iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: VII Month of publication: July 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, July 2017- Available at www.ijraset.com

A Low-Cost Rectifier Topology for High Power PMSG Variable Speed Wind Turbine

Mr. Vipin Sunil Muley[1] , Dr. Hari Kumar Naidu[2] , Mr. Pratik Ghutke[3]
[1]Tulasiramji Gaikwad-Patil College of Engineering & Technology, Nagpur
[2]Dean of Electrical Department, [3]Guide, Tulasiramji Gaikwad-Patil College of Engineering & Technology, Nagpur

Abstract: ***A new topology consists of two three phase diode bridge rectifiers and three naturally commutated thyristors is proposed in the paper for the application of high power variable speed PMSG wind energy conversion system. It follows several prominent features such as low cost, low power loss, simple control and highly reliable. The variable speed wind turbine has some advantage than fixed speed and hence variable speed is used. The Maximum Power Point tracking algorithm is used for obtaining a maximized power output. The operating principle of the rectifier is elaborated. The rectifier and control operations are verified by MATLAB/ Simulink.***

Keywords: Rectifier, Permanent magnet synchronous Generator, Wind energy Conversion system.

I. INTRODUCTION

Wind energy is world's fastest growing energy source field. Over the last ten years, wind energy capacity has increased rapidly. As of 31 March 2016 the installed capacity of wind power in India was 26,743 which was 6,270 MW in 2005.

The future inclination in wind energy conversion systems is to increase the power capacity of wind turbines and generators resulting reduce the cost of generated electricity. The wind energy conversion system operates under two operating modes: fixed speed and variable speed wind turbines. The variable speed wind turbine has some advantages over the fixed speed wind turbines, they have ability to obtain maximum power from varying wind speed, higher overall efficiency audible noise at lower wind speed and lower mechanical stress [1]. Under variable speed operation the power converter in the system plays an important role in transferring the generator output power in the form of variable voltage variable frequency to the fixed voltage fixed frequency grid[2]. A typical PMSG based wind energy conversion system is shown in figure 1, in which a full capacity power converter is employed.

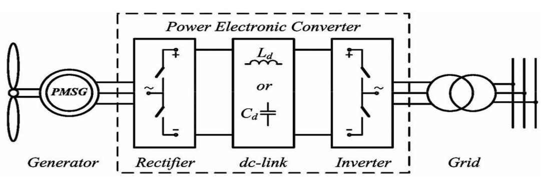


Figure.1. Typical structure of PMSG based wind energy conversion system.

The amount of energy obtained from a wind energy conversion system depends not only on the characteristics of the wind regime at the site, but it also depends on the control strategy used for the WECS[3]. The energy extracted from the wind is transferred from the generator to the dc-link by the generator side rectifier and then to the utility by the grid side inverter. The dc-link capacitor provides decoupling between the generator side and grid side converters. To achieve proper power control in the system, the dc-link has to be higher than the peak of the grid phase voltage[4].

There are many different controlled rectifier circuits, but the full power rating PWM rectifier is more expensive and complex. Also the rectifier generates higher switching losses and it is less efficient even though the input applied is the sinusoidal current[5]. The applications of voltage source inverter based power electronic systems for interfacing variable-voltage DC sources to the grid. A variable-speed wind power conversion system is used for illustration, where the VSI-based interface needs to convert a variable DC voltage to a nearly constant AC voltage with high-quality power[6]. The usage of synchronous generator, simple 3-phase diode rectifier with dc-dc chopper is more cost effective solution for ac-dc converter than 3-phase PWM converter[7]. The strategy combines the idea of Power Signal Feedback control and Input-Output Feedback Linearization method. As the results, the strategy can improve the dynamic response speed of WGS as well as the yield of wind energy in steady and dynamic state[8].

An uncontrolled diode bridge rectifier may be used as the generator side converter, but it is suitable for variable speed wind turbine system. In order to achieve a wind speed range, the grid side inverter is oversized to improve maximum power capture at variable wind speed but it leads to overcost and hence it can be reduced by adding a dc–dc boost converter between the diode rectifier and the inverter[9]. The proposed converter operation will be detailed in the following sections and the variable speed operation of the PMSG will be discussed.

