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Simulation and Modeling of Wind Turbine using PMSG

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***Abstract*- During the last two decades, the production of wind turbines has grown in size from 20 KW to 5 MW. There currently exist various competing technologies for wind generator systems whose differences lie in the complexity, cost and degree of control over the system characteristics. In the wind energy conservation system, the wind turbine captures the wind energy. Then the generator changes it to the electrical power. Wind turbines are classified into two types as fixed speed wind turbine and variable speed wind turbine. Variable speed wind turbines yield more energy than the fixed speed wind turbines, reduce power fluctuations and improve reactive power supply. Basically direct drive Permanent Magnet Synchronous Generator (PMSG) and Double Fed Induction Generator (DFIG) are used in variable speed wind turbine generator. In this paper, the simulations of a variable-speed wind turbine with a permanent magnet synchronous generator and power electronics devices have been analyzed to performance during various input wind velocities.**

***Keywords* - NCES, Wind Energy, PMSG**

I. INTRODUCTION

Wind energy is a source of renewable power which comes from air current flowing across the earth's surface. Wind turbines harvest this kinetic energy and convert it into power. The electricity is sent through transmission and distribution lines to customers. Wind generation is one of the fastest growing sources of electricity and one of the fastest growing markets in the world today.

With an average annual growth rate of more than 25 percent over the past decade, wind is the fastest growing sector of the energy industry all over the world. The advantages of wind energy are numerous and clear, and the technology itself has taken a leap forward in recent years [1-2].

II. MODELING AND OPERATING PRINCIPLE

The typical structure of variable-speed wind energy conversion system is shown in Fig. 1.

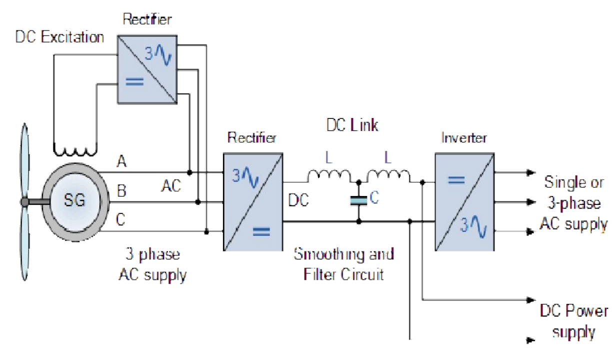

Fig.1 Model of wind generator

The system comprises wind turbine, generator, rectifier, inverter and LC filter. In this system, the wind turbine captures the wind energy and the generator converts it to the electrical power. Then the power electronics equipment converts it to the high quality power and controls the rotor speed of the generator.

The aerodynamic model of wind turbine is given by

$$P = \frac{1}{2}\rho A C_p(\lambda)v^3$$

Where

P = the power generated by the wind turbine,

ρ = air density,
A = the area swept out by the turbine blades,
v = the wind speed,
Cp (λ) = the power coefficient and
λ = tip speed ratio.
The tip speed ratio of a wind turbine is given by

$$\lambda = \frac{Rn\pi}{30v}$$

Where n is wind turbine rotor speed in revolutions per minute(r/min).

The relationship between Cp and λ is shown in Fig. 2. This curve can be calculated based on the aerodynamics and can also be measured by the experiment.

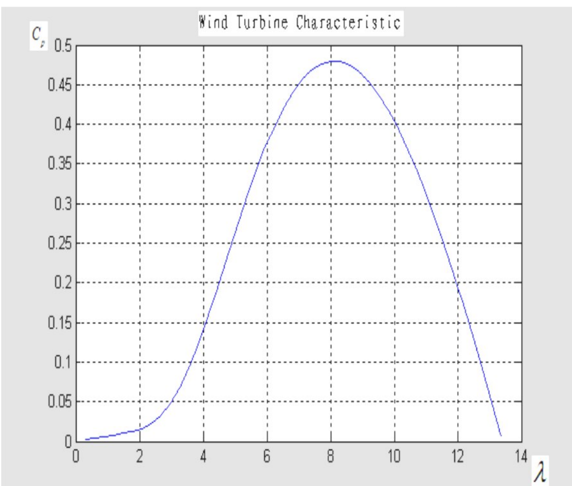

Fig. 2 Characterstic between Cp and λ

Parmanent Magnent Sychronous Generator (PMSG) was wound-field synchronous machines require DC current excitation in the rotor winding. This excitation is done through the use of brushes and slip rings on the generator shaft. However, there are several disadvantages such as requiring regular maintenance, cleaning of the carbon dust, etc. An alternative approach is to use brushless excitation which uses permanent magnets instead of electromagnets [3].

