MODELLING AND CONTROLLING OF WIND TURBINE WITH PMSG FOR MAXIMUM POWER TRACKING

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ABSTRACT
In this paper the generator is controlled to obtain the maximum power from the incident wind by applying so called vector control technique to the generator side converter. From the incident wind the command speed that corresponds to the maximum output power of the turbine is calculated. The controller uses this speed command to control the output power of PMSG, such that the speed of the generator tracks the command speed. Pitch controller is used to limit the output power produced by the turbine at high wind speeds. For validating the controllers, modeling and simulation of the wind turbine system were performed using MATLAB/Simulink. And the performance of the control system has been analyzed by considering different wind speed cases.

Keywords: Wind Energy; PWM inverter; Permanent Magnet Synchronous Generator.

I INTRODUCTION

As energy demands around the world increase, the need for a renewable energy source that will not harm the environment has been increased. Some projections indicate that the global energy demand will almost triple by 2050. And oil can only supply the world for up to 150 years [1]. Using wind energy is one way to meet the future need. So, we can say that the wind energy is the Fuel of the future. Utilities have the flexibility to accept a contribution of about 20% or more from wind energy systems and more than 50% fuel savings from wind-diesel systems [2]. So, it is important to modify the performance of the wind energy systems by modifying the design of mechanical and electrical systems. This paper plays a significant rule in this concept where the gear box has been eliminated by using high efficiency low speed PMSG as shown in Fig.1. In the regular wind turbine generator it has an induction generator that it can rotate at a speed of 1000 to 1500 rpm for normal operation and good efficiency. This means that a gearbox is needed between the turbine and the induction generator because the regular speed of the Wind Turbine Generator (WTG) before the gear-box is 30-60 rpm. But in using low-speed PMSG, the rotor rotates at the same speed as the rotor of the turbine. The PMSG can be connected directly to the wind turbine, which results in a simple mechanical system. However, the gearbox adds to the weight, generates noise, demands regular maintenance and increases losses. The maintenance of the gearbox-generator system may be difficult, because the nacelle is located at the top of the tower. Furthermore, there may also be problems with materials, lubrication and bearing seals. Many disadvantages can also be avoided in gearless WTG. The noise caused mainly by a high rotational speed can be reduced and also high overall efficiency and reliability reduced weight and diminished need for maintenance. However, the WTG can extract maximum power at different wind speeds. In the variable speed operation there is a reduction of the drive train, reduction in mechanical stresses, and the increased energy capture.

II SYSTEM COMPONENTS

The mechanical power and torque production from wind turbine is given by the following equations:

$$P_m = 1/2\ C_P \rho A u^3 = 1/2\ C_P \rho \Pi R^2 u^3 \text{ --------(1)}$$

$$T_m = 1/2\ C_T \rho \Pi R^2 u^3 \text{------------- (2)}$$

ρ= air density
C_p =Power coefficient
C_T =Torque coefficient
R = is the radius of the wind blade.
u = is the velocity of the wind.

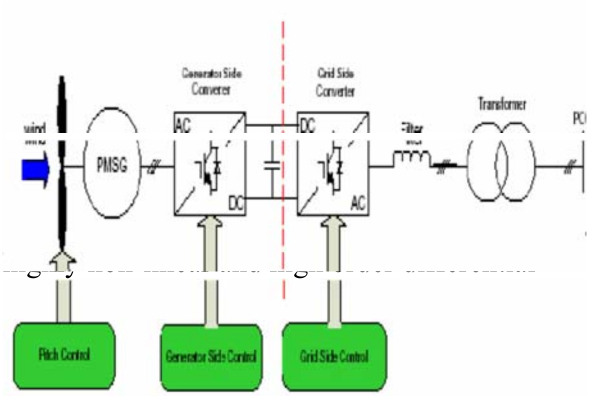

Fig 1 Block diagram of PMSG based wind Turbine

When wind speed changes, the rotational speed, ωm has to achieve the best value of Cp this means that and the wind speed must somehow be combined into a single variable before such a single curve can be drawn. Experiments show that this single variable is the ratio of the turbine *tip speed* R ωm to the wind speed u. this tip ratio λ is defined as [3]:

$$\lambda = \frac{R\,\omega m}{u} \quad \text{---------------} \ (3)$$

The relation between C_p C_T and λ for different kinds of WTG are shown in Fig.2 [4]. From (3), it is important to note that the power coefficient, Cp and the torque coefficient, C_T are functions of the ratio of the shaft speed, to the wind speed, u expressed as the tip speed ratio. However, power coefficient and torque coefficient are interrelated as $C_T=C_P/\lambda$

