Simulink Based Modeling, Design and Performance Evaluation of PMSG Based Wind Energy Conversion System

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Abstract

The Contribution of renewable power source for the power generation becomes more promising renewable energy technology. This paper deals with the wind energy conversion system based on permanent magnet synchronous generator (PMSG). PMSG is integrated with grid with the help of power electronic converters and with a common DC link. This paper presents modeling of entire conversion system with PMSG, study is carried out with constant wind speed turbine and also analysis of different fault condition with resistive type of load and dynamic type of load. The proposed energy conversion system makes use of wind turbine, two mass drive train, PMSG, power electronic converter and DC link voltage as well as control strategy. Maximum power extract from wind with the help of machine side converter. PWM technique is used for inverter as a control technique which is developed to make the line voltages at the point of common coupling. The proposed scheme is modeled and simulated under SIMULINK/MATLAB. The simulation results are authentic and confirm the validity of wind energy conversion system.

***Key Words**: Modeling, PMSG, Pitch Controller, Wind Turbine, Two mass drive train, WECS*

1. INTRODUCTION

Renewable Energy resources exist over wide geographical areas. There are two type of resources renewable and non renewable energy resources. Wind energy is inexhaustible and infinitely renewable resource. Fossil fuels are the non renewable energy resources which are onetime gift that lifted us up but exists in finite supply. For the power generation renewable energy resources are used in a most promising way the reason behind they are non polluting as well as having inexhaustible potential. The drawback seen in the case of wind energy is irregular in occurrence. The problem facing that how to capture maximum wind power form wind for power generation, but this problem can also be solve by use of boost converter (dc-dc) with MPPT technique which helps in maximum power extraction from wind. Beside that there are many other control strategy also used for maximum power extraction. However, the overall objective in all field is the same that the wind energy at varying wind velocities has to be converted to electric frequency. There are two type of generators which are used in large scale for the conversion purpose first one is Doubly fed induction generator (DFIG) and Permanent magnet synchronous generator (PMSG). DFIG are widely used but drawback of DFIG is the requirement of gear box to match turbine and rotor speed. [1]. Implementing PMSG having its own advantages over DFIG that it is reliable, better performance, higher efficiency, lower losses and good controllability. In the case of PMSG it is direct drive type generator, as we don't require gearbox but in this case we have to design PMSG with more number of poles. In the case of PMSG with gearbox design we have to put lesser number of poles. To extract maximum power from fluctuating wind, variable speed operation of the wind turbine generator is needed. Control Strategy has been developed for output maximization of PMSG based WECS. This system is modeled and simulated under SIMULINK with the help of MATLAB software.

2. Modeling and Operating Principle

The proposed energy conversion system is based on PMSG. This type of machine has main features

which are relevant for wind power applications such as no significant losses in the rotor, allows soft start and magnetization provided by the permanent magnets.

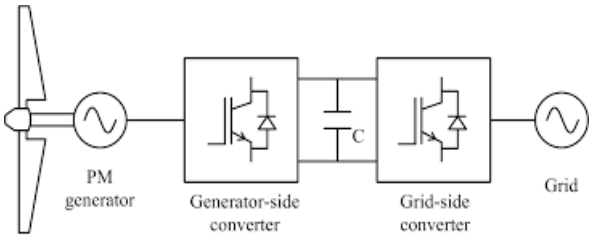

Fig. 1 Proposed Wind Energy Conversion System

2.1 Wind Turbine Characteristics

Wind turbine converts the kinetic energy of the wind into mechanical energy by means of producing torque. The energy taken by the wind is kinetic energy.

The wind power developed by the turbine is given as:

$$P = 0.5\, C_p(\lambda,\beta)\rho A v^3 \quad (1)$$

Where,

P = Power generated by the wind turbine

v = the wind speed

ρ air density

λ = tip speed ratio

A =the area swept out by the turbine blades

β = pitch angle

$C_P(\lambda,\beta)$ = the power coefficient

The pitch angle controller scheme using PI controller is used. C_P is the performance coefficient which in turn depends upon the turbine characteristic.