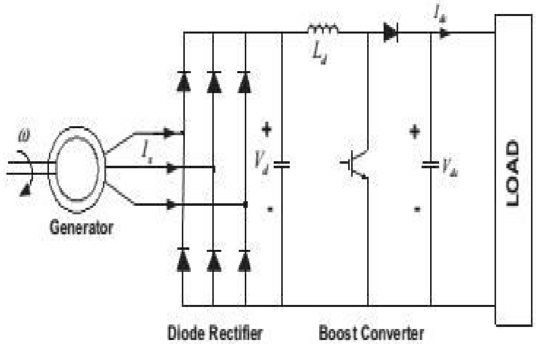


Figure.2. Diode bridge rectifier with dc-dc boost converter.

This chapter gives the brief description of the papers reviewed for the literature survey. About 20 papers were referred for this project. The papers are based on; wind energy conversion systems have become a focal point in the research of renewable energy sources. The trend of wind energy conversion system is to increase the power capacity of wind turbines and generators to reduce the cost of generated electricity. In this chapter, the 20 papers are grouped under following category, such as study on induction generators, converters in variable speed wind turbines, harmonic reduction process and algorithms used.

II. PROPOSED RECTIFIER TOPOLOGY

This section provides a novel rectifier topology for variable speed high-power PMSG wind turbines [8]. From figure we observed that there are only diodes and naturally commutated thyristors are present in this topology. Thus, it gives advantage of low cost, low power loss and high reliability. This topology can work with a non-oversized PWM-VSI and it is able to perform torque/speed control on the generator to absorb maximum input power from varying wind speed.

Fig. 5.1 shows the basic structural diagram of the proposed rectifier topology. The main circuit is consists of two three-phase diode rectifier bridges and three individual thyristors. Each diode bridge is supplied by a three-phase power supply and their outputs are connected in parallel. Here we are using three thyristors to connect the corresponding input phases of the two diode bridges.

In normal operation, when the thyristors are in off position, the rectifier's dc output voltage is equal to the output of a single diode bridge while when we controlled the thyristors and turned on at the right instants, the outputs of the two diode bridges can be cascaded and there resultant output dc voltage is doubled.

To operate the rectifier properly, the two three-phase input power supplies should be equal in magnitude and have 180◦phase displacement with each other. Due to this, surely doubled output voltage is obtained when the thyristors are turned on. To interface the generator in variable-speed WECSs, the voltage-doubling feature of the proposed rectifier can be used. To obtained this feature either a PMSG with dual stator windings or two PMSGs, each having one set of three-phase winding, can be used as the ac power supplies for the rectifier.

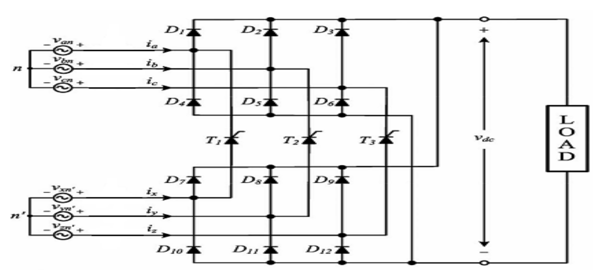


Figure.3. Proposed rectifier circuit.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, July 2017- Available at www.ijraset.com

The operating principle of the proposed rectifier is explained using its waveforms. The sources Van, Vbn, Vcn and vxn′, vyn′, vzn′ are sinusoidal.