In a permanent magnet synchronous generator (PMSG), the excitation field is created using permanent magnets in the rotor. The permanent magnets can be mounted on the surface of the rotor, embedded into the surface or installed inside the rotor. The air gap between the stator and rotor is reduced for maximum efficiency and to minimise the amount of rare earth magnet material needed. Permanent magnets are typically used in low power, low cost synchronous generators.

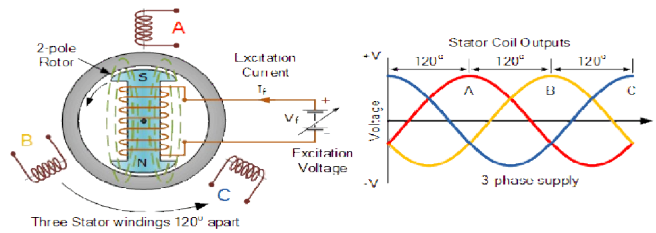

Fig. 3 Synchronous Generator

For low speed direct drive wind turbine generators the permanent magnet generator is more competitive because it can have higher pole number of 60 or more poles compared to a conventional wound rotor synchronous generator. Also, the excitation implementation with permanent magnets is simpler, more durable but does not allow control of excitation or reactive power. The one major disadvantage of permanent magnet wind turbine synchronous generators is that with no control of the rotor flux, they attain their peak efficiency only at one pre-defined wind speed [4-5].

III. SIMULATION AND RESULTS

A simulink model of a wind turbine with permanent magnet synchronous generator (PMSG) was built up using MATLAB /SIMULINK environment. In this model, wind turbine shaft is mechanically connected with permanent magnet synchronous generator's shaft (or direct drive PMSG) which is connected to grid through IGBT based PWM inverters [6-8].

