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Wind energy conversion system with PMSG

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Abstract

We have prepared a solution for the conventional use of generator in wind energy conversion system. Which is mainly depending upon the DFIG for the variable speed of the wind. Here we present a PMSG based wind energy conversion system. In this system we used PMSG which operation is depends upon the two mass drive train. This drive train is operated by the wind system and speed of the wind play a vital role in operation of the total wind conversion system We are used a pitch angle control system to reduce output power variation in high rated wind speed areas. There are different types of generators are present but the multiple pole permanent magnet synchronous generator (PMSG) is chosen as its offers better performance since it does not have rotor current. Simulation of the work is carried out in MATLAB/Simulink.

Keywords

DFIG, PMSG,Tturbine system.

1.Introduction

With the advancement of our developing country a number of ways are open for consumption of electrical energy or many other sources of energy that's why we require the number of renewable sources of energy. Energy exists freely in nature some of them exist infinitely never run out called Renewable Energy. With this in mind, it is a lot easier to lay any type of energy source in its right place.

As we know that the electrical energy is easily converted from mechanical system with a bulk amount of power with small area of occurrence which is not possible in the case of other sources of energy[1]. It is free and not pollute unlike the traditional fossil energy sources. It obtains clean energy from the kinetic energy of the wind by means of the wind turbine. Here we use permanent magnet synchronous generator for converting wind energy into mechanical energy and then into electrical energy The wind turbine convert the kinetic wind energy into mechanical energy through the drive train and then into electrical energy

1.1Wind turbine configuration

In the wind turbine business there are basically two types of turbines to choose from, vertical axis wind turbines and horizontal axis wind turbines. They both have their advantages and disadvantages and the purpose of this article is to help you choose the right system for your application.

1.2Horizontal axis wind turbine

Horizontal axis wind turbine dominate the majority of the wind industry. Horizontal axis means the rotating axis of the wind turbine is horizontal, or parallel with the ground. In big wind application, horizontal axis wind turbines are almost all you will ever see.

1.3Vertical axis wind turbines

In comes the vertical axis wind turbine. With vertical axis wind turbines the rotational axis of the turbine stands vertical or perpendicular to the ground. As mentioned above, vertical axis turbines are primarily used in small wind projects and residential applications. Vertical-Axis-Wind-Turbine We have studied both type of wind turbine but we are familiar with the use of horizontal axis wind turbine. We required a mass production of electrical energy for that we required huge size of wind mill which produces a bulk amount of power.

2.Wind energy conversion

Wind is air in motion. Wind is mainly formed due to the Earth's rotation and the uneven heating of Earth's surface by sunrays. The sunrays cover a much greater area at the equator than at the poles. The hot air rises from the equator and expands toward the poles that cause wind [2]. Air has a mass and mass in motion has a momentum. Momentum is a form of energy that can be harvested.

$$P_w = \frac{1}{2} \times \rho \times S \times V^3 \qquad \text{---------------(1)}$$

Where-

P_w- Power in wind(W/m^2)
P – Air density (kg/m^3)
S – Projected area (m2) (Wind turbine rotor area)
V – Average wind speed (m/s)

The power increase with cube of wind speed

3.Wind turbine system heading

3.1Turbine mathematical model

In the literature survey a number of studies have been shows their view on wind turbines and wind power driven system. Wind energy to mechanical energy conversion is done by wind turbine. The mechanical power of turbine extracted from wind. Overall wind energy conversion system is totally depends upon the power coefficients of the turbine (C_p).this is the function of pitch angle (β) and tip speed ratio (λ). Pitch angle is the angle of the turbine blade, where as tip speed is the ratio of rotational speed & wind speed. C_p is also known as the limit of Betz.[3-5]

A generic equation is used to model C_p (λ, β). This equation, based on the modeling turbine characteristics, which is also called as power coefficient equation

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4\right) e^{\frac{-C_5}{\lambda_i}} + C_6\lambda$$

