

Improvement of Voltage Stability in a Variable Speed Wind Generation by Using SEPIC Converter

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ABSTRACT: This paper presents the results of variable speed wind power generation system using permanent magnet synchronous generator. The Sepic converters are utilized as converters for variable speed wind power generation system. The inverter is designed with space vector modulation (SVM) to reduce total harmonic distortion. Wind power generation system simulated using Matlab consisting of wind turbine, PMSG, diode rectifier, PWM controlled Sepic converter, inverter with SVM and AC load.

KEYWORDS –Variable-speed wind power generation system; Sepic converter; Permanent magnet synchronous generator.

I.INTRODUCTION

Electricity plays an important role in the development of economy of any country, electricity leads to continuous search of alternately available sources of power generation such as Renewable Energy Sources (RES). RES includes Photovoltaic, Wind Power, Fuel Cells, Tidal energy etc. among which wind, power generation is gaining importance. Wind power has evolved as a viable source of power generation and is economical as compared with the other non-conventional energy sources. It offers a feasible solution to the distributed power system. A wind turbine, a rotating device captures the wind energy and converts it into kinetic energy and by coupling electric power generator to wind turbine the kinetic energy can be converted into electrical power. If the wind profile is promising at the location then the implementation of high capacity direct driven wind power generation is more feasible eliminating the gear box. In such case the wind power generation can be used as an isolated or grid connected power generation system, feeding local load in isolated system and feeding the excess power into the grid in grid connected system. A self-sufficient wind power generation system is the one with the energy storage device [2]. This will be not the same when the wind profile is not promising. It is Wind power generation using Induction generator, doubly fed induction generators, Permanent Magnet Synchronous Generator (PMSG), etc. and with various control methods and different ways of extracting power from the wind under different conditions have been proposed by various researchers[3-6]. The large capacity wind turbines have greater inertia which helps it to overcome small changes in the wind speed. Small changes in wind pattern will not affect the output voltage. However when considering small wind turbines the effect of change in wind speed affects the output performance of the wind turbine. Few techniques like gearbox, flywheels etc. are incorporated into small wind turbines to overcome the fluctuations due to change in wind speed. However the gear box adds weight and maintenance due to which the overall system efficiency decreases. In order to overcome these drawbacks direct driven PMSG machines has emerged as the best alternative. PMSG based wind power generation has the advantage of permanent magnets for magnetic flux production eliminating additional supply for excitation and can be used for power generation at low wind speed [7].

II. WIND POWER GENERATION SYSTEM

Fig 1 shows the Variable speed wind power generation system using SEPIC converter .It is not possible to operate the PMSG in the motoring mode, because the diode bridge rectifier limits the direction of DC link current .However it is not a problem, because the motoring mode is not carried out in the wind generator systems. In the meantime, the value of DC link current depends on the relationship between the induce voltage of PMSG and the DC link voltage. Therefore, it is not possible for the diode bridge rectifier to control the generator torque. Then, SEPIC converter circuit is added to improve the Variable speed range in which the diode rectifier cannot control the generator torque, the SEPIC converter can control the generator torque by controlling the DC link current. The mechanical energy from wind turbine is given to PMSG. PMSG converts mechanical energy into electrical energy. Rectifier converts AC into variable DC. Variable DC is converted into Fixed DC by using SEPIC converter. SEPIC converter switch is controlled by PWM technique .Fixed DC is converted into AC by using inverter. Inverter switches are controlled by Space vector modulation which reduces Total Harmonic Distortion (THD). Whatever be the wind speed i.e., low speed, medium speed, high speed the output voltage is maintained constant.

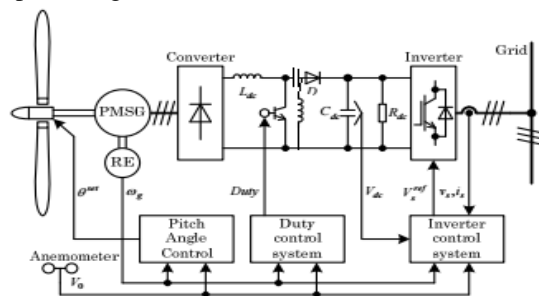


Fig. 1 Variable-speed wind power generation system using Sepic converter.

III. CONTROL SYSTEM

A. Wind Turbine Emulator[6]

Fig. 2 shows the basic structure of wind turbine emulator. The wind turbine model is based on the blade element momentum theory [7]. The wind turbine model consists of the three dimensional table data of wind turbine characteristics and the mechanical model considering the difference between real wind turbine and induction motor. The wind velocity V_0 is given as a condition of emulation. The windmill rotational speed ω_r is detected with the rotary encoder (RE). The V_0 and ω_r are used as inputs of the three dimensional table.