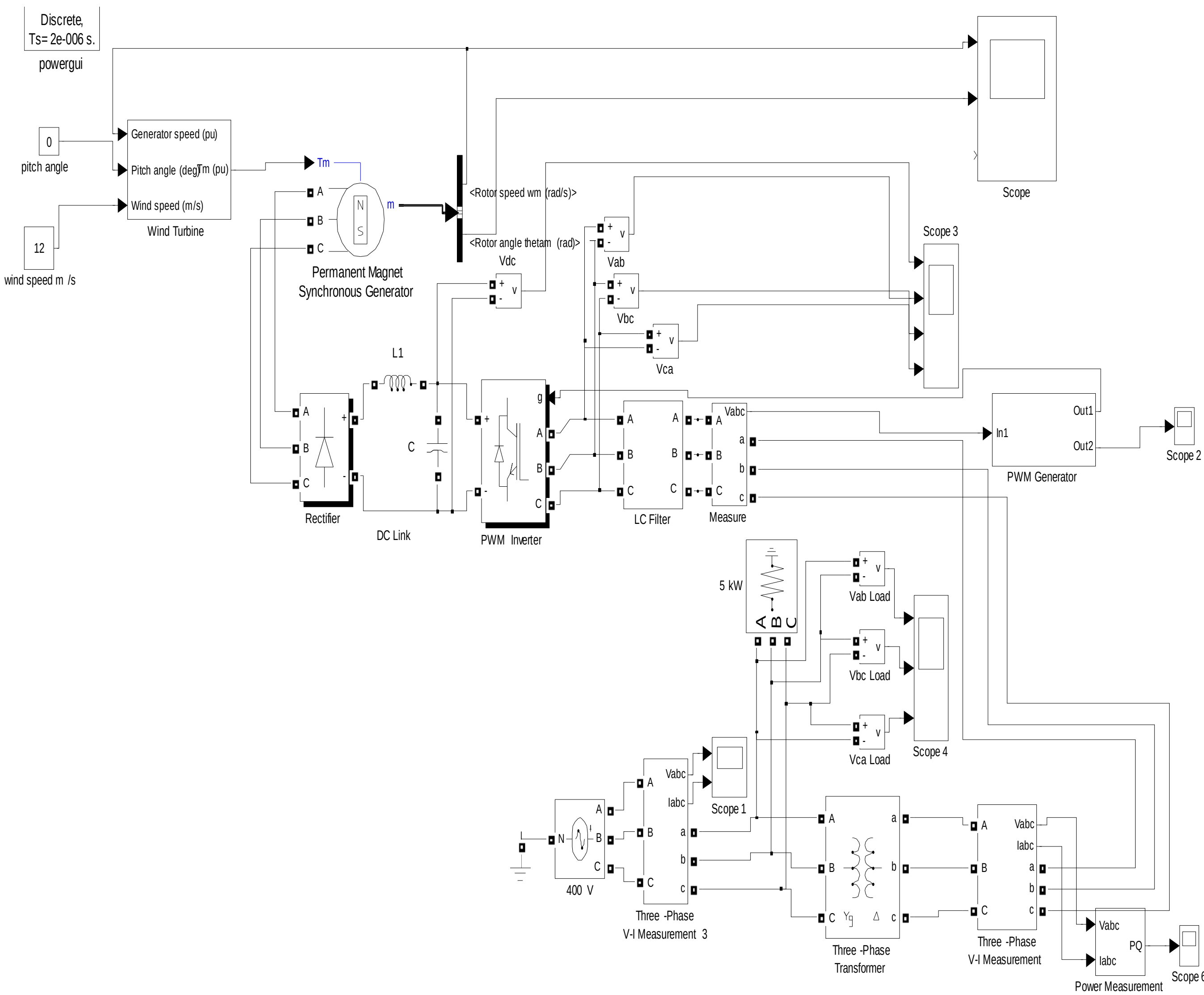

Fig. 4 Simulation model of wind turbine

A. Rotor Speed (rad/sec) at Different Wind Speed

When wind speed is changed then, corresponding to it, mechanical energy is changed. So speed of mechanical shaft is varied. Corresponding to shaft speed, rotor speed of permanent magnet synchronous generator is changed. Fig. 5 and 6 show rotor speeds (rad/sec) Vs time (second) curves at different wind speeds.