From Fig.2, it is clear that there exists a point where the power coefficient of performance is maximal.

The C_p must be maximum in order to obtain the maximum output power when the wind speed is below the rated value. Therefore, the value of the tip speed ratio has to be optimum for all wind speeds within this working region. For any change in the wind speed, the optimum tip speed ratio is obtained by adjusting the Rotor velocity. The wind turbine power characteristics are depicted in Fig 2 for wind speed varying from 4m/s to 15m/s. It can be seen that for any value of the wind speed, there is an optimum speed which generates the maximum output power [5-9].

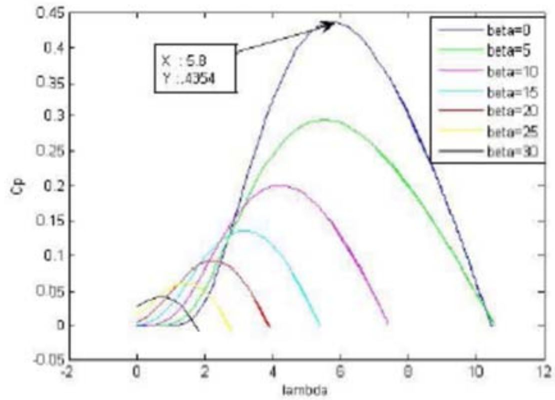

Fig 2 Cp curves as a function of λ for different pitch angles.

III SIMULATION AND ANALYSIS

A. PITCH CONTROLLER

The first study case analyzes the most unfavorable case which is a step change in the wind speed. Thesimulation has been run for 12 seconds and a speed step of 3m/s has been applied at 6th sec as in Fig 3.

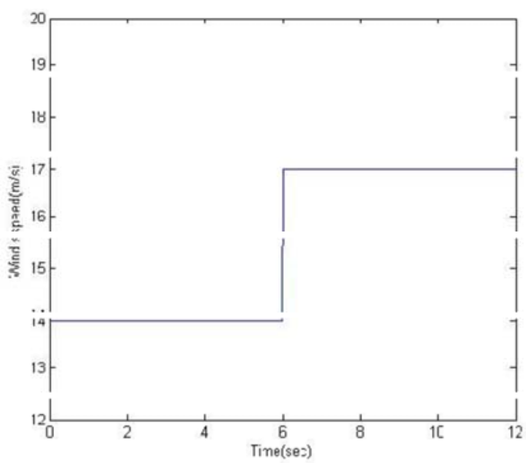

Fig 3 Step change in the wind speed

Fig 4 –Fig 7 shows the response of the system. With the above wind speed the pitch angle control response is as shown in Fig 5

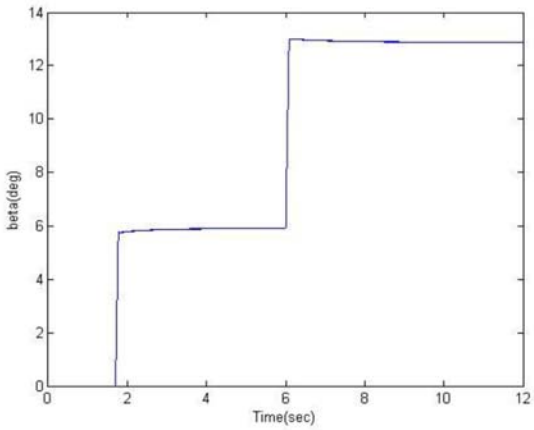

Fig 4 pitches angle response.

