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CONTROL TECHNIQUE FOR INTEGRATION OF PMSG WIND TURBINE WITH GRID

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Abstract: The technology of back to back converters are used for direct-driven PMGS with wind turbine. The generation-side converter gives guaranty of the maximum power and the smooth operating of the generator through the double-loop control scheme of the maximum ratio of torque to current. The grid-side converter adopts the synchronous reference frame of grid voltage orientation, realizing the decoupling control of the active and reactive power. Meanwhile, the working state of the converter can be maintained in a unity power factor state. The simulation results show that the converters are not only realizes the dynamic control of the system but also ensures the high quality of the electricity delivered to the grid.

I. INTRODUCTION

Now days, due to concern of global warming, immerging area of research are renewable resources as they give free and clean energy. Among them, wind and solar energy are most focused area for researches. Due to cost reduction of high quality permanent magnet material, new area of research is PMSG as the requirement of excitation system is not there and PMSG can work on variable speed. So it became possible to operate multi pole PMSG without gearbox. As result, PMSG became interacting solution for wind energy problem. Problem in integration arise in case of PMSG due to variable frequency because of variable speed. But back to back convertor is essential solution as IGBT have quick switching capability. This Paper discuss about control stratergies about developed for converters at grid end and turbine end. This paper also check performance of PMSG with wind turbine with different variable speed Section I gives introduction and Section II gives brief of Mathematical Model of PMSG and wind turbine. Section III shows developed control stratergies and which is evaluated it performance in section IV.

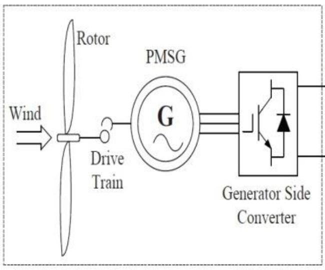

Fig. 1. Schematic diagram of PMSG based wind turbine connected to Grid

II. MATHEMATICAL MODEL

The description and the modeling of the wind turbine equipped with a PMSG are described throughout this section. Because the paper is focused mainly on the control of the generator side converter for large wind turbine applications, only the wind turbine components until the DC-link will be presented. Fig. 1 presents the basic topology of a PMSG driven wind turbine connected to the utility grid.

A. Wind Turbine Model

The mechanical power extracted from the wind can be expressed as follow:

$$Pm = \frac{1}{2}\, C_p \pi \rho v^3 r^2 \qquad (1)$$

$$\lambda = \frac{\omega r}{v} = \frac{2\pi r n}{60 v} \qquad (2)$$

where ρ is the air density (*kg/m*^{3}), *r* is the blade radius (m), ω is the wind speed (rad/s), *Cp* (λ, β) is utilization factor of wind power with a maximum value is about 0.5, and it could be expressed as:

$$C_p = 0.22\,(116\,\frac{1}{\eta} - \ 0.4\beta - 5)e^{-125\frac{1}{\eta}} \qquad (3)$$

$$\frac{1}{\eta} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \qquad (4)$$

where β is the pitch angle, λ is the tip speed ratio. The wind turbine mechanical torque output T_m is given by:

$$T_m = \frac{P_m}{\omega} \qquad (5)$$

Therefore, a generic equation is used in order to model the mechanical power based on the modeling turbine characteristics described as:

$$P_m = \frac{1}{2}\, C_p \pi \rho R^2 \left(\frac{\Pi\, R}{30\, \lambda}\right)^{\beta} n^3 \qquad (6)$$

Equation (6) shows that the mechanical power is a function of the rotational speed for any particular wind speed.

B. Modeling of PMSG

First it makes the following assumptions:

- Linear magnetic circuit;
- Completely symmetrical three-phase windings;
- Ignoring the cogging;
- Excluding core loss.

According to the assumptions above, we establish the mathematical model of PMSM in the α-β axis rotating coordinate system in a series of equations that include the flux, mechanical motion and torque.