With

$$\frac{1}{\lambda_i} = \frac{1}{\lambda+0.08\beta} - \frac{0.035}{\beta^3+1} \text{ ---------------(2)}$$

The coefficients C_1 to C_6 are: C_1 =0.5176, C_2 = 116, C_3 = 0.4, C_4 =5, C_5 =21 and C_6 = 0.0068. The C_p-λ characteristics, for different values of the pitch angle β, are illustrated below in *Figure 2*. The maximum value of C_p (C_{Pmax} = 0.48) is achieved for β = 0 degree and for λ = 8.1.This particular value of λ is defined as the nominal value (λ_nom).
The power coefficient is given by,

$$C_p = \frac{P_m}{P_w};\ C_p < 1 \text{-----------------(3)}$$

$$P_m = C_p(\lambda,\beta)\frac{\rho S}{2} V_{wind}^3 \text{----------(4)}$$

Where, P_m is the mechanical output power of the turbine, C_P is the performance coefficient of the turbine, ρ is the air density, S is the turbine swept area, V_{wind} is the wind speed, λ is the tip speed ratio, β is the blade pitch angle. The tip speed ratio is defined as

$$\lambda = \frac{\omega_t R}{V_{wind}} \text{--------------------(5)}$$

Where ω_t is the rotational speed (rad/sec), of the wind turbine, and R is the rotor radius (m),
The mechanical torque is given by,

$$T_m = \frac{P_m}{\omega_t} \text{--------------------(6)}$$

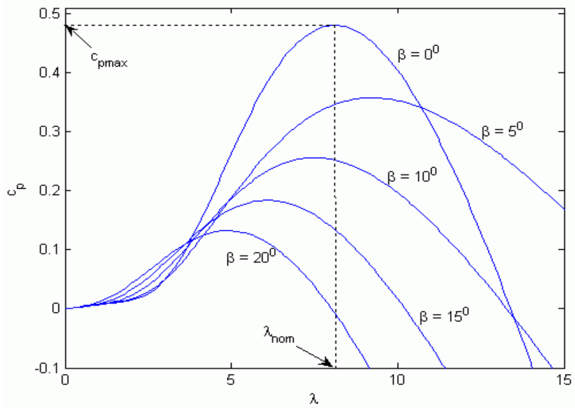

Figure 1 Shows $C_p(\lambda,\beta)$ characteristic for different values of the pitch angle

3.2Turbine control

We have many methods for control of Wind turbines when the speed of wind is vary with respect to time. Wind turbines are therefore generally designed so that they yield maximum output at wind speeds around 15 meters per second. (30knots or 33 mph). Its does not pay to design turbines that maximize their output at stronger winds, because such strong winds are rare.

3.2.1Pitch controlled wind turbines

On a pitch controlled wind turbine the turbine's electronic controller checks the power output of the turbine several times per second. When the power output becomes too high, it sends an order to the blade pitch mechanism which immediately pitches (turns) the rotor blades slightly out of the wind. Conversely, the blades are turned back into the wind whenever the wind drops again. The rotor blades thus have to be able to turn around their longitudinal axis (to pitch) as shown in the picture. Note, that the picture is exaggerated:

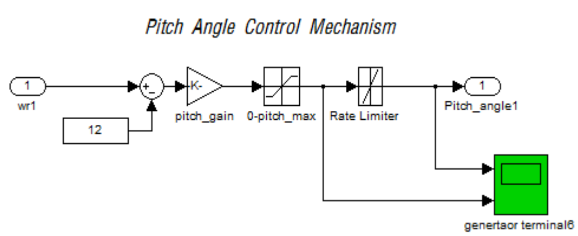

Figure 2 Shows pitch angle control mechanism

4.Drive train

In power system studies drive trains are modeled as a series of rigid disk's connected via mass less shafts. For small-signal analysis of permanent magnet synchronous generator (PMSG) in conventional wind power plant's. The one mass or lumped-mass model is used because the drive train behaves as single equivalent mass[6].

