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A Review on "Performance Analysis of PMSG in Wind Energy Conversion System"

Dhirendra Deode[1] Mr Nand Kishor Meena[2]
Student[1], Asst Professor[2]
LNCT Bhopal Approved By AICTE & PCI, New Delhi &Affiliated to RGPV Bhopal

Abstract*— The main object of this paper is to analyze performance and operation of PMSG connected with wind turbine under varying wind speed in place of DFIG. In this system a PMSG convert wind power into electrical power and transmit it to an AC grid through an AC-DC-AC converter. We are going to use 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 PMSG is chosen as its offers better performance since it does not have rotor current and can be used without a gearbox which also implies a reduction of weight of the nacelle and a reduction of the cost. Simulation of the work is carried out in MATLAB/Simulink.

***Index Terms*— PMSG - Permanent magnet synchronous generator, DFIG - Doubly fed induction generator, AC – Alternating current, DC – Direct current.**

I. INTRODUCTION

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. Let's look at this type of energy in the diagram below-

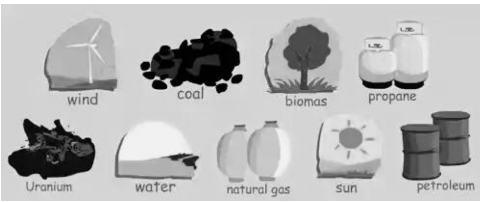

Fig.-1 Type of Energy Sources

We notice that water, wind, sun, and biomass are all available naturally and were not formed. The others do not exist by themselves they were formed. Renewable energy resources are always available to be tapped and will not run out. This is why some people call it Green Energy.

Here we are use wind power for the production of electrical energy because wind power is a very important renewable energy source. It is free and not pollutes unlike the traditional fossil energy sources. It obtains clean energy from the kinetic energy of the wind by means of the wind turbine. The wind turbine convert the kinetic wind energy into mechanical energy through the drive train and then into electrical energy by means of the permanent magnet synchronous generator (PMSG).

A. *Wind 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.

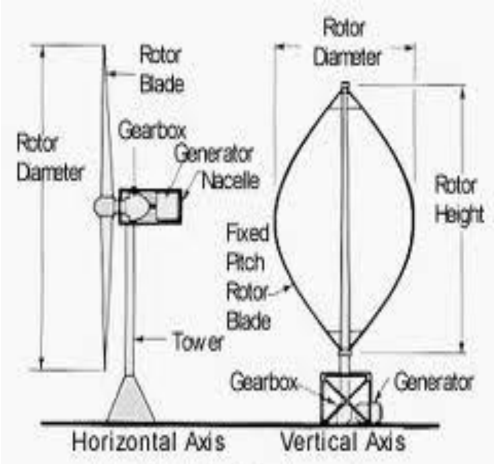

Fig. 2 Wind turbine configurations

II. HORIZONTAL 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. However, in small wind and residential wind applications, vertical axis turbines have their place. The advantage of horizontal wind is that it is able to produce more electricity from a given amount of wind. So if you are trying to produce as much wind as possible at all times, horizontal axis is likely the choice for you. The disadvantage of horizontal axis however is that it is generally heavier and it does not produce well in turbulent winds.

III. VERTICAL 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 this niche comes from the OEM's claims of a vertical axis

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turbines ability to produce well in tumultuous wind conditions. Vertical axis turbines are powered by wind coming from all 360 degrees, and even some turbines are powered when the wind blows from top to bottom. Because of this versatility, vertical axis wind turbines are thought to be ideal for installations where wind conditions are not consistent, or due to public ordinances the turbine cannot be placed high enough to benefit from steady wind.

IV. GENERATOR CONFIGURATION

There are different type of generator used in wind energy conversion system (WECS). Such as induction generator (IG), double feed induction generator (DFIG) and permanent magnet synchronous generator (PMSG). The PMSG based on WECS can connect to the turbine without using gearbox. Wind turbine are classified with a view to the rotational speed, the power regulation and the generator system, the turbines are classified into the geard and the direct drive types. The direct drive type is known with the advantages as it has a lower cast smaller size and consequently weight is used. Hear we consider two types generator with their basic principles-