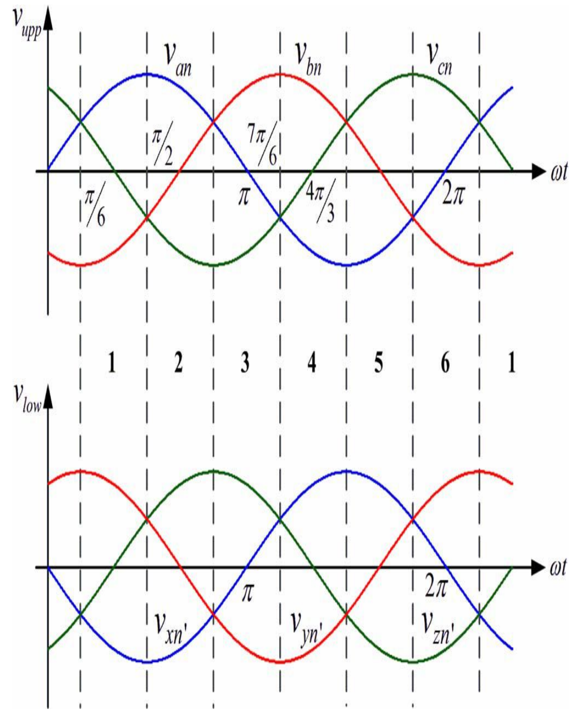
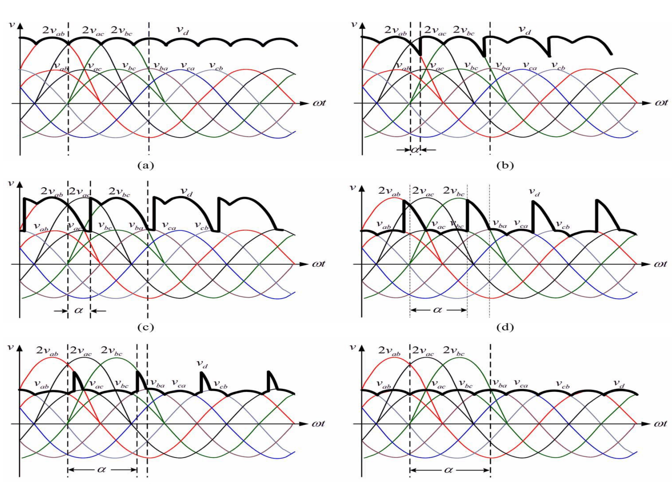


Figure.4. Input voltage supplied to the proposed rectifier.

The current path in each and every sections are explain using its circuit diagram. The current path in section 1 is explained using the input voltage supplied to the upper and lower diode bridge rectifiers. The maximum and minimum input phase voltages in the upper supply are van and vbn, respectively; whereas for the lower supply, the maximum is vyn′ and the minimum is vxn′. As illustrated in the figure below, the two diode bridges have separate current paths and maintain their own rectification when the thyristors are off. Assuming that we have an inductive dc load that behaves like an ideal current source, the rectifier’s output voltage vd is equal to the input line-to-line voltage vab.

The thyristor T2 connect the minimum voltage phase in the upper supply phase b and the maximum voltage phase in the lower supply phase y is turned on at any time within Section 1, the two diode bridges are forced into a series connection through the thyristor. The dc voltagevdthen becomes the sum of vaband vyx, equaling to 2vab in magnitude.



International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, July 2017- Available at www.ijraset.com

Fig. 11. Typical rectifier output waveforms. (a) $\alpha = 0^\circ$. (b) $0^\circ < \alpha < 30^\circ$. (c) $30^\circ < \alpha < 60^\circ$. (d) $60^\circ < \alpha < 120^\circ$. (e) $120^\circ < \alpha < 150^\circ$. (f) $\alpha = 150^\circ$.\

IV. MPPT CONTROL FOR VARIABLE SPEED PMSG WECS

The simplified system diagram of a variable-speed PMSG wind turbine using the proposed rectifier as the generator side converter is illustrated in Figure.12. Under normal operating conditions, the VSI is responsible for maintaining a constant dc voltage while regulating the grid side power factor as. The whole system consists of two identically rated PMSGs which are directly coupled to the rotor shaft of the wind turbine. Each PMSG is feeding one of the two inputs of the rectifier. By adjusting the mechanical angles of the generators during installation, the 180º phase displacement requirement on the rectifier input voltages can be satisfied easily. It is worth noting that due to the distinctive structure of the rectifier, the power rating of the two PMSGs is approximately half that of the system's rated power, such that the ratings of the generator-side and the grid-side converters.