4.1Two mass drive train

The equation for the two-mass model are based on the torsional version of the second law of Newton, deriving the state equation for the rotor angular speed at the wind turbine and for the rotor angular speed at the generator is given by

$$\frac{d\omega_t}{dt} = \frac{1}{Jt}(T_t - T_{dt} - T_{at} - T_{ts}) \text{----(8)}$$

$$\frac{d\omega_g}{dt} = \frac{1}{J_g}(T_{ts} - T_{dg} - T_{ag} - T_g) \text{--(9)}$$

Where Jt the moment of inertia for blades and hub, T_{dt} is the resistant torque in the wind turbine bearing, T_{at} is the resistant torque in the hub and blade due to the viscosity of the air flow, T_{ts} is the torque of torsional stiffness, ω_g is the rotor angular speed at the generator , Jg is the generator moment of inertia, T_{dg} is the resistant torque in the generator bearing, T_{ag} is the resistant torque due to the viscosity of the airflow in the generator

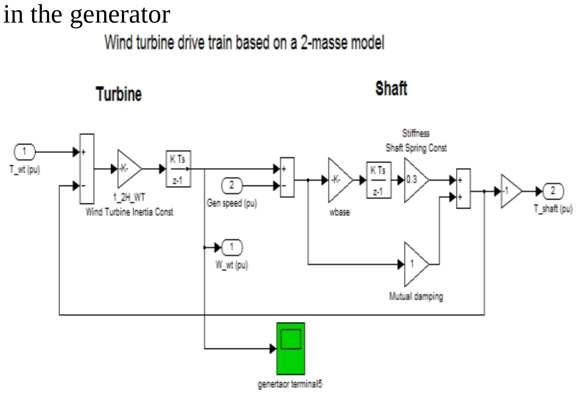

Figure 3 Shows two mass drive train model

5.Generator

5.1Permanent magnet synchronous generator

There are many designs for permanent magnet where proposed such as, modular design, outer rotor design, the coreless type, PMSG has large number of poles to operate at low speed as it works in a gearless drive train system. To increase the efficiency and reduce the weight of the active parts, direct-drive generators are usually designed with a large diameter and a small pole pitch. The rotor excitation is provided by PM which decreases the reactive power compensation arrangement used in electrically excited generators and removes the slip rings, minimizing size and lowering cost of the system. Modular design of PMSG allows simplicity in manufacturing process by using high quality magnet (NdFeB) which ensures larger life time. The generator coil can be protected against environment conditions to satisfy working in offshore farms. The damper windings are not existed in PMSG and the stator direct flux is constant since the excitation is provided by the magnets unlike that in the electrically excited generator[7-9]. It is common in large-scale stability analysis to neglect the stator flux transients of synchronous generators.

5.2Mathematical model of PMSG

Considering the equivalent circuit of PMSG based on WECS in figure.1 below the model of PMSG is established in the d-q synchronous reference frame, the three-phase sinusoidal mathematical equations are expressed in the rotor reference frame (d-q frame). All quantities in the rotor reference frame are referred to the stator. And it is give as

$$\frac{d}{dt}i_d = \frac{1}{L_d}v_d - \frac{R}{L_d}i_d + \frac{L_q}{L_d}P\omega_r i_q \text{------(13)}$$

$$\frac{d}{dt}i_q = \frac{1}{L_q}v_q - \frac{R}{L_q}i_q - \frac{L_d}{L_q}P\omega_r i_d - \frac{\lambda P\omega_r}{L_q} \text{--------(14)}$$