- Turbine driving a DFIG

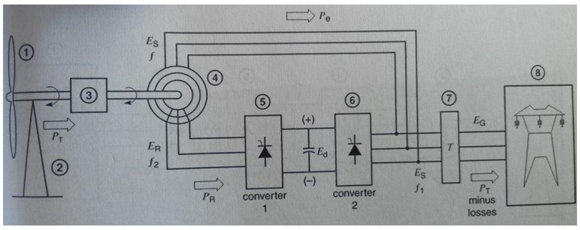

Fig.-3 View of DFIG

Fig.-3 shows a large commercial wind turbine (1) that drive a wound rotor induction generator (4), by way of a gear box (3), the electric utility grid voltage is stepped down to a lower voltage by means of a transformer (7). Converter (6) transforms the line voltage to a content dc voltage. Power can flow from the ac side to the dc side of this converter (5) transforms the dc voltage into a voltage whose magnitude, frequency, phase shift and phase sequence can be varied at will. The stator of the wound rotor induction generator is connected directly to the power line whose frequency f is 50 Hz or 60 Hz.

- Turbine directly driving a PMSG

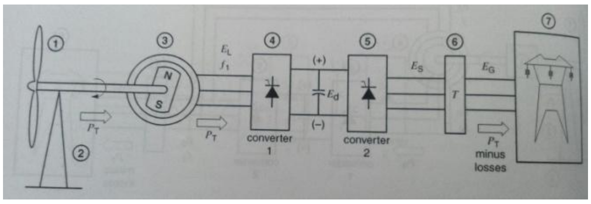

Fig.-4 View of PMSA

Fig.-4 shows how a wind turbine directly connected to a PMA. Converter (4) and (5) & transformer (6) play same role as in figure (3). The frequency f_1 generated by converter (4) impose the optimal speed of rotation on the generator. Note that converters have to carry the entire power developed by the turbine; consequently they are inherently larger than those in the doubly fed generator.

The direct drive has the advantage of eliminating the speed-multiplying gear box. However since the turbine speed of the order of 30 rpm or less. However, the permanent magnet alternator does not require any brushes, & the rotor losses are nil. For this reasons, this arrangement is sometimes preferred in turbines that generate power in the 2 MW to 5 MW range.

V. 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. 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

VI. WIND TURBINE SYSTEM

A. *Turbine 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 (Cp).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. Cp is also known as the limit of Betz.

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

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

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

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

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

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,

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

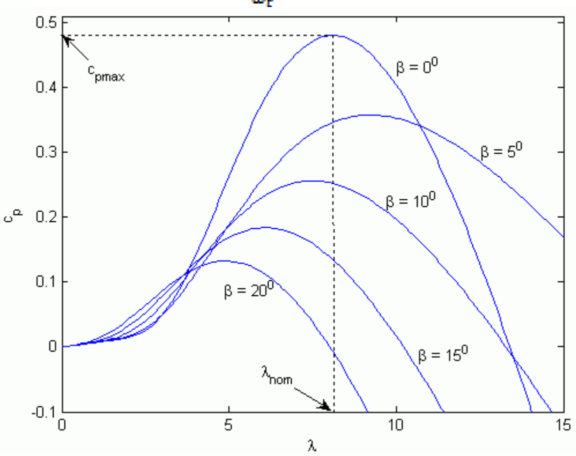

Fig.-5 Shows $C_p(\lambda, \beta)$ characteristic for different values of the pitch angle

B. *Turbine Control*

Wind turbines are designed to produce electrical energy as cheaply as possible. 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.

In case of stronger winds it is necessary to waste part of the excess energy of the wind in order to avoid damaging the wind turbine. All wind turbines are therefore designed with some sort of power control. There are two different ways of doing this safely on modern wind turbines.

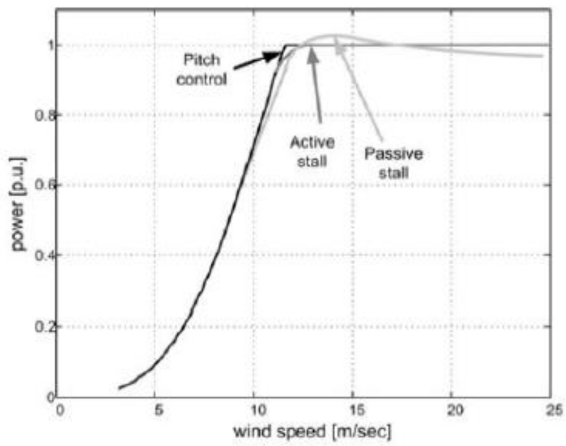

Fig.-6 shows different wind turbine control strategies

a. *Pitch 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:

During normal operation the blades will pitch a fraction of a degree at a time - and the rotor will be turning at the same time.