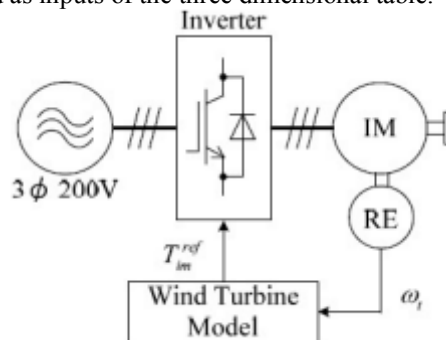


Fig. 2. Wind turbine emulator

The three dimensional table data are composed of the torque Q for V_0 and ω_r . The three dimensional data are calculated by applying the wind turbine parameters of fig. 3 to the blade element momentum theory in advance.

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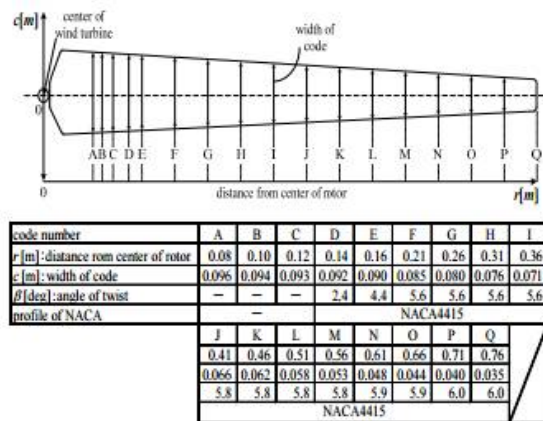


Fig. 3. Wind turbine blade shape

B. Converter Control System

Duty control system for Sepic converter Fig. 4 shows the duty control system for boost converter. The change of wind velocity includes the ranges of low wind velocity, middle wind velocity, and high wind velocity. For the low wind velocity, the duty control system adjusts the DC link current which corresponds to the generator torque necessary for controlling the windmill speed, by controlling the boost converter. The DC link voltage is maintained at voltage 100V necessary for the system interconnection by the inverter, when the duty control system is on. Duty becomes 0, because the DC link voltage is maintained at 100V by the inverter, when the windmill speed rises, and when the line voltage of PMSG becomes over 100V. The operating range is correspondent to middle wind velocity, and only the rectification using the reactor and diode bridge rectifier is carried out.

$$Duty = \left(K_{PS} + \frac{K_{IS}}{s} \right) (\omega_g^{ref} - \omega_g)$$

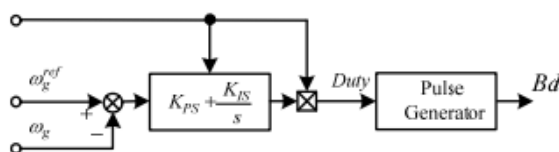


Fig. 4. Duty ratio control system.

C. Inverter Control System

Space vector modulation technique is used to control the inverter. Compared to SPWM the Total Harmonic Distortion (THD) and Lower Order harmonics (LOH) contents are decreased in SVPWM. It is known that the maximum value of the peak phase voltage that can be obtained from a three phase inverter with Sinusoidal Pulse Width Modulation (SPWM) technique is equal to $V_{dc}/2$. It is therefore evident that SVPWM achieves a better DC bus utilization compared to SPWM (by about 15.4%)

Space vector modulation is an algorithm for the control of pulse width modulation. It is used for the creation of alternating current waveforms, most commonly to drive three phase AC powered motors at varying speeds from DC. The figure 5 shows the three modes of operation of SVPWM. The operation within the inscribed circle of the regular hexagon is the linear region while operation outside the inscribed circle till the circumscribed circle around the hexagon depicts overmodulation region.

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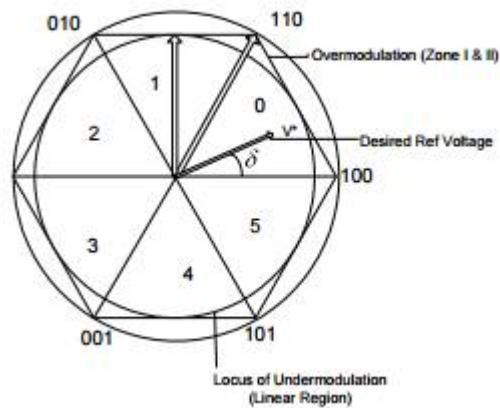


Fig. 5. Showing the various regions of modulation

At the end of the liner modulation i.e. at a $MI > 0.907$, the reference voltage vector tip traces a circle whose radius becomes greater than that of the inscribed circle of the hexagon representing the voltage vectors which can be applied in the six sectors.