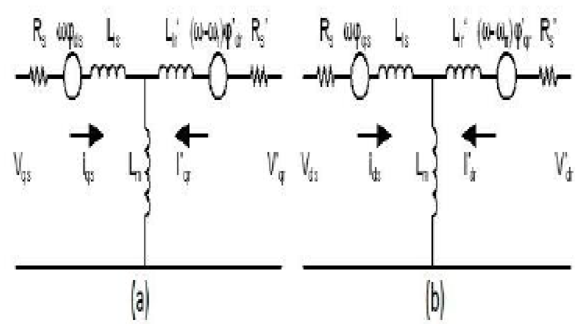

Figure 4 Shows equivalent circuit of PMSG in d-q reference frame

The electromagnetic torque equation is given by

$$T_e = \frac{3}{2}P[\lambda i_q + (L_d - L_q)i_d i_q \text{---------(15)}$$

Where L_q & L_d are q and d axis inductance, R is resistance of the stator windings, i_q & i_d are q and d axis current, v_q & $v_d$are q and d axis voltage, ω_r is angular velocity of the rotor, λ is amplitude of flux induced by permanent magnets of rotor in the stator phase , P is the number of pole pairs[10].

The mechanical equation is given by

$$\frac{d}{dt}\omega_r = \frac{1}{J}(T_e - T_f - F\omega_r - T_m) \text{--(16)}$$

$$\frac{d\theta}{dt} = \omega_r \text{-------------------(17)}$$

Where J is combined inertia of rotor & load, F is combined viscos friction of rotor & load, θ is rotor angular position, T_m is shaft mechanical torque, T_f is shaft static friction torque.

6.Methodology

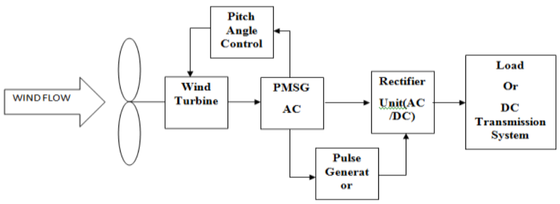

Figure 5 Shows block diagram of used mechanism

The schematic representation of the system subject to control is depicted in above figure. Which shows that the variation of wind is maintain by pitch angle control system.

6.1Modeling of the proposed system

The MATLAB Simulation of proposed topology has been shown in the *Figure 10*. The matlab Simulink tool box simpower has been used for getting `the required results

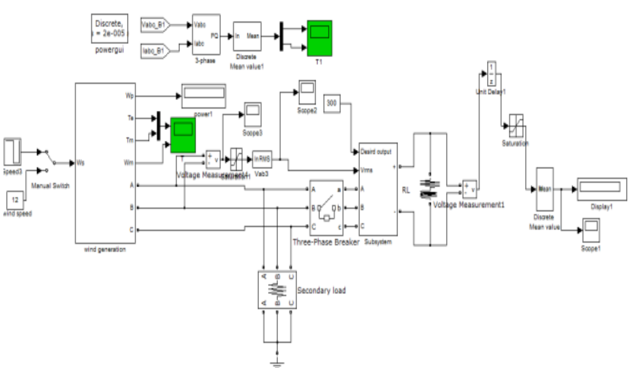

Figure 6 View of control system

7.Simulation results

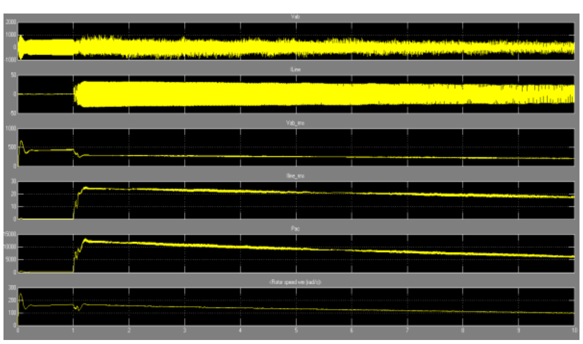

Figure 7 Showes PMSG output for given wind speed

a) Line voltage V_{ab} b) Line Current I_{Line}
c) RMS value of V_{ab} d) RMS value of I_{Line}
e) Generated power P_{ac} f) Rotor speed w_m rad/s