Designing a pitch controlled wind turbine requires some clever engineering to make sure that the rotor blades pitch exactly the amount required. On a pitch controlled wind turbine, the computer will generally pitch the blades a few degrees every time the wind changes in order to keep the rotor blades at the optimum angle in order to maximize output for all wind speeds. The pitch mechanism is usually operated using hydraulics.

b. *Stall Controlled Wind Turbines*

Passive stall controlled wind turbines have the rotor blades bolted onto the hub at a fixed angle.

The geometry of the rotor blade profile however has been aerodynamically designed to ensure that the moment the wind speed becomes too high, it creates turbulence on the side of the rotor blade which is not facing the wind as shown in the picture on the previous page. This stall prevents the lifting force of the rotor blade from acting on the rotor.

If you have read the section on aerodynamics and aerodynamics and stall, you will realize that as the actual wind speed in the area increases, the angle of attack of the rotor blade will increase, until at some point it starts to stall.

If you look closely at a rotor blade for a stall controlled wind turbine you will notice that the blade is twisted slightly as you move along its longitudinal axis. This is partly done in order to ensure that the rotor blade stalls gradually rather than abruptly when the wind speed reaches its critical value. (Other reasons for twisting the blade are mentioned in the previous section on aerodynamics).

The basic advantage of stall control is that one avoids moving parts in the rotor itself, and a complex control system. On the other hand, stall control represents a very complex aerodynamic design problem, and related design challenges in the structural dynamics of the whole wind turbine, e.g. to avoid stall-induced vibrations. Around two thirds of the wind turbines currently being installed in the world are stall controlled machines.

c. *Active Stall Controlled Wind Turbines*

An increasing number of larger wind turbines (1 MW and up) are being developed with an active stall power control mechanism. Technically the active stall machines resemble pitch controlled machines, since they have patchable blades. In order to get a reasonably large torque (turning force) at low

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wind speeds, the machines will usually be programmed to pitch their blades much like a pitch controlled machine at low wind speeds. (Often they use only a few fixed steps depending upon the wind speed).

When the machine reaches its rated power, however, you will notice an important difference from the pitch controlled machines: If the generator is about to be overloaded, the machine will pitch its blades in the opposite direction from what a pitch controlled machine does. In other words, it will increase the angle of attack of the rotor blades in order to make the blades go into a deeper stall, thus wasting the excess energy in the wind. One of the advantages of active stall is that one can control the power output more accurately than with passive stall, so as to avoid overshooting the rated power of the machine at the beginning of a gust of wind. Another advantage is that the machine can be run almost exactly at rated power at all high wind speeds. A normal passive stall controlled wind turbine will usually have a drop in the electrical power output for higher wind speeds, as the rotor blades go into deeper stall.

The pitch mechanism is usually operated using hydraulics or electric stepper motors.

As with pitch control it is largely an economic question whether it is worthwhile to pay for the added complexity of the machine, when the blade pitch mechanism is added.

d. Other Power Control Methods

Some older wind turbines use ailerons (flaps) to control the power of the rotor, just like aircraft use flaps to alter the geometry of the wings to provide extra lift at takeoff.

Another theoretical possibility is to yaw the rotor partly out of the wind to decrease power. This technique of yaw control is in practice used only for tiny wind turbines (1 kW or less), as it subjects the rotor to cyclically varying stress which may ultimately damage the entire structure.

VII. 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. Different models of drive train for wind turbine have been reviewed in this paper In[1]author presents the gearbox is coupled between wind turbine and induction generator of 225 KW 50 Hz the gear box ratio is 1:23.4 is discussed. In [2] author describe about the two mass drive train. The stiffness of the drive train is infinite and the friction factor and the inertia of the turbine must be combined with those of the turbine, and obtained the mechanical output power generated by turbine, such as load torque, turbine moment of inertia, and load power is discussed. In[3] author presents for VSWT , the drive train modeling is not so influential due to the decoupling effect of the power electronic converter‘s between the generator and the grid system therefore in [3] study on simple one mass lumped model of WTGS is used is discussed. In [4][5][8] author presented a wind turbine is direct-drive with permanent magnet synchronous generator is discussed. In [6] author discuss about the one-mass model is used for dynamic model of PMSG-WT based on power system. In [7] author focuses on the interaction between wind farms and AC grid. The drive train can be treated as one-lumped mass model for the sake of time efficiency and acceptable precision is discussed. In[9] author present‘s a multi mass drive train is considered for small-signal stability studies of WECS with DFIG but in[9] it is sufficient to consider the two mass model (one for the turbine, the other for the generator) is discussed .

