, i.e. Cpmax = 0.59 [9]. Wind turbines cannot operate at this maximum limit though as the real world is well below the Betz limit with values of 0.35 or 0.45 common even in best designed wind turbines [10].

III. Results:

A 10 Kw load is conncted to the system and simulated using MATLAB/Simlink.

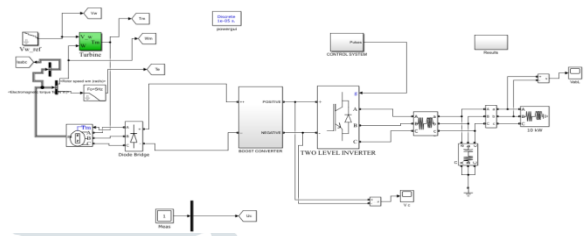

Fig 3. Simulink model of the system

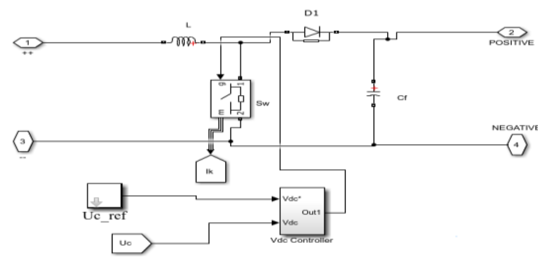

Fig 4. DC-DC Boost Converter circuit in MATLAB

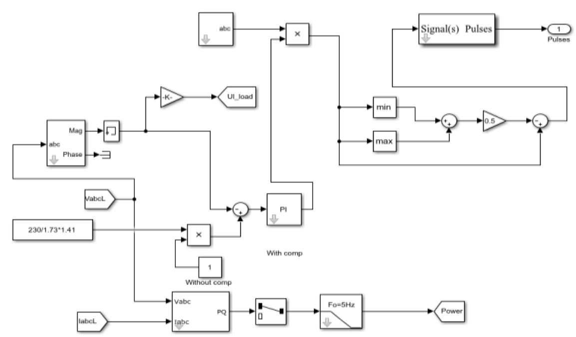

Fig 5. PI controller Simulink model

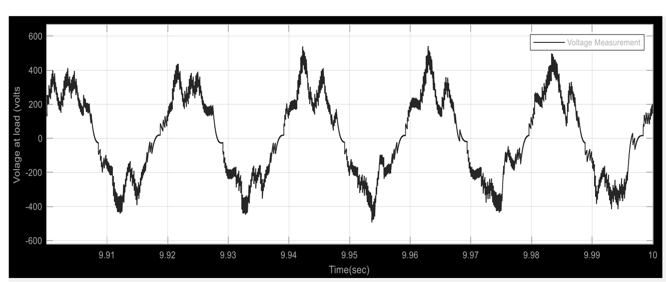

Fig 6. Load Voltage Waveform

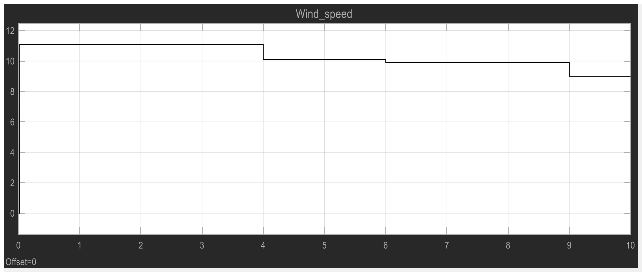

Fig 7. Wind Velocities inputs

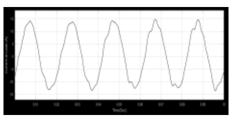

Fig 8. Load Current waveform

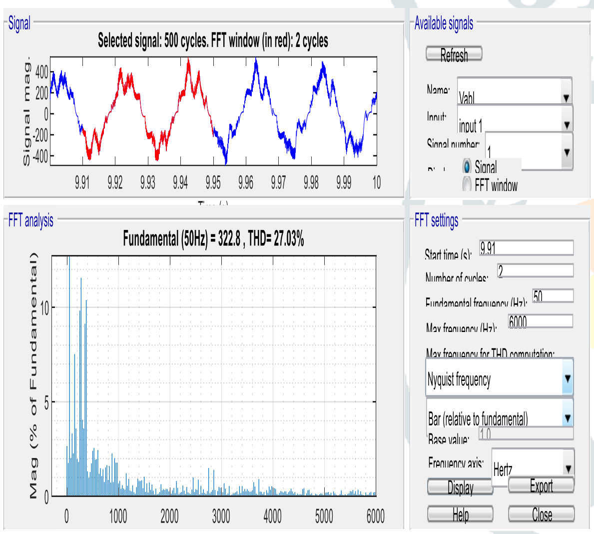

Fig 9. FFT analysis of Load Voltage(Line to line)

Total Harmonic Distortion of load voltage is 27.03%

IV. Conclusions: This paper presented results of a small scale wind energy systems with load of 10 KW. The paper described the basic s of wind energy conversion, how to obtain the volatge regulation at the output of the boost converter whose output is given to Inverter. For variable to wind speeds the MATLAB/Simulink model is The paper describes wind turbines with direct drive systems using fully rated converters. The control mechanism for permanent magnet synchronous generator based wind turbines were presented.

References:

[1] Dong-Min Miao; Jian-Xin Shen, "Comparative study on permanent magnet synchronous generator systems with various power conversion topologies," 2013 Fourth International Conference on Power Engineering, Energy and Electrical Drives (POWERENG) pp.1738,1743, 13-17 May 2013.

[2] Ming Yin; Gengyin Li; Ming Zhou; Chengyong Zhao, "Modeling of the Wind Turbine with a Permanent Magnet Synchronous Generator for Integration," Power Engineering Society General Meeting, 2007. IEEE , pp.1,6, 24-28 June 2007.

[3] Slootweg, J.G.; Kling, W.L., "Aggregated modelling of wind parks in power system dynamics simulations," Power Tech Conference Proceedings, 2003 IEEE Bologna , vol.3, pp.6, 23-26 June 2003.

[4] Shariatpanah, H.; Fadaeinedjad, R.; Rashidinejad, M., "A New Model for PMSG-Based Wind Turbine With Yaw Control," IEEE Transactions on, Energy Conversion, vol.28, no.4, pp.929,937, Dec. 2013.

[5] Xia, Y.; Ahmed, K.H.; Williams, B.W., "A New Maximum Power Point Tracking Technique for Permanent Magnet Synchronous Generator Based Wind Energy Conversion System," IEEE Transactions on ,Power Electronics, vol.26, no.12, pp.3609,3620, Dec. 2011.

[6] Sharma, S.; Singh, B., "Control of permanent magnet synchronous generator-based stand-alone wind energy conversion system," Power Electronics, IET , vol.5, no.8, pp.1519,1526, September 2012.

[7] Wai, R.-J.; Lin, C.Y.; Chang, Y. -R, "Novel maximum-power-extraction algorithm for PMSG wind generation system," Electric Power Applications, IET , vol.1, no.2, pp.275,283, March 2007.

[8] Koutroulis, E.; Kalaitzakis, K., "Design of a maximum power tracking system for wind-energy-conversion applications," IEEE Transactions on , Industrial Electronics, vol.53, no.2, pp.486,494, April 2006.

[9] Busawon, K.; Dodson, L.; Jovanovic, M., "Estimation of the power coefficient in a wind conversion system," 44th IEEE Conference on Decision and Control and European Control Conference. CDC-ECC '05. pp.3450-3455, 12-15 Dec. 2005.