The PMSG mathematical model is described in the α-β reference system as follows:

$$\frac{d\psi_s}{dt} = -i_s R_s + u_s \qquad (7)$$

where, R_s is the stator resistance and the expression for the electromagnetic torque can be described as:

$$T_e = 1.5\, p_{n\,(\psi_{s\alpha} i_{s\beta} + \psi_{s\beta} i_{s\alpha})} \qquad (8)$$

And p_n denotes the number of pole pairs. In addition, the dynamic equation of the wind turbine is given as:

$$T_m = T_e + B\omega + J\,\frac{d\omega}{dt} \qquad (9)$$

where J is the total inertia, B is the viscous friction coefficient and T_m is the mechanical torque developed by turbine.

Control Strategy of System

Control Strategy of Generator-Side Converter

The control objectives of generator-side converter is guaranting the point tracking of the maximum power and the smooth operating of the generator. We use maximum ratio of torque to current control strategy to accomplish this goal. The relationship between electromagnetic torque T_e, i_d and i_q is as follows.

$$\begin{cases} T_e = \sqrt{-i_d\,(1-i_d)^3} \\ i_q = \frac{1}{2}\sqrt{(1-2i_d)^2 - 1} \\ i_d = \frac{1}{4}\,(1-\sqrt{1+8i^2{}_s}) \end{cases} \qquad (10)$$

The simulation using multi polepair PMSG, $L_q > L_d$ .When PMSG using the maximum ratio of torque to current control strategy, $i_d < 0$,in other words, the essence of this control scheme is to use direct axis current demagnetization effect. So we can control the generator dq axis current real-time by the relation of formula. Figure 2 is generator side converter control block diagram.

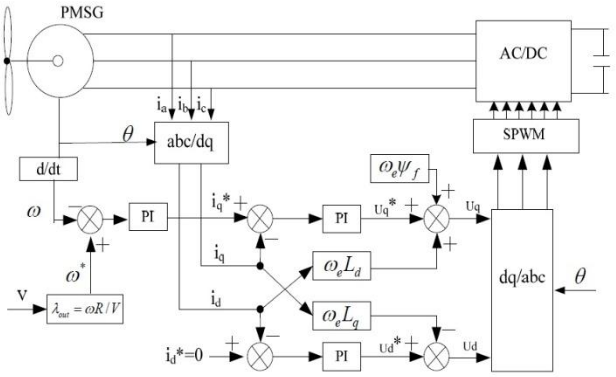

Fig. 2. generator side converter control block diagram.

In a sampling cycle, suppose the torque change is caused only by the change of current vector. Stator reference voltage $u_d{}^*$ and $u_q{}^*$ can be solved by the formula, then use SPWM technology modulate switch signal to realize the control of generator.

Control Strategy of Grid-Side Converter

Grid-side converter is controlled by double closed loop.

The purposes are:

(1) The stability of DC voltage;

(2) Inverter's power factor is 1;

(3) The input grid current contain low harmonics

Double closed loop include voltage outer ring and current inner ring. The role of voltage outer ring is to make the active power track the change of the load, because of whether the DC voltage of is constant or not depends on whether active power is balance,therefore the voltage outer ring decide whether the DC bus voltage is stable.Through controlling the current inner ring, the reactive power on the AC side can be regulated. Inverter working in unit power factor can also be realized. We use grid voltage oriented control strategy, make synthesize grid voltage vector oriented in the d axis of synchronization coordinate system. In the dq0 axis , the active power and the reactive power of grid-side converter are respectively:

$$\begin{cases} P = 1.5\,(e_d i_d + e_q i_q) = 1.5\, e_s i_d \\ Q = 1.5\,(e_q i_d + e_d i_q) = 1.5\, e_s i_q \end{cases} \qquad (11)$$