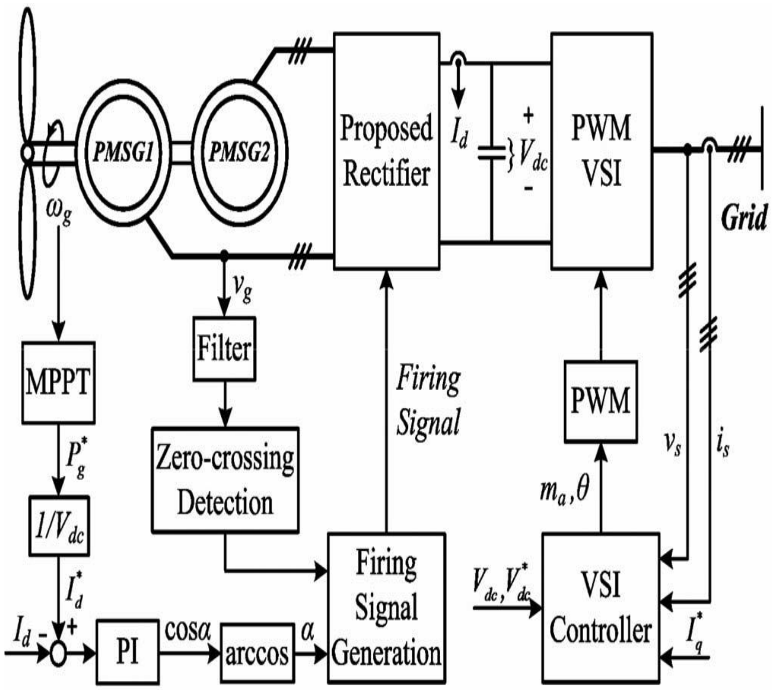


Fig. 12. MPPT control of PMSG wind turbine with the proposed rectifier.

V. SIMULATION RESULTS

A simulation model in matlab/simulink has been constructed to verify the rectifier operation, as shown in Figure 14. The proposed rectifier and its MPPT control for variable-speed operation are designed. The simulink model is shown in figure 13 below.

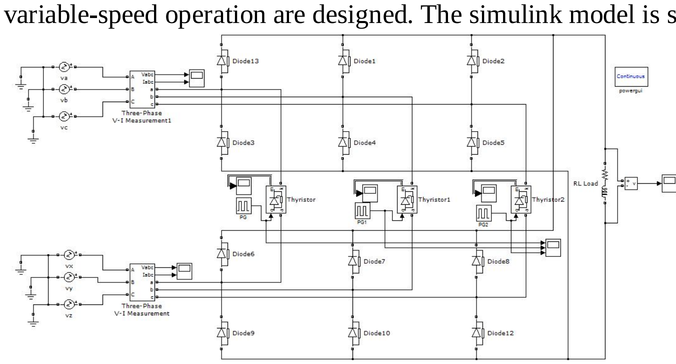


Figure.13. Simulation diagram for proposed rectifier.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, July 2017- Available at www.ijraset.com

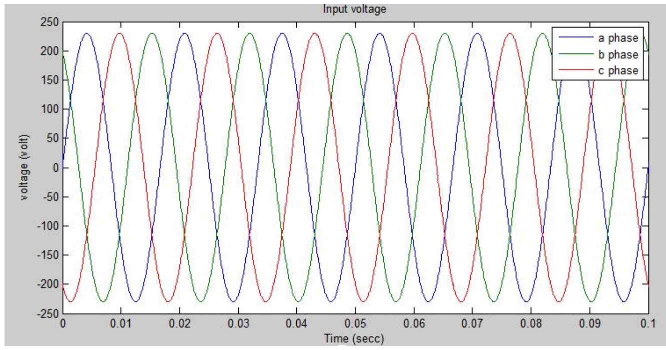


Figure.14. Input voltage supplied to the upper diode bridge rectifier.