A. Different type of drive train model

a. One mass drive train

In a one-mass drive train model all inertia components are lumped together, i.e. modeled as a single rotating mass. The equation for the one-mass model is based on the second law of Newton, deriving the state equation for the rotor angular speed at the wind turbine given by

$$\frac{d\omega_t}{dt} = \frac{1}{J}(T_t - T_g) \text{ -----------------------(7)}$$

Where J is the moment of inertia for blades, hub and generator, Tt is the mechanical torque, Tg is electrical torque.

b. Two 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

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

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

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.

c. Three mass drive train

The equations for the three-mass model are also based on the torsional version of the second law of Newton and it is given by

$$\frac{d\omega_t}{dt} = \frac{1}{Jb}(T_t - T_{db} - T_{bs}) \text{---------(10)}$$

$$\frac{d\omega_h}{dt} = \frac{1}{Jh}(T_{bs} - T_{dh} - T_{ss}) \text{--------(11)}$$

$$\frac{d\omega_g}{dt} = \frac{1}{Jg}(T_{ss} - T_{dg} - T_g) \text{---------(12)}$$

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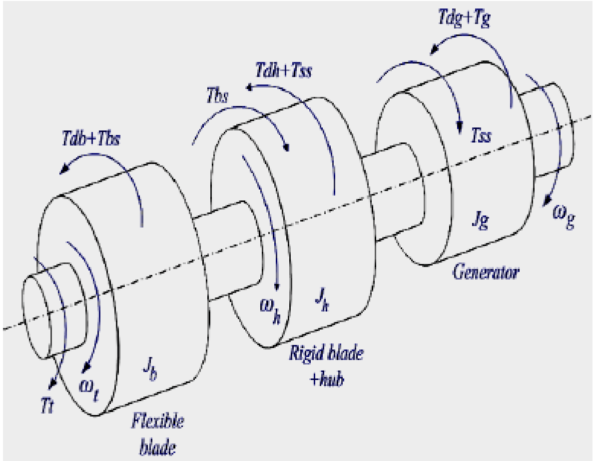

Fig-7 Three mass drive train

Where J_b is the moment of inertia of the flexible blades section, T_{db} is the resistant torque of the flexible blades, T_{bs} is the torsional flexible blades stiffness torque, ω_h is the rotor angular speed at the rigid blades and the hub of the wind turbine, J_h is the moment of inertia of the hub and the rigid blades section, T_{dh} is the resistant torque of the rigid blades and hub, T_{ss} is the torsional shaft stiffness torque, T_{dg} is the resistant torque of the generator.

VIII. GENERATOR

The electrical generator system of the wind turbine includes all components for converting mechanical energy in to electrical power. A brief review of the generator has been illustrated here In [1] author present existing constant speed system and variable speed drive for wind turbine is discussed. In which existing constant speed system consist of a induction generator which is mechanically coupled to the shaft of a turbine and electrical power generated is directly feed in to grid Where as the variable speed system uses only a six pole winding through out the operation. Therefore the speed variation in the case of the variable speed controller is smooth from minimum wind speed; as a result the power generated in this range is always better than the original system (which is constant speed system) is discussed. In [2][3][4][5][6][7][8] author discussed about the permanent magnet synchronous generator based on wind energy power generation. In [9] author presented the DFIG (Double feed induction generator) is used as a generator is discussed.

A. Different type of Wind Generator

A classification of generating system. The principal division lies in the nature of the field patterns produced independently by the stator and rotor.

❖ ***Electro Mechanical Generator***

- Synchronous Devices
  - De-generators
  - AC-synchronous generator
    - Permanent magnet excitation
    - Brushless
    - Field modulated generator
    - Static excitation
    - Rotating exciter
  - Inductor alternator
- Slipping devices
  - AC-commutator machines
  - Cage rotor
  - Multiple rotor
  - Wound rotor
  - Slip energy dissipation
  - Slip energy recovery

B. Permanent 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. Regarding electrically losses than PM excitation which increases with number of poles, although PM also has low losses because of the circulation of eddy current and, consequently, control of output voltage independent of load current is the main advantage of the wound rotor excitation system which is very important in constant speed hydro and turbo generator. This advantage is not important in variable speed wind driven systems since they are connected to grid via power electronic interface. 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. It is common in large-scale stability analysis to neglect the stator flux transients of synchronous generators.