IV. BLOCK DIAGRAM AND SIMULINK DIAGRAM

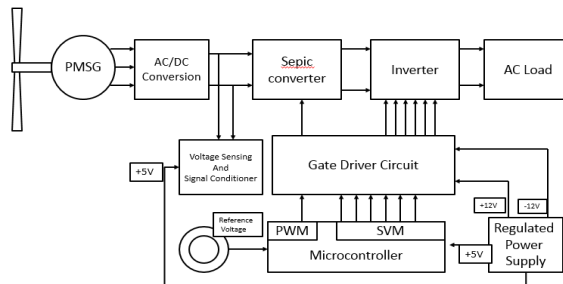


Fig. 6. Block Diagram

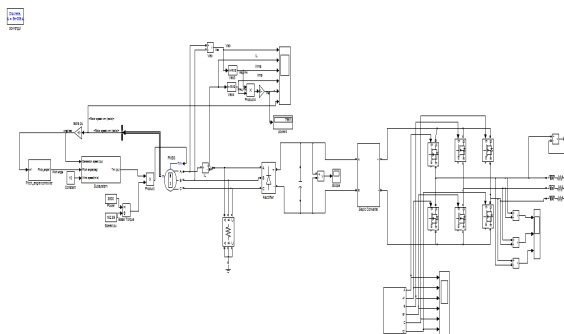


Fig. 7. Simulink Circuit

V. SIMULATION RESULTS



Fig. 8. Three phase output voltage wind speed = 7M/S (Without Converter)



Fig. 9. Three phase output voltage wind speed = 10M/S (Without Converter)

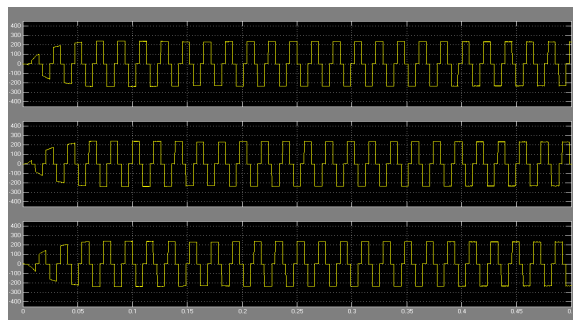


Fig. 10 Three phase output voltage wind speed = 7 m/s (With Sepic Converter)

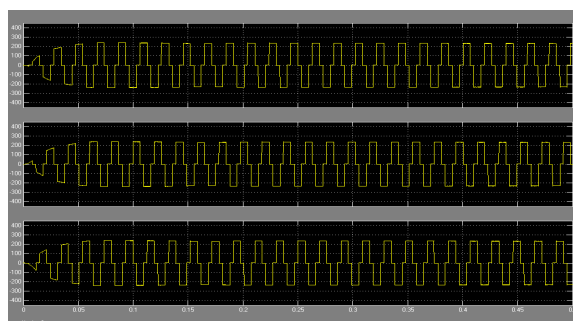


Fig. 11 Three Phase Output Voltage wind speed = 10 m/s (With Sepic Converter)