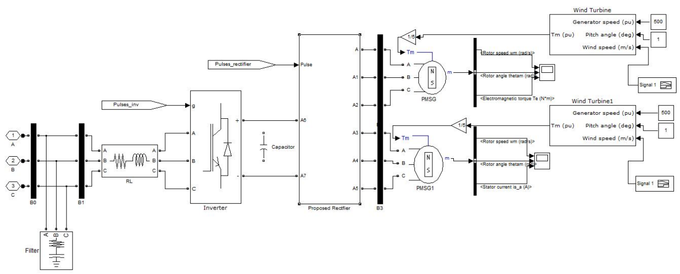


Figure.15. Simulated design of WECS.

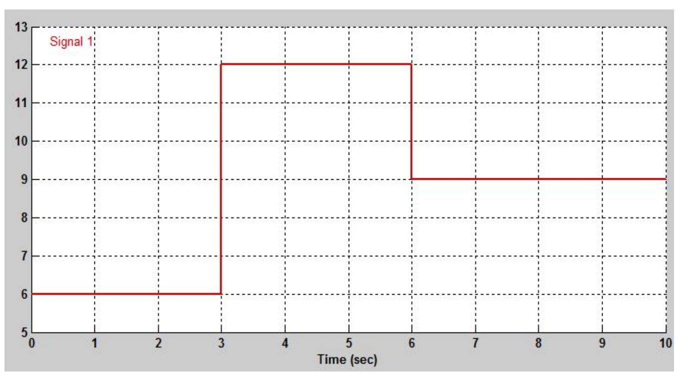


Figure.16. Wind speed to the wind turbine.

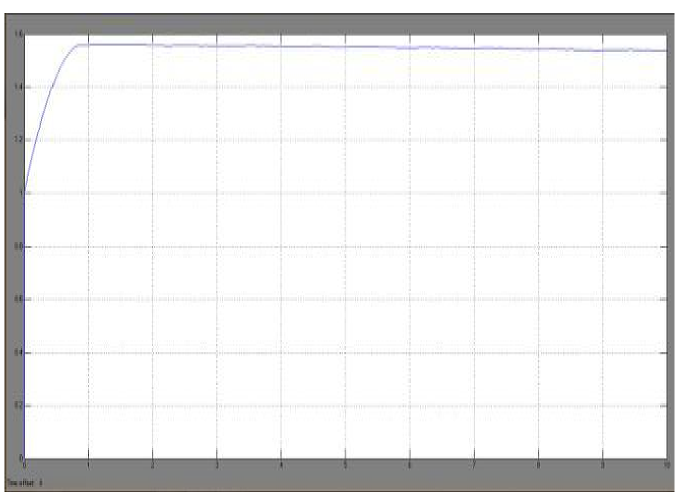


Figure.17. Generator speed of conversion system.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, July 2017- Available at www.ijraset.com