The response of the pitch angle is observed in the Fig 4, where the pitch angle raises from 6 degrees to 13 degrees as the wind speed increases from 14m/s to 17m/s.

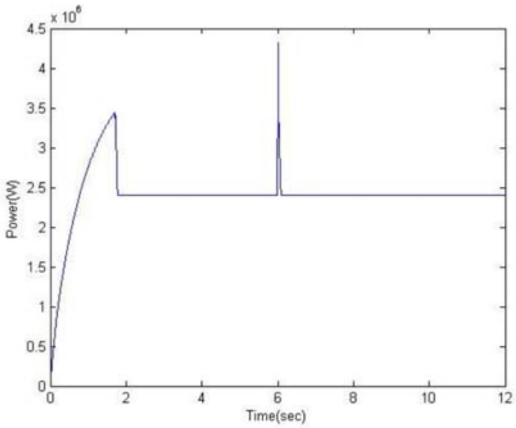

Fig 5 the output power response

It can be seen that above the rated speed the output power is limited to its rated value i.e. 2.4 MW, but due to the step change in the wind speed, there is a rise in output power above the rated value at the step time i.e, at 6th sec .as shown in Fig 5

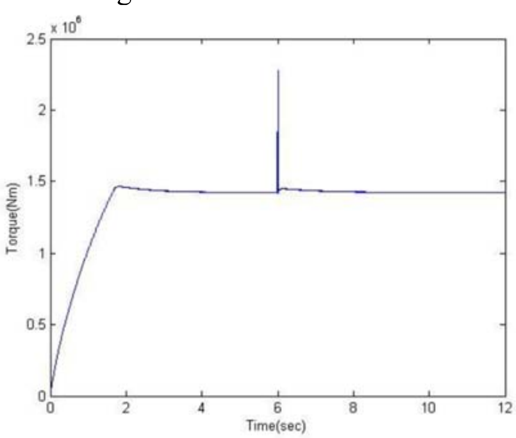

Fig 6 Wind turbine Torque

Fig 6 shows that the torque output is limited to its rated value and at 6th sec due to the step change in wind speed torque output increases above the rated value.

B. SPEED CONTROLLER

In this section the analysis of the speed controller is performed. Fig 15 shows the wind speed variation in time. Fig 8 shows the step increase in wind speed from 8m/s to 12 m/s. The simulation is run for 18seconds.

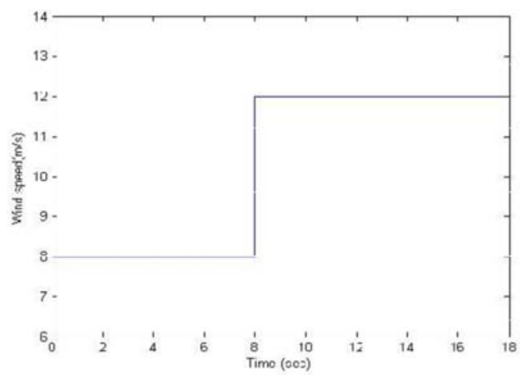

Fig 7: Wind turbine rotor speed.

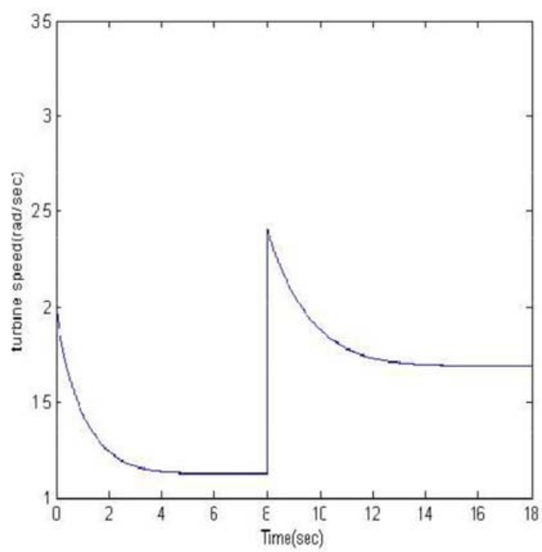

Fig 8 shows the rotor speed response.