The power coefficient of wind turbine given as

$$C_P(\lambda,\beta) = C_1(C_2/\lambda_i - C_3\beta - C_4)\, e^{-C5/\lambda i} + C_6\lambda \quad (2)$$

$$\frac{1}{\lambda 1} = \frac{1}{\lambda} + 0.08\beta - \frac{0.035}{\beta 3+1} \quad (3)$$

When pitch angle β=0 and λ = 6.325 C_P is maximum value.

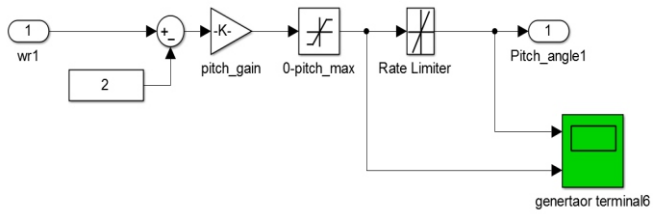

Fig. 2 Pitch angle control scheme

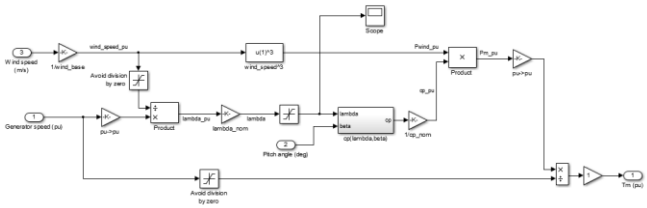

Fig. 3 Wind turbine Model

Various Parameters of wind turbine are:

Nominal mechanical output power (W): 8.5e3

Base power of the electrical generator (VA): 8.5e3/0.9

Base wind speed (m/s): 12

Maximum power at base wind speed (p.u. of nominal mechanical power): 0.8

Base rotational speed (p.u. of base generator speed): 1

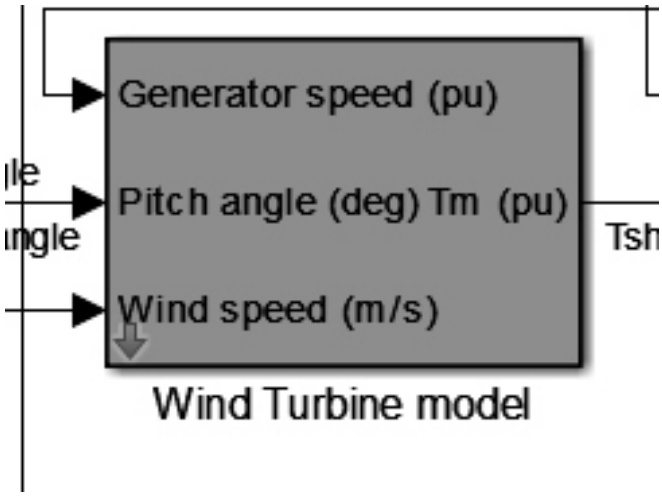

Fig. 4 Mask of Wind Turbine

2.2 Two Mass Drive Train

This model consists of turbine and shaft coupling

system. The shaft torque T_shaft (p.u) output is fed to the PMSG as input. The main Purpose of presence of two mass drive drain or gearbox is only that we can keep generator pole lesser in number.