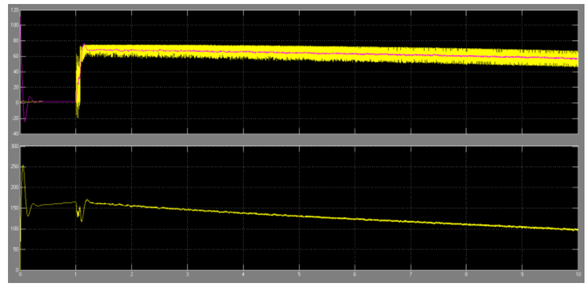

Figure 8 Shows Te, Tm and Rotor speed

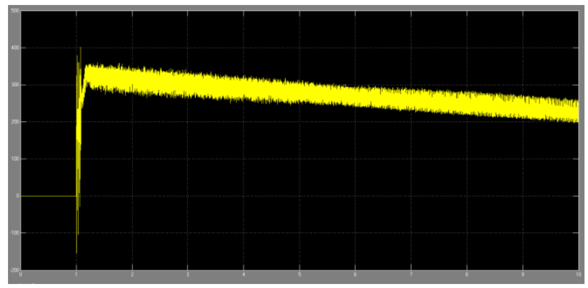

Figure 9 Output DC voltage of the system

8.Conclusion

In the proposed scheme, output DC voltage is provided to load and connected DC transmission system. This is controlled by pitch angle control mechanism and a secondary load is provided for balancing the low load condition.

Appendix

Permanent Magnet Synchronous Generator:
3 phase, 300 volt, 50 Hz, 3000 rpm, 4 pole

Electromagnetic Torque	: 3.24 Nm
Stator Resistance	: 0.425 ohm
Inductance Ld(H)=Lq(H)	: 0.0082 H
Flux Induced by magnets	: 0.433 wb

References

[1] Sharma S, Singh B. Control of permanent magnet synchronous generator-based stand-alone wind energy conversion system. IET Power Electronics. 2012; 5(8):1519-26.

[2] Sharma S, Singh B. An autonomous wind energy conversion system with permanent magnet synchronous generator. In energy, automation, and signal (ICEAS), 2011 international conference on 2011 (pp. 1-6). IEEE.

[3] Toumi S, Elghali SB, Trabelsi M, Elbouchikhi E, Benbouzid ME, Mimouni MF. Robustness analysis and evaluation of a PMSG-based marine current turbine system under faulty conditions. In Sciences and techniques of automatic control and computer engineering (STA), 2014 15th international conference on 2014 (pp. 631-6). IEEE.

[4] Sasi C, Mohan G. Performance analysis of grid connected wind energy conversion system with a dfig

during fault condition. International Journal of Computer Applications. 2013;70(19).

[5] Verma J, Tiwari Y, Mishra A, Tapre P. Performance analysis of various parameters by comparison of conventional pitch angle controller with fuzzy logic controller. International Journal of Research in Engineering and Technology.2014;3(3):177-83.

[6] Pareta N, Sen N. Modelling and simulation of permanent magnet synchronous motoer based wind energy conversion system. International Journal of Emerging Research in Management &Technology. 2014; 3:43-52.

[7] Khare M, Agnihotri G, Kumar Y, Sethi V.K. Performance analysis of a grid connected wind energy system. American Journal of Engineering Research (AJER). 2014; 3(2):204-8.

[8] Varghese A. A. , Bharath S, Aswathy P.R. SMES based DVR for mitigating the voltage fluctuations in a direct current vector control PMSG wind turbine. International Journal of Innovative Research in Science, Engineering and Technology 2014; 3(5): 12759- 67.

[9] Verma J, Tiwari Y, Mishra A, Singh N. Performance, analysis and simulation of wind energy conversion system connected with grid. International Journal of Recent Technology and Engineering. 2014;2(6):33-8.

[10] Goel PK, Singh B, Murthy SS, Kishore N. Autonomous hybrid system using PMSGs for hydro and wind power generation. In industrial electronics,. IECON'09. 35th Annual Conference of IEEE 2009 (pp. 255-60). IEEE.