C. Mathematical Model of PMSG

Considering the equivalent circuit of PMSG based on WECS in figure.5 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

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

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

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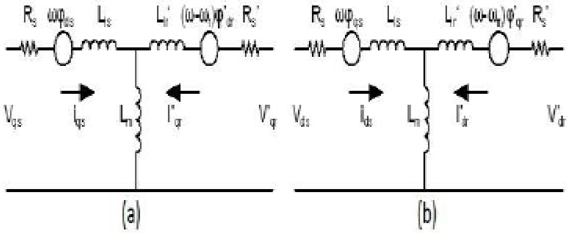

Fig-8 shows equivalent circuit of PMSG in d-q reference frame

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.

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.

IX. CONTROL METHODOLOGY

The schematic representation of the system subject to control is depicted in figure. As it can be observed, the generator is fully decoupled from the grid by means of the power converter; thus, the power factor of the generator is independent of the reactive power factor at the grid connection.

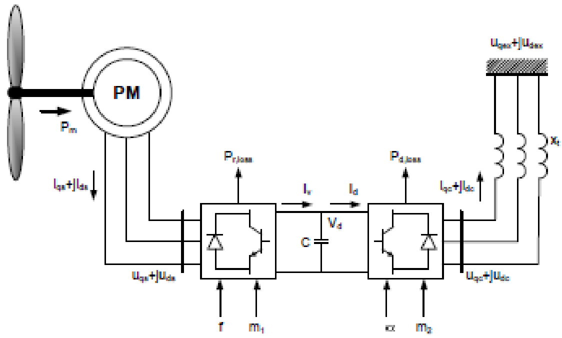

Fig.-9 View of Control System

A. Control of the Generator side converter

The terminal voltage of the generator in terms of modulation ratio m_1 and phase angle θ is defined as

$$\left.\begin{aligned} v_{qs} &= m_1 v_d Cos\theta, \\ v_{ds} &= -m_1 v_d Sin\theta \end{aligned}\right\} \text{------------------------(18)}$$

Where the phase angle θ is

$$\frac{d\theta}{dt} = \omega_{base}(\omega_m - f) \text{ ----------------------(19)}$$

The reference power to archive the maximum efficiency of a wind turbine is given by

$$P_{ref} = T_m \omega_m = K_{turb}\,\omega_m^3 \text{------(20)}$$

Where Tm is mechanical torque and K_{turb} is the turbine coefficient, which, according to (2), can be calculated as follows-

$$K_{turb} = \frac{\frac{1}{2}\rho C_{p,opt}\pi r^5 \omega_{base}^3}{\lambda_{opt}^3 S_{base}} \text{ ---------------(21)}$$

Where ρ is the air density [kg/m^3], $C_{p,opt}$ is the optimal turbine efficiency,λ_{opt} is the optimal tip speed ratio, r is the turbine radius [m], S_{base} is the base power of the generator [MVA], and ω_{base} is the nominal rotor speed [rad=s].

Recognize that for a synchronous generator the stator frequency is equal to the rotor speed in per unit values, the control of the generator frequency can be performed as presented in Fig.-10

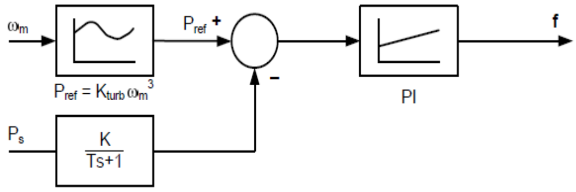

Fig.-10 Control of generator frequency

The modulation ratio m_1 of the generator side convertor is controlled as shown in fig.-11, where

$$|V_s| = \sqrt{v_{qs}^2 + v_{ds}^2} \text{ ---------------------(21)}$$

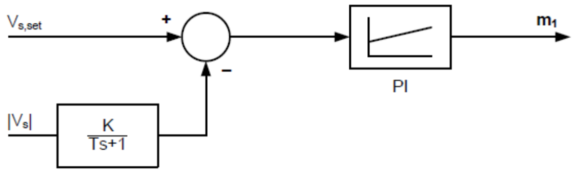

Fig.-11 Control of modulation ratio m_1

D. Control of grid side converter

The terminal voltage of the grid side converter is given by

$$\left.\begin{aligned} v_{qc} &= m_2 V_d cos(\alpha), \\ v_{dc} &= -m_2 V_d sin(\alpha) \end{aligned}\right\} \text{ ----------------(22)}$$