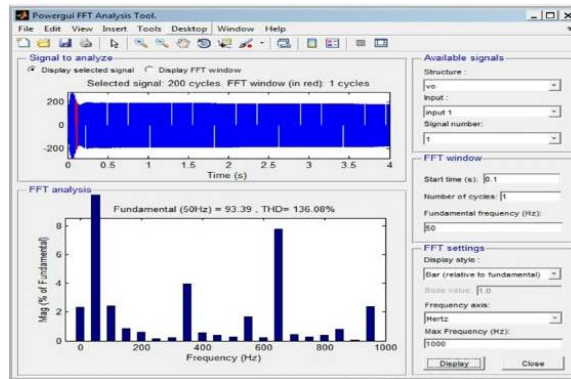


Fig. 12 THD without Converter

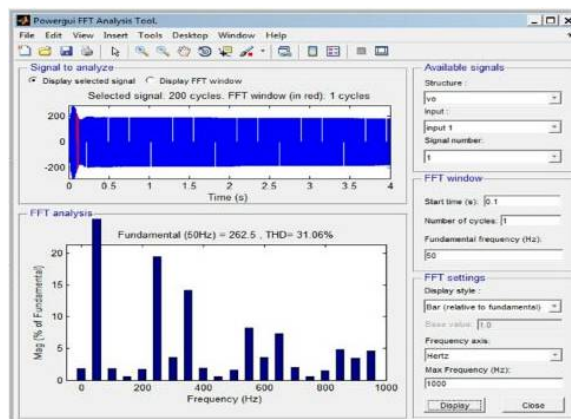


Fig. 13 THD with Sepic converter

V. CONCLUSION

This paper described the control strategy of variable speed wind power generation system using SEPIC converter. The simulation models of the variable speed wind generation system using SEPIC converter are implemented by using MATLAB/Simulink. The results of variable speed wind power generation without converter is compared with the results of variable speed wind power generation with SEPIC converter. Under variable wind speed condition the output of wind power is maintained constant with the help of SEPIC converter. The SEPIC converter makes the variable rectified output voltage from the PMSG to a constant DC voltage. SEPIC converter has played a key role in improving the voltage stability of variable speed wind power system. Space Vector Modulation reduces Total Harmonic Distortion (THD).

REFERENCES

- [1] Dong-Min Miao; Jian-Xin Shen, "Comparative study on permanent magnet synchronous generator systems with various power conversion topologies," 2013 Fourth International Conference on Power Engineering, Energy and Electrical Drives (POWERENG) pp.1738,1743, 13-17 May 2013.
- [2] Ming Yin; Gengyin Li; Ming Zhou; Chengyong Zhao, "Modeling of the Wind Turbine with a Permanent Magnet Synchronous Generator for Integration," Power Engineering Society General Meeting, 2007. IEEE, pp.1.6, 24-28 June 2007.
- [3] Slooetweg, J.G.; Kling, W.L., "Aggregated modelling of wind parks in power system dynamics simulations," Power Tech Conference Proceedings, 2003 IEEE Bologna, vol.3, pp.6, 23-26 June 2003.
- [4] Shariatpanah, H.; Fadaeinedjad, R.; Rashidinejad, M., "A New Model for PMSG-Based Wind Turbine With Yaw Control," IEEE Transactions on, Energy Conversion, vol.28, no.4, pp.929,937, Dec. 2013.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

- [5] Xia, Y.; Ahmed, K.H.; Williams, B.W., "A New Maximum Power Point Tracking Technique for Permanent Magnet Synchronous Generator Based Wind Energy Conversion System," IEEE Transactions on Power Electronics, vol.26, no.12, pp.3609,3620, Dec. 2011.
- [6] Sharma, S.; Singh, B., "Control of permanent magnet synchronous generator-based stand-alone wind energy conversion system," Power Electronics, IET , vol.5, no.8, pp.1519,1526, September 2012.
- [7] Wai, R.-J.; Lin, C.Y.; Chang, Y. -R., "Novel maximum-power-extraction algorithm for PMSG wind generation system," Electric Power Applications, IET , vol.1, no.2, pp.275,283, March 2007.
- [8] Koutroulis, E.; Kalaitzakis, K., "Design of a maximum power tracking system for wind-energy-conversion applications," IEEE Transactions on , Industrial Electronics, vol.53, no.2, pp.486,494, April 2006.
- [9] Busawon, K.; Dodson, L.; Jovanovic, M., "Estimation of the power coefficient in a wind conversion system," 44th IEEE Conference on Decision and Control and European Control Conference. CDC-ECC '05. pp.3450-3455, 12-15 Dec. 2005
- [10] Thongam, J.S.; Bouchard, P.; Beguenane, R.; Okou, A.F.; Merabet, A., "Control of variable speed wind energy conversion system using a wind speed sensorless optimum speed MPPT control method," IECON 2011 - 37th Annual Conference on IEEE Industrial Electronics Society , pp.855,860, 7-10 Nov. 2011.
- [11] Rolan, A.; Luna, A.; Vazquez, G.; Aguilar, D.; Azevedo, G., "Modeling of a variable speed wind turbine with a Permanent Magnet Synchronous Generator," IEEE International Symposium on Industrial Electronics ISIE, pp.734-739, 5-8 July 2009.
- [12] Lopez-Ortiz, E.N.; Campos-Gaona, D.; Moreno-Goytia, E.L., "Modelling of a wind turbine with permanent magnet synchronous generator," North American Power Symposium (NAPS), 2012, pp.1,6, 9-11 Sept. 2012
- [13] Jian Gao; Jining Lu; Keyuan Huang; Ying Zhang; Shoudao Huang, "A Novel Variable Step Hill-Climb Search Algorithm Used for Direct Driven PMSG," International Conference on Energy and Environment Technology, ICEET '09, pp.511-514, 16-18 Oct. 2009.