Control Strategy of PMSG Connected to Grid

[1]Mr. Md. Rayhan Tanvir, [2]Prof. Alpesh S. Adesara

[1]ME Scholar, [2]Professor
Electrical Engineering Department
V.V.P.Engineering College, Rajkot, India

***Abstract-* Wind energy is a promising alternative to the traditional energy sources. Due to the increasing wind power penetration, the improvement of the control strategies becomes a new challenge for the manufacturers in order to comply with the grid interconnection requirements. By implementing different control techniques the control of permanent magnet synchronous generator (PMSG) can be achieved for wind turbine applications. In this paper, speed control and current control techniques are considered at generator side and grid side converter model respectively in PMSG which provides full controllability of the DC-link voltage and the reactive power delivered to the grid. Simulation and experimental results are presented.**

***Keywords-* Permanent Magnet Synchronous Generator, Power Converter Control Strategies, Wind Power Generation.**

Introduction-

Wind power generation has registered a large increase over the last years. The installed wind power capacity is doubling every third year and the recent energy crisis has stimulated even more its growth.

However, in order to keep increasing the wind power penetration, the cost reduction of the generated energy is crucial. This can be achieved through the use of more efficient, reliable and cost-effective wind turbines. Among the many different wind energy conversion technologies, one of the most promising is the direct drive topology based on PMSGs with a full-scale power converter, because it allows variable speed operation and fulfills the grid requirements with high efficiency. Two Control strategies are applied at Generator and Grid Side Control model respectively.

PMSG drive system

The PMSG drive system is composed of a generator, whose parameters are shown in Table I, two three-phase voltage-source converters in a back-to-back topology, with a dc-link capacitor of 4.7 mF, and an output filter of 15 mH.

Table 1. Permanent magnet synchronous generator parameters

Power	*P*	2.2 kW
Speed	*N*	1750 rpm
Voltage	*V*	316 V
Current	*I*	5.2 A
Number of pole pairs	*p*	8
Armature resistance	*Rs*	3.85 Ω
Magnet flux linkage	Ψ_{PM}	0.244 Wb
d-axis inductance	*Ld*	1 mH
q-axis inductance	*Lq*	1 mH

Speed control technique

A speed control strategy with hysteresis current control is applied to the PMSG- generator side converter (Fig. 1), in order to control the generator speed and to obtain the maximum electromagnetic torque with the minimum current. To achieve this goal, the *d* component of the stator currents is forced to zero and the electromagnetic torque is controlled through the *q* component. As the current control is performed in the rotor reference frame, a coordinate's transformation is required to obtain the reference stator currents.

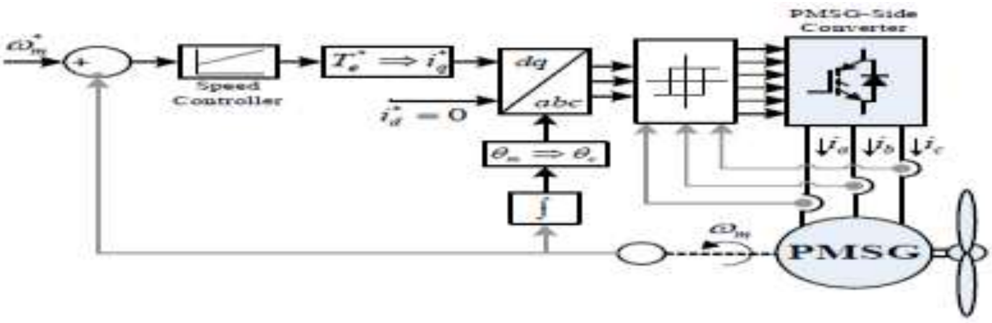

Figure 1: Speed control technique

Current control technique

For the grid-side converter, in order to keep the dc link voltage constant, as shown in Fig. 2, Current control technique requires internal current control loops, in a rotating reference frame and the elimination of the current cross coupling between d and q components, which needs a feed-forward compensation of some terms (ωLid, ωLiq). The Phase Locked Loop (PLL) estimates the grid voltage space vector angle, ϒ, for the coordinate's transformation. The d-axis of the reference frame is aligned with the grid voltage space vector; then, a unity power factor is achieved when iq is set to zero, and the current and voltage space vectors are in phase. Finally, the gate drive pulses are obtained through a PWM scheme.