The speed takes around 4 seconds to reach the steady state value

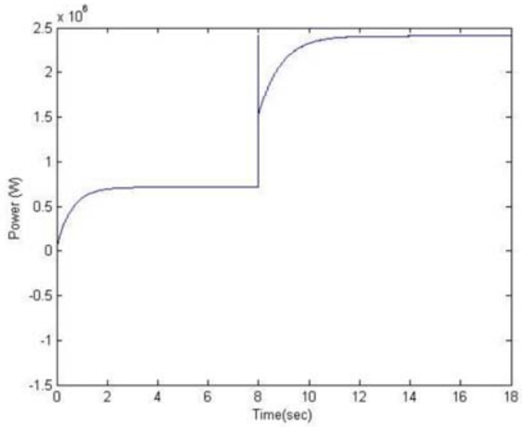

Fig 9 Output power

It is observed from the Fig 9 the wind speed increases the output power increases .The power increases from 0.7 MW to 2.4 MW as wind speed increases from 8m/s to 12m/s. At the time of step change a spike is observed in the power output.

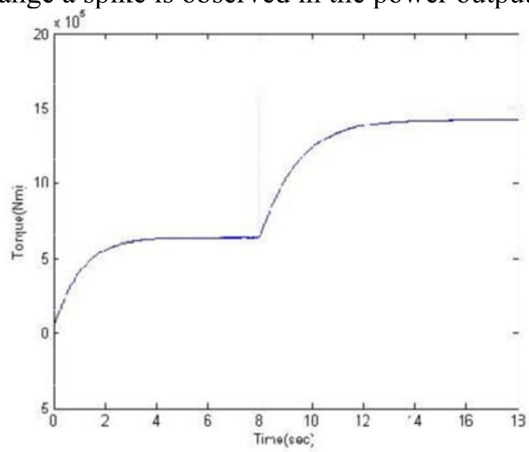

Fig 10 Wind turbine torque.

As the wind speed increases the turbine also torque increases from 6*105 Nm to 14*105 Nm. When the rotor speed reference is met the wind turbine torque equals the electromagnetic torque. At the time of step change in wind speed a spike in turbine torque is also observed.

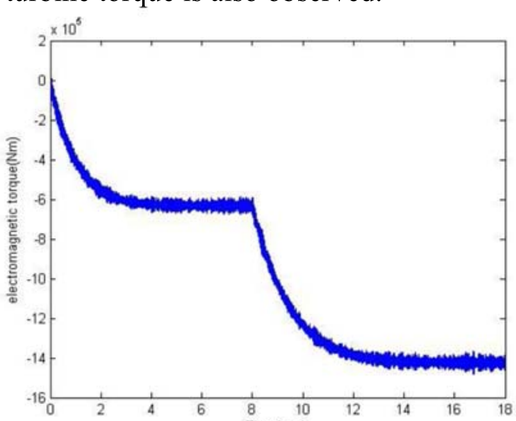

Fig 11 Electromagnetic torque.

For the wind speed variation shown in Fig , the optimum speed set as reference in order to generate maximum power is shown in Fig 9 .As the wind speed increases from 8m/s to 12 m/s the reference optimum speed changes from 1.13rad/sec to 1.69rad/sec.

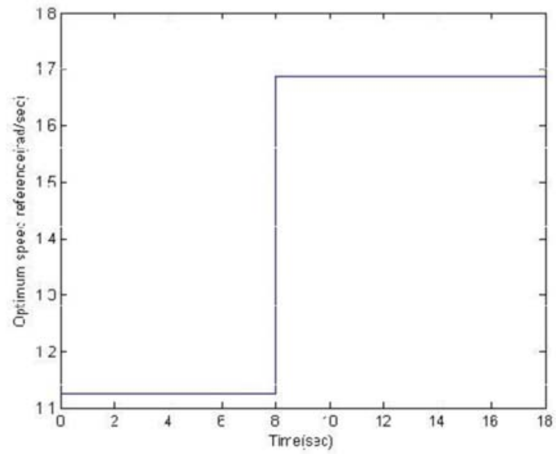

Fig 12 Optimum command speed

It is also seen that with the change in wind speed there is change in rotor reference speed which causes to the change in generator speed. Thus the generator tracks the optimum speed for maximum poweroutput. Fig 14 shows the speed error