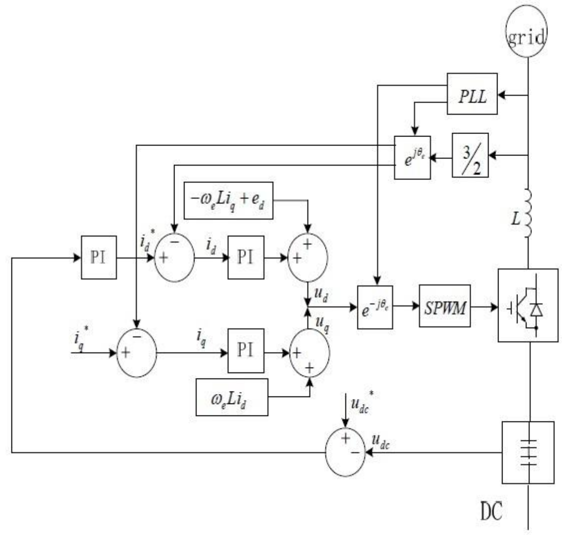

Fig. 3. Grid side converter control block diagram.

If $P > 0$, then the grid-side converter works under rectifying state; if $P < 0$, then the grid-side converter works under inverting state; if $Q = 0$, then the grid side convertor′s power factor is 1.

Figure 5 shows the control block diagram of grid-side.

Simulating Validate

Simulation of back to back convetor

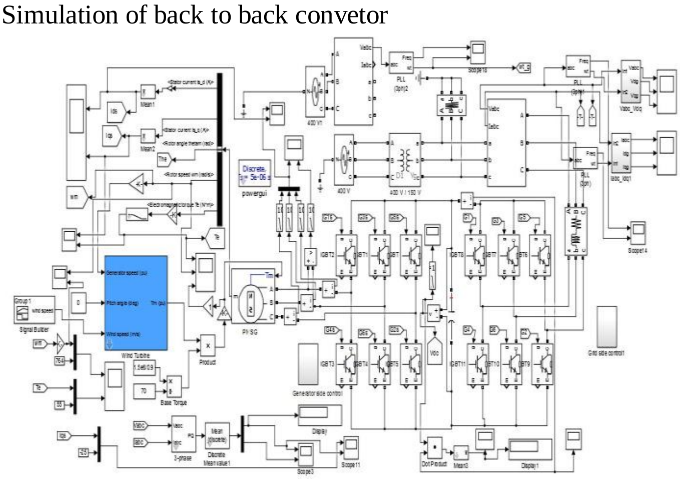

Fig. 4. Simulation model for integration of PMSG to grid.

In order to proving the correctness of the proposed control stetergy, a back to back convertor with PMGS was designed in the Matlab which is shown in fig 3. Table 1 & 2 shows the simulation parameter.

TABLE 1: THE SIMULATION PARAMETERS OF THE THREE-LEVEL INVERTER

Paramater	Values
DC voltage U_{dc}/V	1100
Filter inductance L/mH	3
Filter capacitor $C/\mu F$	50
Load impedance R/Ω	3.5
Load inductive reactance X_L/mH	10
Switch frequency $F_s\ /kH_z$	10

Simulation of PMSG System

Table 2 display the simulation parameters of PMSG system.

Paramater	Values
Wind turbine radius r/m	55
Rated wind speed $v/(m/s)$	12
Rated speed $\omega/(rad/s)$	38
Rated power P/MW	1.0
Air density $\rho/(kg/m^3)$	1.25
Poles pairs P	5
Stator resistance R_s/Ω	0.006
DC bus voltage U_{dc}/V	1000
DC bus capacitance $C/\mu F$	3000
Rms grid line voltage e_{ABms} /V	690
Grid fundamental frequency $\omega/(rad/s)$	314

FIGURE SHOWS THE SIMULATION RESULTS OF WHOLE SYSTEM.

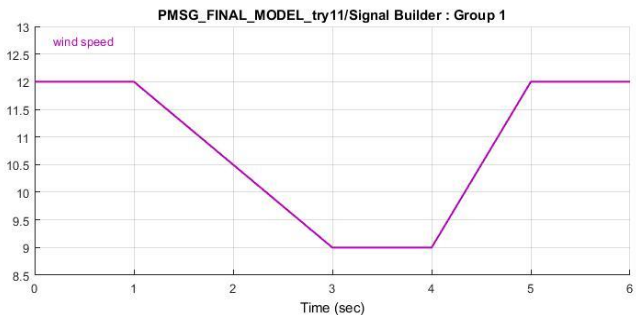

Fig. 5. Wind speed.