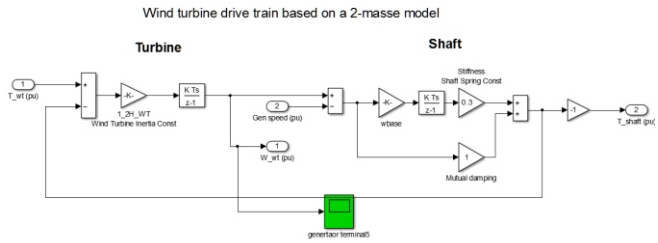

Fig 5 Two Mass Drive Train Model

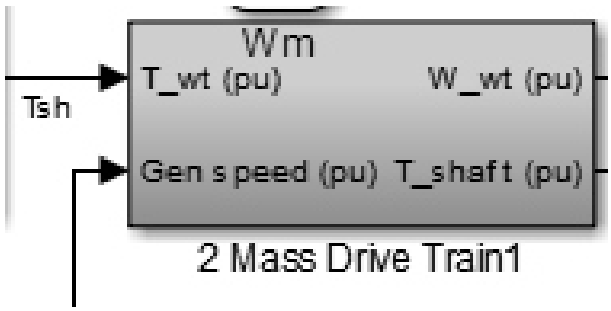

Fig. 6 Mask of Two Mass Drive Train

2.3 Permanent Magnet Synchronous Generator

PMSG is used for conversion process mechanical energy gets converted into electrical energy with the help of generator. For PMSG modeling we have to develop model based on equations. These equations are represented in rotor reference frame. All quantities in the rotor frame referred to the stator.

$$\frac{d}{dt} i_d = \frac{1}{Lds+Lls}(-R_S i_d + \omega_e(Lqs+Lls) i_q + u_d) \quad (4)$$

$$\frac{d}{dt} i_q = \frac{1}{Lqs+Lls}(-R_S i_q - \omega_e[(Lqs+Lls) i_d + \psi_f] + u_q \quad (5)$$

Where,

Rs stator resistance, Lds and Lqs are direct and quadrature axis inductances of generator, L_{ls} and L_{ls} are leakage inductances, f is the permanent magnetic flux, ωe is the electrical rotating speed of the generator , Id is d axis stator current , Iq is q axis stator current, Ud is direct axis stator voltage, Uq is quadrature axis stator voltage.

P is the number of pole pair of the generator. The electromagnetic torque equation is given as

$$\tau_e = 1.5P\,(L_{ds} - L_{qs}) i_d i_q + i_q \psi_f \quad (6)$$

3. Control Strategy for WECS

In this proposed wind energy system the output ac voltage is controlled through amplitude and frequency. The reactive power and an active power exchange with the grid are function of phase and amplitude of terminal voltage at AC terminal. This conversion system consists of PWM IGBT Converter, in this figure three phase converters has three legs a, b and c. Only one switch on the same leg cab be conducting at the same time each switch S1,S2,S3,S4,S5,S5&S6 in the inverter branch is composed of semiconductor devices connected with antiparallel diode. Here, diode bridge rectifier is used for protection and semiconductor device is a controllable device.

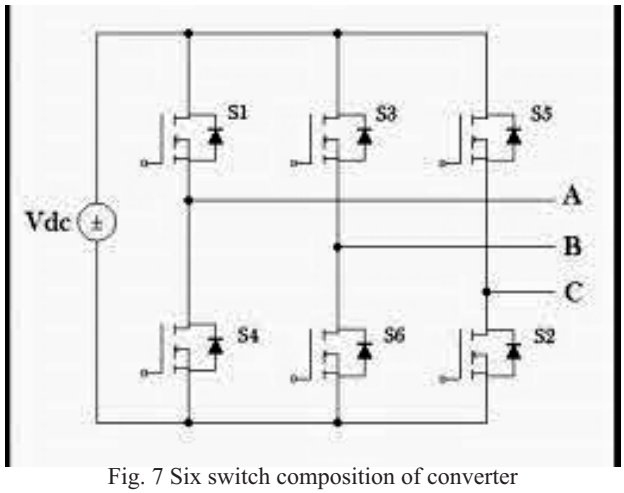

Fig. 7 Six switch composition of converter

The conversion system consists of power electronics converter, inverter present at the load side here in three phases the current are not same in all the three phases due to the unbalanced load. LC filters are used in order to minimize the harmonic content present at grid side as well it causes unequal voltage drop just because of unbalanced current. The rms value of phase voltage and reference phase voltage is given to the PI controller. Now the output gets multiplied with the sine wave generator to get

the reference phase voltage. PWM pulses are generating by reference voltages to switch the load side inverter.

For the control purpose various controllers are used such as PWM controller, Voltage Controller, Discrete PID Controller in wind energy conversion system.

4. Wind **Energy Conversion System In MATLAB/SIMULINK**

Wind energy conversion system WECS, it includes wind turbine, two mass drive train, PMSG, converters, DC link, PWM converter and its control model. Here, in the system the wind generation block consists of masked wind turbine block, two mass drive train and PMSG after then with the help of converters and DC link it is integrated with grid. The proposed model in MATLAB/ SIMULINK is given here.