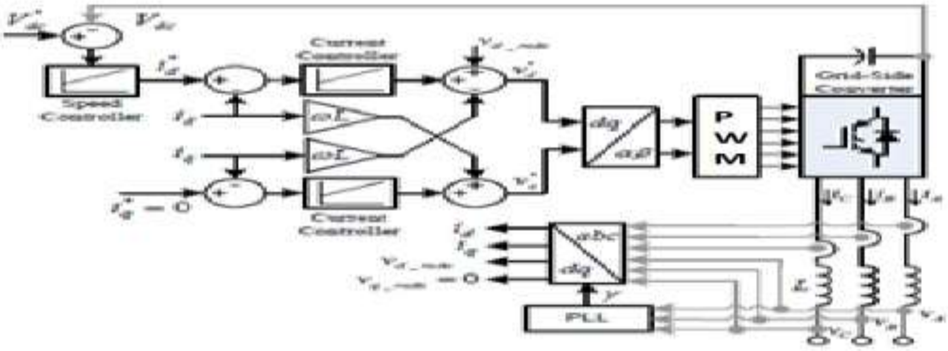

Figure 2: Current control technique

Simulation Result

The simulation of PMSG drive system was carried out using the PSIM. Speed control and current control techniques were implemented in generator and grid side converter model. Mathematical model of wind turbine with torque equation is used in the simulation. Generator switching pulse g_1, g_2 and grid switching pulse s_1, s_2 are shown. Also V_{dc}, V_{g1}, I_{g1}, P_grid, P_inverter, P_load, Torque, I_{alpha}, I_{beta} are shown in the figures.

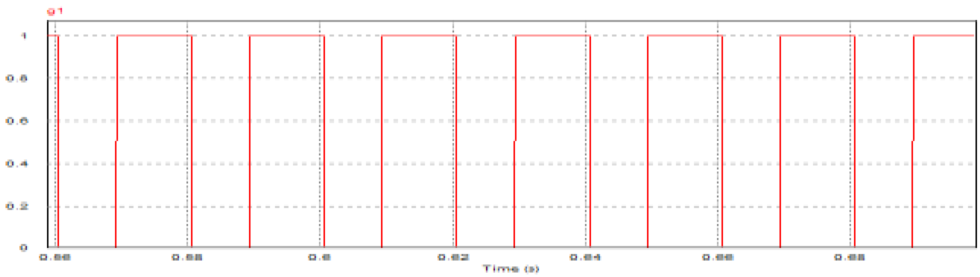

Figure 3: Graph of (g_1)

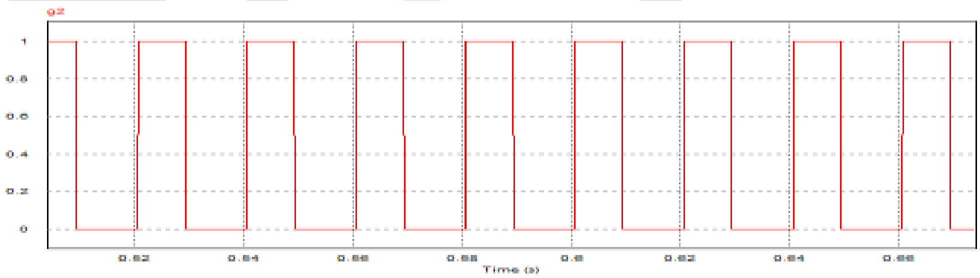

Figure 4: Graph of (g_2)

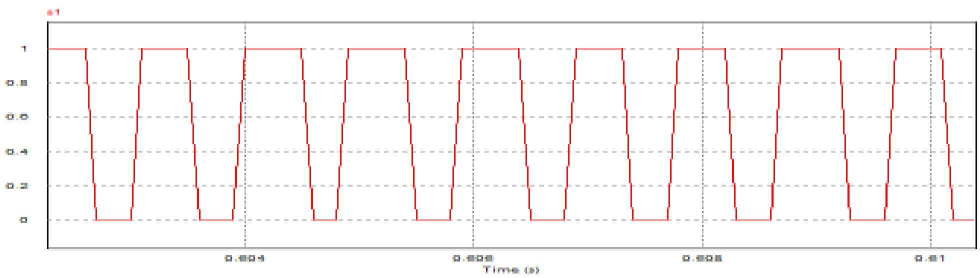

Figure 5: Graph of (s_1)