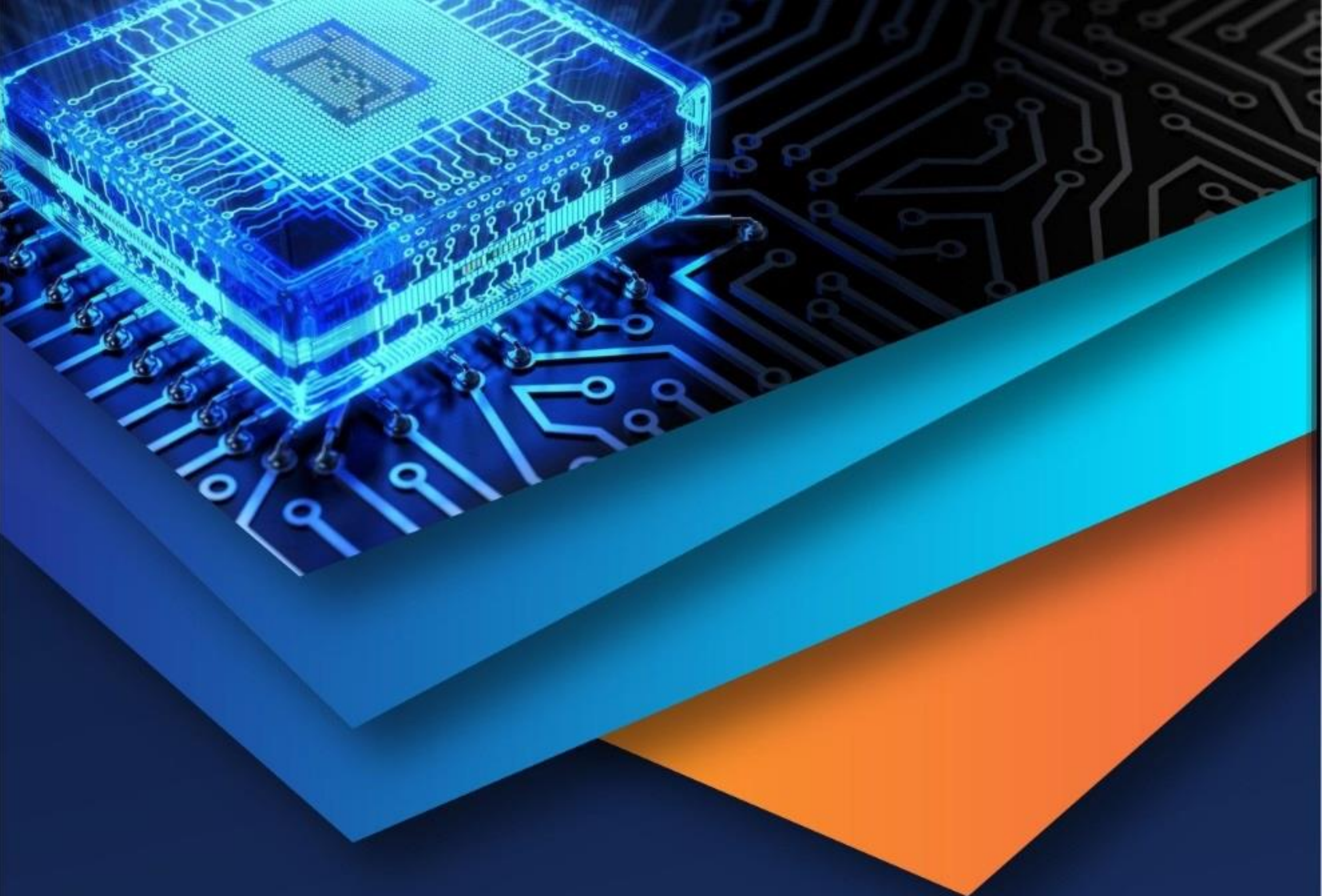
VI. CONCLUSION

The major advantage of the proposed rectifier is to cascade the inputs to accommodate power inflow when wind speed and the generator voltage is lower than rated. This feature of topology is equivalent to a voltage boost function that cannot be found in conventional diode or thyristor rectifiers. Also, the rectifier can be used with a PWM-VSI for PMSG-based high-power direct-drive WECS, in which the generators and the inverter do not need to be oversized. When comparing this proposed rectifier with PWM voltage-source rectifier that has been frequently used in existing systems, it has the advantage of lower cost and power losses. Also, it can only be used with synchronous generators due to the lacking of reactive current control capability.

In short, this proposed rectifier provides a cost-effective solution for generator-side converter in variable-speed high power PMSG-based wind turbines. Wind power generation has grown at a very fast rate in the past decade and it will continue to do so as power electronics technology is increasing day-by-day.