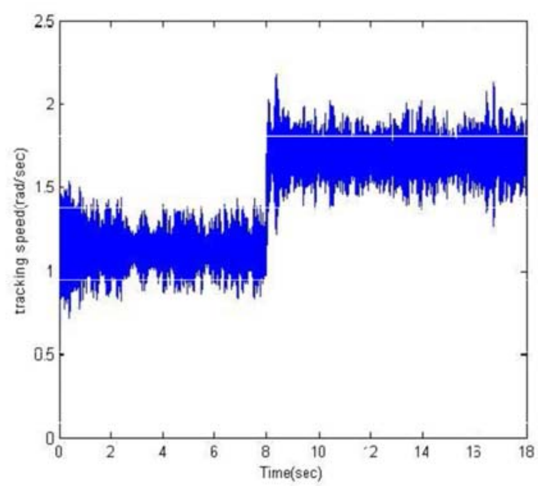

Fig 13 Tracking speed of PMSG

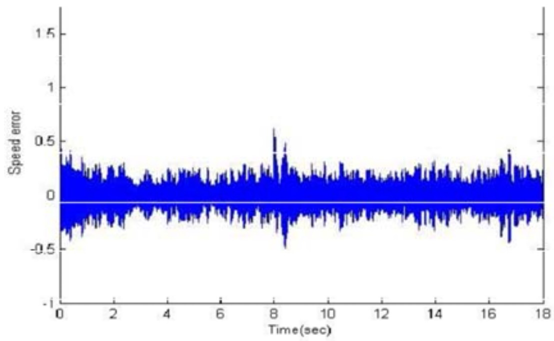

Fig 14 speed error

CONCLUSION

With the step increase in the wind speed above the rated value, it is observed that the pitch angle increases so that the power output is limited at its rated value. But due to the step change in wind speed there is rise in output power above the rated value at the instant when step change is applied. With the smooth increase or decrease in wind speed above the rated value, the controller sets the rated speed of 1.69rad/sec as the command speed, and the generator tracks this command speed and delivers the rated output power.

REFERENCES

[1] International Energy agency report " Key Issues in Developing Renewable ", 1997.

[2] Hernán De Battista, Pablo F. Puleston, Ricardo J. Mantz, Carlos F. Christiansen, " Sliding Mode Control Of Wind Energy Systems With DOIG – Power Efficiency And Trosional Dynamics Optimization", IEEE Transactions On Power System 2000, Vol.15, No.2, pp 728-734, May 2000.

[3] Gary L. Johnson "WIND ENERGY SYSTEMS ", book, prentic-hall, INC, ENGLAND cliffs, 2001.

[4] E. M.Fateev " Wind Motors and Wind Power Stations", book, Moscow 1948.

[5] PSIM user Manual, Refer to this website:www.powerdesign.com.

[6]A. Schonung and H. Stemmler, "Static Frequency Changer with Sub-harmonics Control in Conjunction with Reversible Variable Speed AC Drives," BBC Review, Aug./Sep. 1964.

[7] N. Mohan, T. Undeland, W. Robbins " Power electronics converters, application and design" Book, John Willy&Sons, INC., 1995.

[8] H. Nacfaire " Grid Connected Wind Turbines", book, Elsevier Applied Science, London and New Yourk, 1988, ISBN 1-85166-185-9.

[9] Ali M. Eltamaly " A New Relation Between Firing Angle Of Three-Phase SCR Converter And Best Reinjection Current Angle" The Ninth International Middle-East Power Systems Conference, MEPCON'2003 Minoufiya University, Shebin El-Kom, Egypt, December 16-18, 2003 PP.793-798