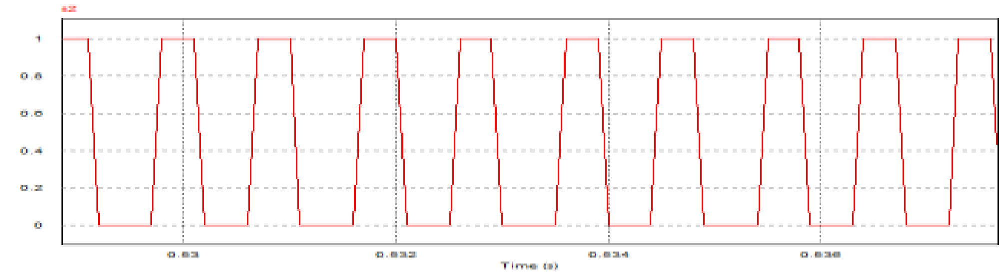

Figure 6: Graph of (s_2)

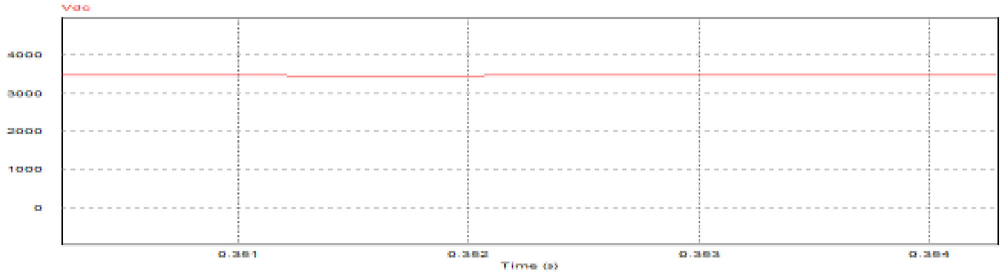

Figure 7: Graph of (V_{dc})

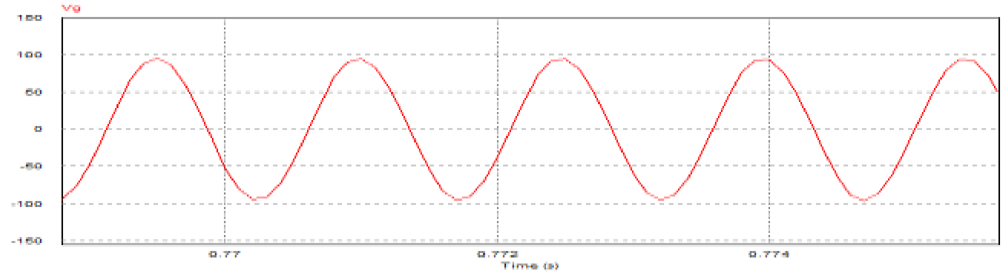

Figure 8: Graph of (v_g)

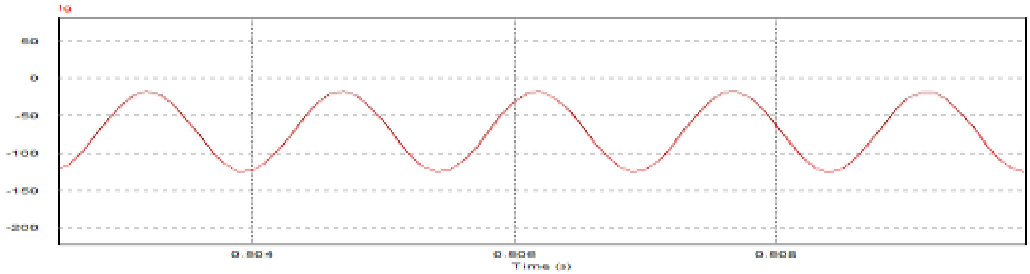

Figure 9: Graph of (i_g)

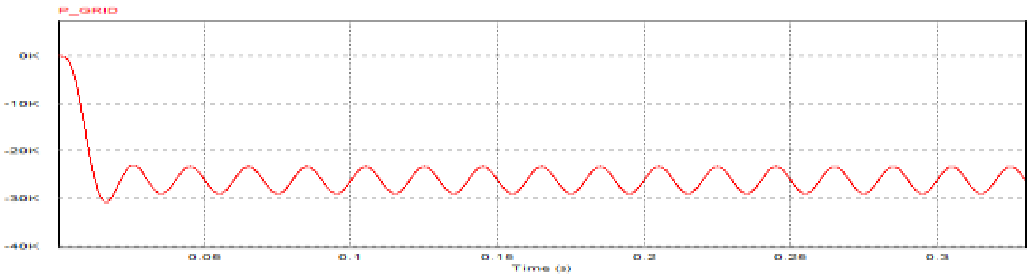

Figure 10: Graph of (P_grid)

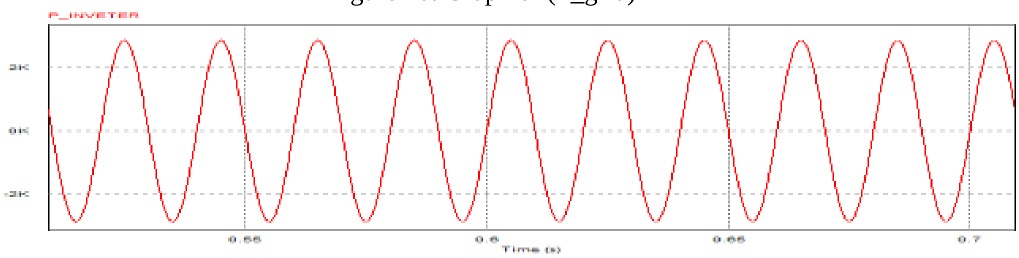

Figure 11: Graph of (P_inverter)

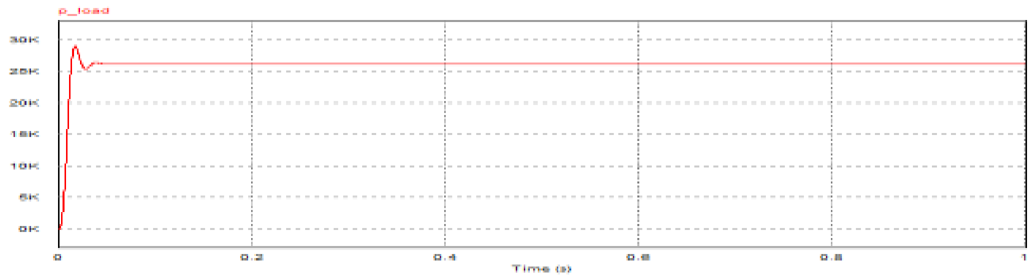

Figure 12: Graph of (P_load)

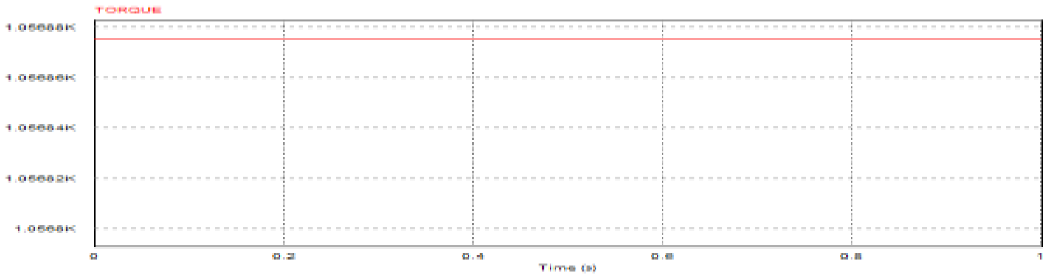

Figure 13: Graph of (Torque)

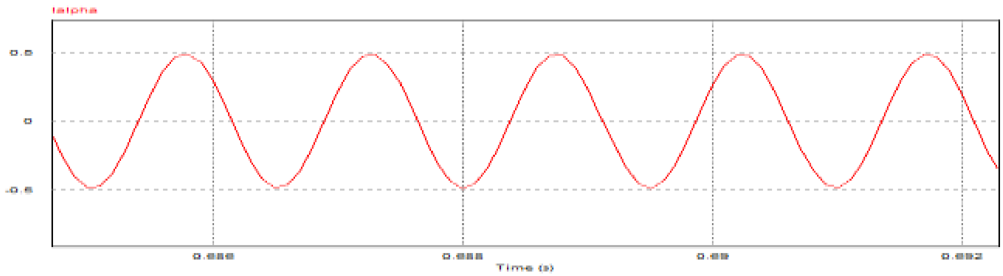

Figure 14: Graph of (I_{alpha})

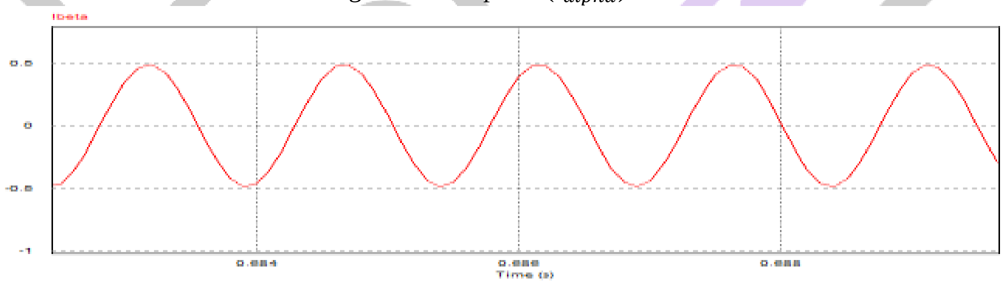

Figure 15: Graph of (I_{beta})

Conclusion

The performed comparative study allows to conclude that all the implemented control strategies are suitable to PMSG drives for wind turbines applications. However, with speed control techniques applied to the drive, it shows a better general performance since lower current distortion, higher grid power factor and higher overall efficiency are obtained. On the other hand, current control has a better dynamic response and it is less computational demanding.

Speed and current control combination might be an ideal choice, depending on the desired performance tradeoff.

Acknowledgement

I wish to express my deepest gratitude to my institute guide **Prof. A. S. Adeshara,** PG Coordinator (EPS), Electrical Engineering Department, Vyavasayi Vidhya Pratisthan Engineering College, Rajkot, and my internal guide, for their constant guidance, encouragement and support. I warmly acknowledge and express my special thanks for their inspiring discussions and infallible suggestions.

I am also grateful to **Prof. Sachin Rajani**, Head of Electrical Engineering Department, Vyavasayi Vidhya Pratisthan Engineering College, Rajkot, for giving me opportunity to carry out project in the premises of Vyavasayi Vidhya Pratisthan Engineering College, Rajkot.

Reference

[1] T. Noguchi, H. Tomiki, S. Kondo, and I. Takahashi, "Direct power control of PWM converter without power-source voltage sensors", *IEEE Trans. on Ind. Appl, vol. 34, no. 3, pp. 473-479,* May/June 1998

[2] J. A. Martínez, J. E. G. Carrasco and S. Arnaltes, "Table-based direct power control:
a critical review for microgrid applications", *IEEE Trans. on Power Electron., vol. 25, no. 12, pp. 2949*- 2961, Dec. 2010

[3] M. Malinowski, M. P. Kazmierkowski, S. Hansen, F. Blaabjerg and G. D. Marques, "Virtual-flux-based direct power control of three-phase PWM rectifiers", *IEEE Trans. on Ind. Appl., vol. 37,* no. 4, pp. 1019-1027, July/Aug. 2001

[4] M. Malinowski and M. P. Kazmierkowski, "DSP implementation of direct power control with constant switching frequency for three-phase PWM rectifiers", *28th Annual Conf. of the Ind. Electron. Society, vol. 1, pp. 198-203, March 2002*

[5] D. Zhiand and L. Xu, *"Direct power control of DFIG with* constant switching frequency and improved transient performance", *IEEE Trans. on Energy Convers., vol. 22, no. 1,* pp. 110-118, March 2007

[6] Design and Implementation of an FPGA-Based Digital Control IC of Maximum-Power- Point-Tracking Charger for Vertical-Axis Wind Turbine Generators (Ming-Fa Tsai, Member IEEE Wei-Chieh Hsu Tai-Wei Wu Jui-Kum Wang)

[7] MULJADI E., BUTTERFIELD C.P.: 'Pitch-controlled variable speed wind turbine generation', IEEE Trans. Ind. Appl., 2001, 37, (1), pp. 240–246

[8] ASIMINOAEI L., BLAABJERG F., HANSEN S.: 'Harmonic detection methods for active power filter applications', IEEE Ind. Appl. Mag., 2007, pp. 22–33

[9] M. Malinowski, S. Stynski, W. Kolomyjski and M. P. Kazmierkowski, "Control of three-level PWM converter applied to variable-speed-type turbines", *IEEE Trans. on Ind. Electron.*, vol. 56, no. 1, pp. 69-77, Jan. 2009

[10] "IEEE Recommended practices and requirements for harmonic control in electrical power systems", IEEE Std 519-1992, 1993

[11] 'Connection of wind turbines at the grid under 100 kV'. Technical regulations T.F. 3.2.6, Eltra/Elkraft, July 2004. Internet, http://www.eltra.dk

[12] SENJYU T., KINJO T., FUJITA H., AICHI: 'Analysis of terminal voltage and output power control of wind turbine generator by series and parallel compensation using SMES'. IEEE 35th Ann. Power Electronics Specialists Conf., June 2004, vol. 6, pp. 4278–4284