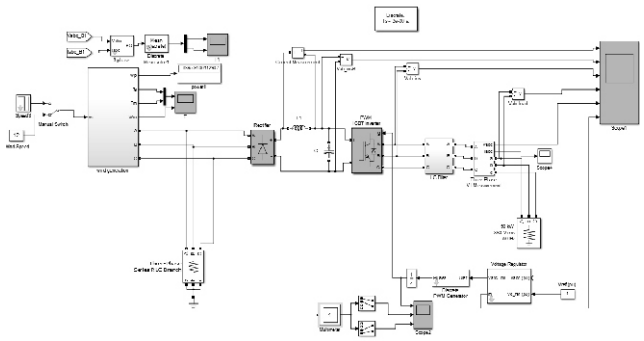

Fig. 8 Wind Energy Conversion System in MATLAB/SIMULINK

5. Simulation Results And Discussion

The DC link capacitor providing decoupling between generator-side and grid side. The simulation results are presented here under the constant wind speed of 12m/s.

Under the healthy condition with resistive type of load the grid output voltage and current will be pure sinusoidal in nature. With RL type or dynamic type of load the distorted grid output voltage and current appear as shown in the fig. 16.

CASE-1 UNDER CONSTANT WIND SPEED

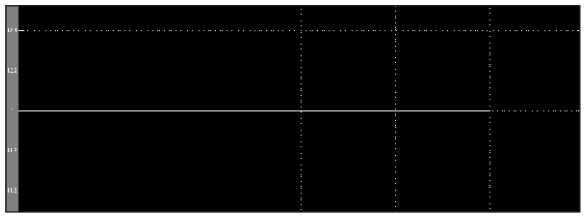

Fig. 9 Constant wind speed at 12 m/s

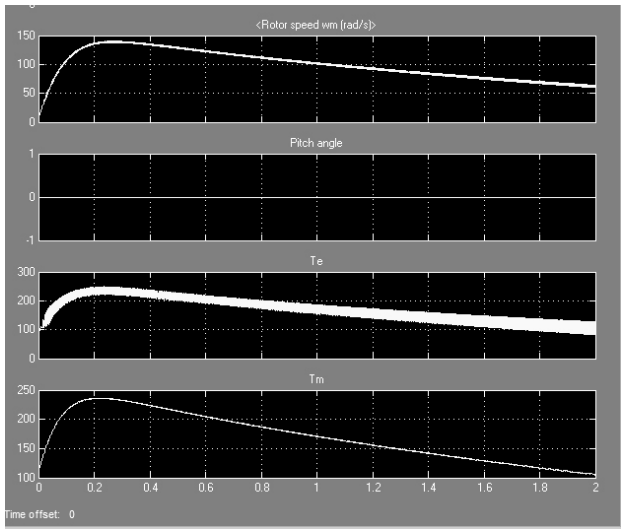

Fig. 10 (i) synchronous generator wind speed wm (rad/sec) (ii) pitch angle (iii) electromagnetic torque(Te) (iv) mechanical torque (Tm).