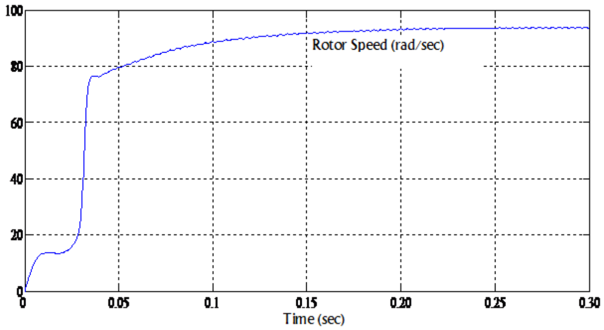

Fig.5 Rotor speed at wind speed 12 m/s

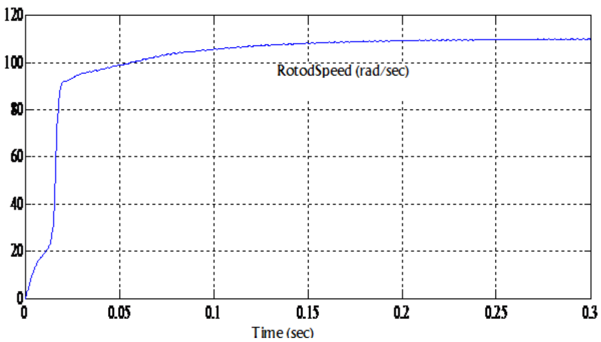

Fig.6 Rotor speed at wind speed 14 m/s

B. DC Link Voltages

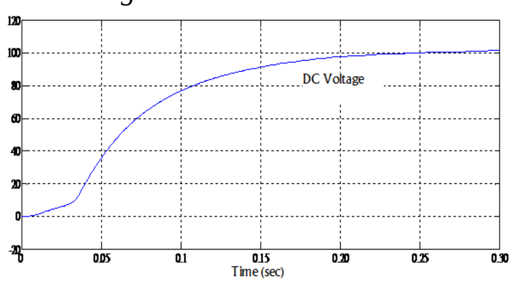

Fig.7 DC Link voltage at wind speed 12 m/s

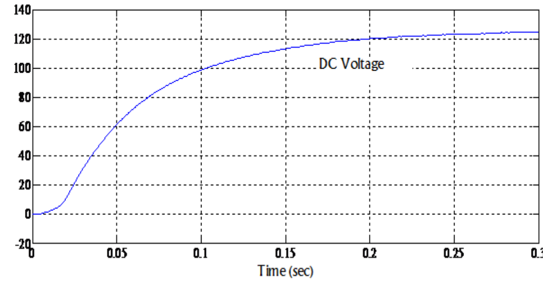

Fig.8 DC Link voltage at wind speed 14 m/s

C. PWM Inverter output Voltages

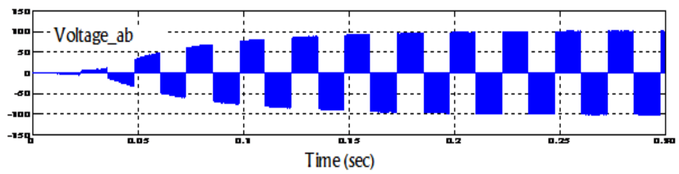

Fig.9 PWM output Voltage at 12 m/s wind Speed

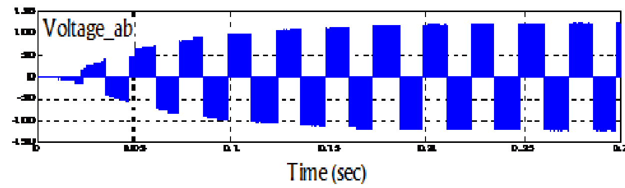

Fig.10 PWM output Voltage at 14 m/s wind Speed

If wind speed is changed from 12 m/s to 14 m/s then DC Link Voltages (fig. 7 and 8) and PWM inverter output voltages (fig. 9 and 10) are varied according to wind speed.

D. Transformer output voltage

Output voltage of PWM inverter is fed into three phase transformer through LC filter which generates three phase sinusoidal voltage waveform as shown in fig. 11.

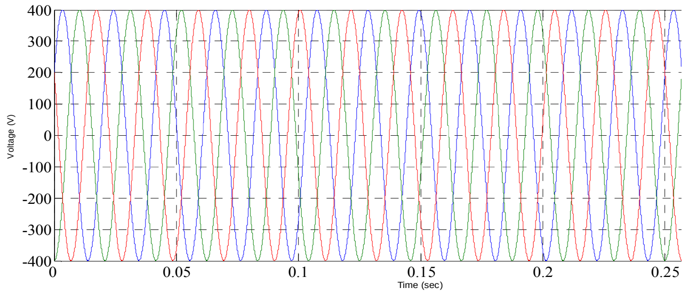

Fig.11 Three phase sinusoidal output voltage across transformer

IV. CONCLUSION

The wind turbine driven Permanent Magnet Generator is modeled using MATLAB/SIMULINK tool and analyzed for various input wind velocities. As the wind velocity varies the rotor speed and output voltage of permanent magnet synchronous generator also varies. AC output voltage of PMSG is rectified into DC voltage which varies with wind velocity. DC voltage from the rectifier is inverted in a Pulse Width Modulation (PWM) Inverter to obtain an AC output. This output voltage is increased or decreased with wind speed. In direct drive permanent magnet synchronous generator system, gearbox is not necessary so cost of gear box and its maintenance is eliminated.

V. REFERENCES

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