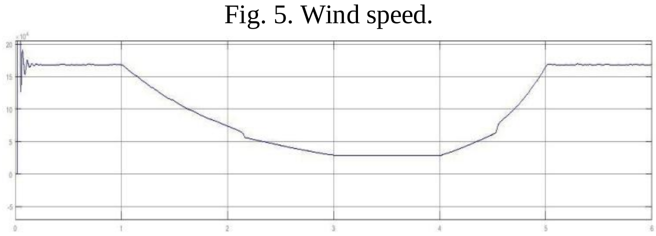

Fig. 6. Active power feed to grid.

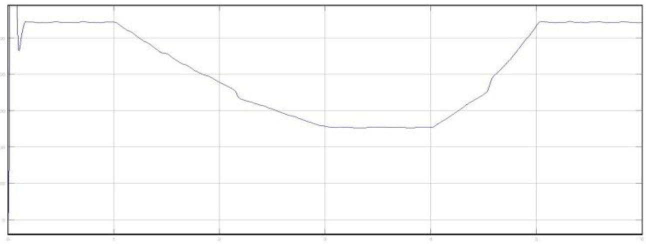

Fig. 7. DC-BUS VOLTAGE.

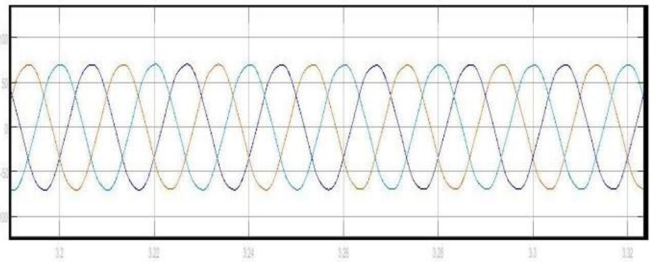

Fig. 8. GRID- SIDE THREE PHASE CURRENT.

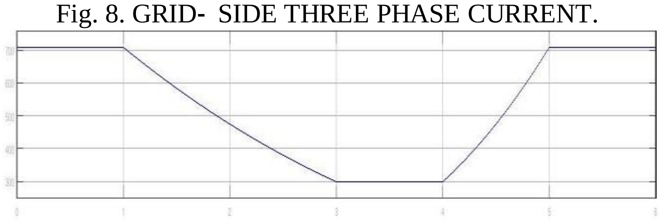

Fig. 9. Mechanical Power input to PMSG from Wind turbine

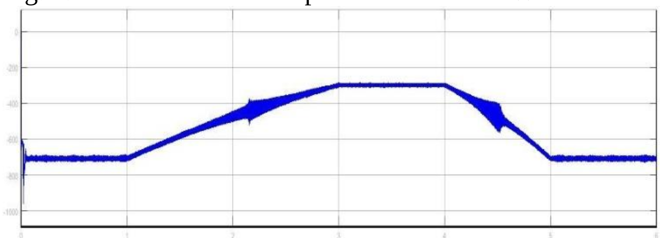

Fig. 10. Electrical Torque generated in PMSG.

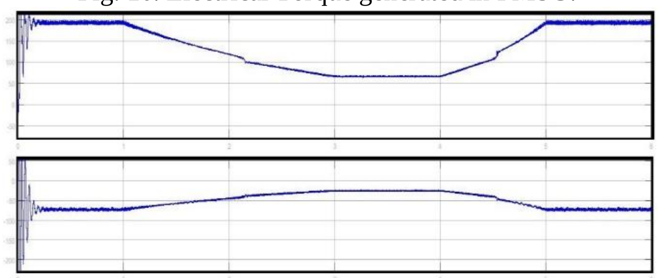

Fig. 11. Direct & indirect axis current of Grid.

Conclusion

Results shows that this control stetergies can work on variable speed system. Shown simulation results show that generator- side can realize the maximum wind power tracking, and makes the generator operate stably and efficiently by using double closed loop control based on maximum ratio of torque to current. The grid- side converter adopts the synchronous reference frame based control technique for grid voltage orientation, realizing the decoupling control of the active and reactive power while feed- in grid high quality electrical energy, it also improves the stability of the whole system.

REFERENCES

[1] Anders Grauers and Z.Styczynski, “Efficiency of three wind energy generator systems”, IEEE transactions on energy conversion, Vol. 11, No.3, September 1996, pp. 650-657.

[2] Monica Chinchilla, Santiago Arnaltes, and Juan Carlos Burgos, “Control of Permanent Magnet Generators”,IEEE transactions on energy conversion,Vol. 21, No.1, March 2006.

[3] K.Rudion, A.Orths, and Z.Styczynski, “Modeling of variable speed wind turbines with pitch control”, securing critical infrastructures, Grenoble, October 2004.

[4] I.Syed Meer, Kulam Ali P, Aravindan Dr and M.Y.Sanavullah, “MPPT based permanent magnet synchronous generator for wind energy conversion system”, International Journal of Communications and Engineering, Vol. 4, No. 4, Issue. 02, March 2012.

[5] BU He, REN Yong feng, NIU Hai wei.XUE Yu, HU Hong bin, LIU Hai tao, “Grid Connection Control and Simulation of PMSG Wind Power System Based on Three Level NPC Converter”,IJAPE,Vol. 2, Issue. 4, May 2013, pp. 192-199.

[6] Faeke Khater and Alaa Omar, “A Review of Direct Driven PMSG for Wind Energy Systems”, International Journal of Automation and Power Engineering, Vol. 7, June 2013, pp. 1592-1603.

[7] Mirza Mohd.Shadab and Abu Tariq, “Performance analysis of permanent magnet synchronous generator connected with wind turbine”, International Journal of Advanced Technology & Engineering Research, Vol. 2, Issue. 2, MAY 2012, pp. 46- 49.

[8] N. Gautam And A. Rentschler, “Modeling and analysis of parallel connected permanent magnet synchronous generators in a small hydropower plant”, International Conference on Energy & Environmental Systems, Vol. 3, May 2006, pp. 83-88.

[9] S. Samanvorakij ”Modeling and simulation PMSG based on wind energy conversion system”.Proc. Of The Second Intl. Conf. On Advances in Electronics and Electrical Engineering, Vol.5, March 2013, pp. 37-41.

[10] Satyam Kumar Upadhyay and Sudhanshu Tripathi, “Optimization and Control of a Variable Speed Wind Turbine with a Permanent Magnet Synchronous Generator”, International Journal of Engineering Trends and Technology, Vol. 4, No. 6, June 2013, pp. 2226-2228.

[11] Mayouf. Messaoud, Rachid. Abdessamed, “Modeling and Optimization of Wind Turbine Driving Permanent Magnet Synchronous Generator”, Jordan Journal of Mechanical and Industrial Engineering, Vol. 5, No. 6, December 2011, pp. 489 – 494.

[12] Wei Qiao, Member, Liyan Qu and Ronald G. Harley, “Control of IPM Synchronous Generator for Maximum Wind Power Generation Considering Magnetic Saturation”, IEEE transactionson industry applications, Vol. 45, No. 3, may/June 2009, pp. 1095-1105.

[13] R. Bharanikumar, A.C. Yazhini and A. Nirmal Kumar, “Modeling and Simulation of Wind Turbine Driven Permanent Magnet Generator with New MPPT Algorithm”, Asian Power Electronics Journal, Vol. 4, No. 2 August 2010,pp. 52-58.

[14] A.Bharathi sankar, Dr.R.Seyezhai, “MATLAB Simulation of Power Electronic Converter for PMSG Based Wind Energy Conversion System”, International journal of innovative research in electrical, electronics, instrumentation and control engineering,Vol. 1,No. 8, November 2013,pp. 348-353.

[15] F. Blaabjerg, M. Liserre, and K. Ma, “Power electronics converters for wind turbine systems”, IEEE Transactions on Industry Applications, Vol. 48, No. 2, pp708-719, 2012.