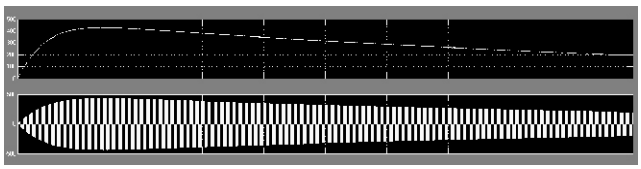

Fig. 11 (i) DC Link voltage, (ii) Inverter output voltag

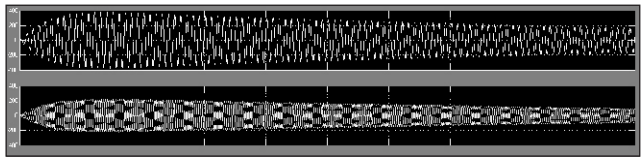

Fig. 12 (i) Line to line voltage Vab (ii) Grid output voltage

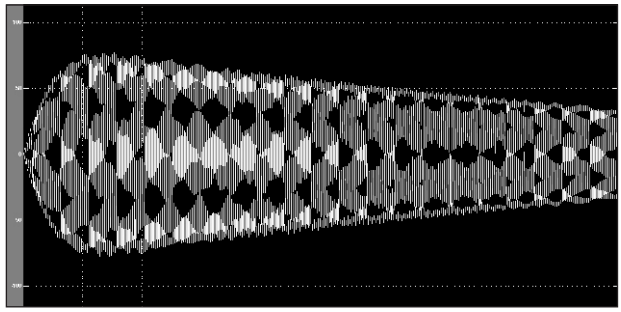

Fig. 13 Three phase output grid current

CASE-2 WITH RL TYPE OF LOAD

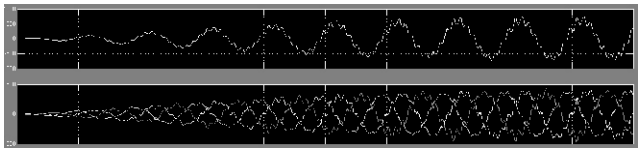

Fig. 14 (i) Line to line voltage (Vab) (ii) Three phase output grid voltage with RL type of load.

CASE-3 UNDER FAULT CONDITION AT GRID SIDE

Fault condition shown in simulink simply by adding three phase fault block from simulink library at the grid side and can examine the variation and transient that occur during unhealthy condition.

(I)Waveform during three phase to ground fault(L-L-L-G)

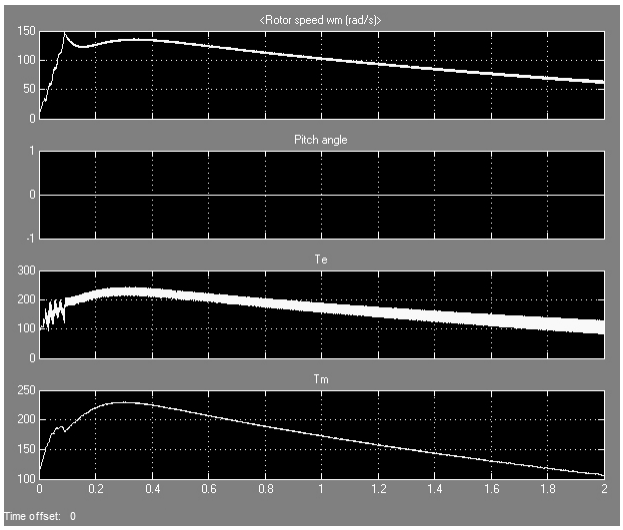

Fig. 15 (i) synchronous generator wind speed wm (rad/sec) (ii) pitch angle (iii) electromagnetic torque(Te) (iv) mechanical torque (Tm).

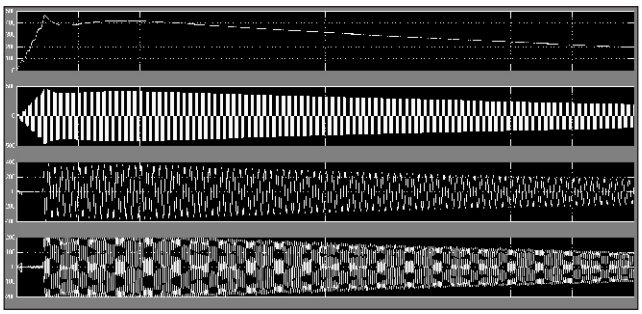

Fig. 16 (i) DC link voltage (ii) inverter output voltage (iii) Line to line voltage (Vab) (iv) Three phase grid output voltage.

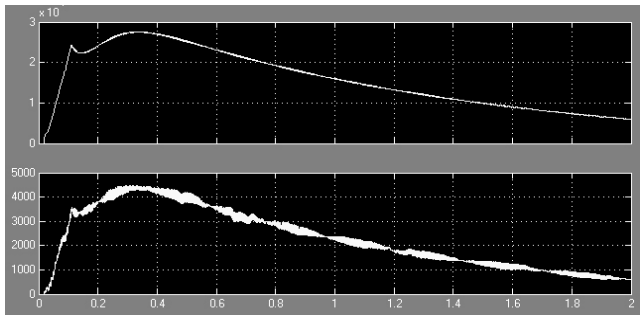

Fig. 17 Active and Reactive power during three phase fault condition. CASE-3 (II) Wave form during single line to ground fault (L-G)

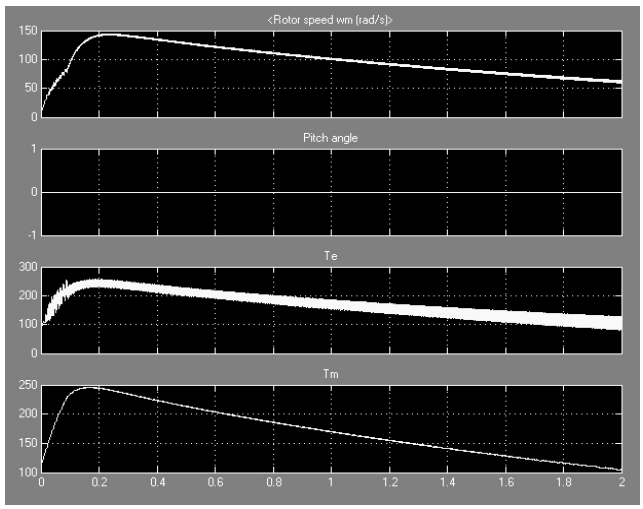

Fig. 18 (i) synchronous generator wind speed wm (rad/sec) (ii) pitch angle (iii) electromagnetic torque(Te) (iv) mechanical torque (Tm).

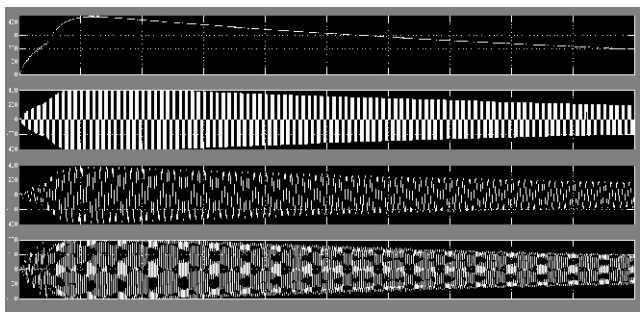

Fig. 19 (i) DC link voltage (ii) inverter output voltage (iii) Line to line voltage (Vab) (iv) Three phase grid output voltage.

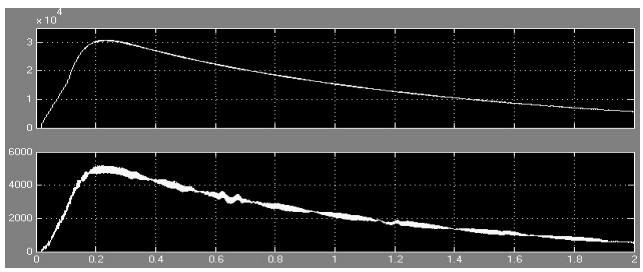

Fig. 20 Active and Reactive power during single line to ground fault.

Table -1: PARAMETERS OF WECS

Wind Turbine	
Density of air	1.225 kg/m^3
Area swept by blades, A	1.06m^2
Base wind speed	12m/s
PMSG	
Rated speed	153rad/s
No. of poles	10
Rated current	12amp
Stator resistance	0.425
Stator inductance	0.000835H
Magnetic flux	0.433wb
Rated torque	40 Nm
Rated power	6Kw

6. Conclusion

Active power for the constant speed gives the constant power under the healthy condition. When unhealthy condition occurs variation in various waveforms has seen. Under the fault condition it occurs with transient time 1/60 5/60. In future scope MPPT Technique can be used for maximum power extraction as well as we can go for fuzzy logic control. In order to enhance the power quality we can implement FACTS devices also.

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his doctorate. His area of interest includes Image Processing, Bio-Medical Instrumentation and Signal Processing.