The phase angle α and the modulation ratio m_2 can therefore be controlled independently (Fig.- 12 and 13)

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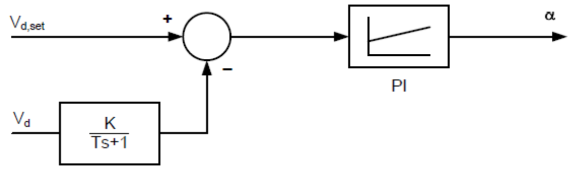

Fig.-12 Control of the phase angle

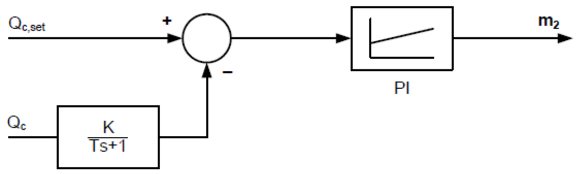

Fig.-13 Control of modulation ratio m_2

X. MAXIMUM POWER POINT TRACKING SYSTEM

The function of MPPT (maximum power point tracking) is to automatically adjust the generator speed to converge to the optimum one where the generated power is maximized. This may be obtained using PI control with the use of the electrical power at the grid-side instead of the mechanical power of wind turbine. With this option, the losses of both generators and converters will also be taken into consideration and, the overall energy conversion can then be optimized.

For a given wind speed, the optimal rotational speed of the wind turbine rotor can be simply estimated as follows

$$\omega_{opt} = \frac{V_{wind}\lambda_{opt}}{R} \text{--------------------(23)}$$

Then the maximum mechanical output power of the turbine is given as follows

$$P_{Turbine} = \left(\frac{1}{2}\rho_{air}\right) \times C_{p\ max} \times \left(\frac{\omega_{opt} R}{\lambda_{opt}}\right) 3 \text{ ---(24)}$$

Then, the maximum power $P_{Turbine\_max}$ can be achieved by regulating the turbine speed in different wind speed under rated power of the wind power system. Therefore, an optimum value of tip speed ratio λ_{opt} can be maintained and maximum wind power can be captured. The MPPT curve and the corresponding torque are defined as function of ω_{opt}, the speed referred to the generator side of the gear box

$$MPPT=K_P\ \omega_{opt}3 \text{---------------------(25)}$$

From the optimum power the optimum torque can be calculated

$$MPPT=K_P\ \omega_{opt}2 \text{---------------------(26)}$$

There are different methods to perform MPPT control for wind turbines.

A. *Tip Speed Ratio Control.*

Using TSR (tip speed ratio) control, the wind speed needs to be measured using anemometer. This is difficult to perform, since the accurate wind speed is not available and the cost with increasing complexity is the result

B. *Power Signal Feedback Control.*

With this control the turbine maximum speed curves must be known. With comparing the current speed and the stored speed curves the controller and tracks the maximum power point.

C. *Hill Climbing Searching Control.*

This control is used in small turbines and is very similar to MPPT scheme used in photovoltaic system. When the wind turbine speed increases, the output power should normally increase as well otherwise the speed should be decreased.

D. *Sensor less Control.*

In the machine-side converter, control of the speed is required to extract maximum power during speed variation. Presence of sensors for rotor speed and position signals has effects on cost, system size and reliability. Therefore, sensor less concept is utilized to estimate rotor position and speed signals. [3, 4]. In ref [5] a novel method to obtain the information is by monitoring the terminal waveform (output control signal) and rate of change. Recently, position and speed estimation is proposed in ref [6] by using an adaptive network based on fuzzy interference system for wide range of speed operation. Such estimator indicates immunity against parameter variation [4]

XI. CONCLUSION

This paper present a comprehensive review on study of modeling and simulation of permanent magnet synchronous generator based on WECS. Detail of the MPPT concept is provided for variable speed operation. The PMSG is introduced as construction and model with some information about generators already available in market. Different types of wind turbine generator is also discussed, the mathematical equation of PMSG which is established in d-q reference frame is also provided in this paper, and concept about the drive train, different types of drive train, configurations of the possible power converters have been presented and discussed as well the semiconductor power switches used in converters. Wind turbine controls have been considered as pitch control and stall control. Various control methods and techniques for generator side and grid side converters are presented in details for the purpose of satisfaction of technical requirements. Such requirement are control of active and reactive power, high quality of power delivered to the grid, capability of voltage ride-through during voltage dip, better stability performance as well as possibility to simplify the wind turbine system by using sensor less control.

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