REFERENCES

[1] S. Muller, M. Deicke, and R. W. De Doncker, “Doubly fed induction generator systems for wind turbines,” IEEE Ind. Appl. Mag., vol. 8, no. 3, pp. 26–33, May/Jun. 2002.
[2] Z. Chen, J. M. Guerrero, and F. Blaabjerg, “A review of the state of the art of power electronics for wind turbines,” IEEE Trans. Power Electron., vol. 24, no. 8, pp. 1859–1875, Aug. 2009.
[3] J. A. Baroudi, V. Dinavahi, and A. M. Knight, “A review of power converter topologies for wind generators,” Renewable Energy, vol. 32, no. 14, pp. 2369–2385, 2007.
[4] A. Yazdani and R. Iravani, “A neutral-point clamped converter system for direct-drive variable-speed wind power unit,” IEEE Trans. Energy Conv., vol. 21, no. 2, pp. 596–607, Jun. 2006.
[5] S. Alepuz, S. Busquets-Monge, J. Bordonau, J. A. Martinez-Velasco, C. A. Silva, J. Pontt, and J. Rodriguez, “Control strategies based on sym-metrical components for grid-connected converters under voltage dips,” IEEE Trans. Ind. Electron., vol. 56, no. 6, pp. 2162–2173, Jun. 2009.
[6] C. H. Ng, M. A. Parker, L. Ran, P. J. Tavner, J. R. Bumby, and E. Spooner, “A multilevel modular converter for a large, light weight wind turbine generator,” IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1062–1074, May 2008.
[7] J. Dai, D. D. Xu, and B. Wu, “A novel control scheme for current-source-converter-based PMSG wind energy conversion systems,” IEEE Trans. Power Electron., vol. 24, no. 4, pp. 963–972, Apr. 2009.
[8] P. Tenca, A. A. Rockhill, T. A. Lipo, and P. Tricoli, “Current source topol-ogy for wind turbines with decreased mains current harmonics, further reducible via functional minimization,” IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1143–1155, May 2008.
[9] P. Tenca, A. A. Rockhill, and T. A. Lipo, “Wind turbine current-source converter providing reactive power control and reduced harmonics,” IEEE Trans. Ind. Appl., vol. 43, no. 4, pp. 1050–1060, Jul./Aug. 2007.
[10] Z. Chen and E. Spooner, “Voltage source inverters for high-power, variable-voltage DC power sources,” Inst. Electr. Eng Proc. Gener., Transm. Distrib., vol. 148, no. 5, pp. 439–447, Sep. 2001.
[11] S. H. Song, S. Kang, and N. Hahm, “Implementation and control of grid connected AC-DC-AC power converter for variable speed wind energy conversion system,” in Proc. IEEE APEC, 2003, pp. 154–158.
[12] J. D. S. Oliveira, M. M. Reis, C. E. A. Silva, L. H. S. Colado Barreto, F. L. M. Antunes, and B. L. Soares, “A three-phase high-frequency semicontrolled rectifier for PM WECS,” in IEEE Trans. Power Electron., no. 3. vol. 25, Mar. 2010, pp. 677–685.
[13] D. Xu and Z. Luo, “A novel AC–DC converter for PMSG variable speed wind energy conversion systems,” in Proc. IEEE IPEMC, 2009, pp. 1117– 1122.
[14] R. G. Wagoner, A. M. Ritter, and A. M. Klodowski, “Wind turbine with parallel converters utilizing a plurality of isolated generator windings,” US Patent 2009/0322081 A1, 2008.
[15] K. Tan and S. Islam, “Optimum control strategies in energy conversion of PMSG wind turbine system without mechanical sensors,” IEEE Trans. Energy Conv., vol. 19, no. 2, pp. 392–399, Jun. 2004.
[16] S. Bhowmik, R. Spee, and J. H. R. Enslin, “Performance optimization for doubly fed wind power generation systems,” IEEE Trans. Ind. Appl., vol. 35, no. 4, pp. 949–958, Jul./Aug. 1999.
[17] H. Geng and G. Yang, “A novel control strategy of MPPT taking dynamics of wind turbine into account,” Proc. IEEE PESC, pp. 1–6, 2006.
[18] S. Morimoto, H. Nakayama, M. Sanada, and Y. Takeda, “Sensorless output maximization control for variable-speed wind generation system using IPMSG,” IEEE Trans. Ind. Appl., vol. 41, no. 1, pp. 60–67, Jan./Feb. 2005.
[19] K. E. Johnson, L. J. Fingersh, M. J. Balas, and L. Y. Pao, “Methods for increasing region 2 power capture on a variable-speed wind turbine,” J. Solar Energy Eng., vol. 126, p. 1092, 2004.
[20] W. Quincy and C. Liuchen, “An intelligent maximum power extraction algorithm for inverter-based variable speed wind turbine systems,” IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1242–1249, Sep. 2004.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY