International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

High-Power Transformer-Less Wind Energy Conversion System with three phase Cascaded Multilevel Inverter

C.MALLIKA DEVI, R.NAGARAJAN

Abstract — In this paper mainly focused on the design and implementation of new topology in a three phase five level Cascaded Multilevel Inverter. The objective of this paper is to increase output voltage with a low number of switches and sources at the output without adding any complexity to the power circuit. In this paper, Phase Shifted pulse width modulation techniques are proposed, which can minimize the total harmonic distortion and enhances the output voltages from proposed work of five level output with reduced switches. It is justified that the new topology can be recommended to three phase five level Cascaded H-bridge inverter for better performance in comparison with conventional method. The simulation is done by MATLAB/SIMULINK software.

Index Terms—CMLI-Cascaded Multilevel Inverter, PSCPWM- Phase Shifted Carrier Pulse Width Modulation, PMG-Permanent Magnet Generator, HWC-Half Wave Converter

1 INTRODUCTION

The wind turbines use the kinetic energy of the wind and convert that energy into mechanical energy, which in turn can be converted into electricity by means of generator. The Wind energy touches the turbine blades and creating Mechanical energy. The turbine shaft is connected to the Generator, producing alternating electric energy. The voltage level of a wind power converter is usually in the range of (380 to 690 V) due to generator voltage rating and voltage limitation of power electronics devices. Therefore, the power converter is connected to the grid via a step-up transformer to match the grid voltage level (10.5 to 35 kV) in the wind farm collection system. In this paper, a three phase 5-level output is obtained from the series connection of Cascaded Half H-Bridge Multilevel Inverter

The converter modules (Full H-Bridge) are cascaded (17level) to achieve medium voltage output and the Inverse Sin PWM scheme is adopted to regulate the converter active and reactive power transferred to the grid. In Proposed System Each converter (Half H-Bridge) are cascaded to achieve medium voltage output. Each module is fed by a Constant DC voltage and the Phase shifted PWM scheme is adopted to increase the converter output voltage. In this paper each converter (Half H-Bridge) are cascaded to achieve medium voltage output. Each module is fed by a constant DC voltage and the Phase shifted PWM scheme is adopted to control the converter output voltage.

2 PROJECT DESCRIPTION

A permanent magnet generator (PMG) interfaced to the grid through a half power converter is increasingly being adopted due to its higher power density, better controllability, and reliability, especially so during grid faults. The voltage level of a wind power converter is usually in the range of 380 to 690 V due to generator voltage rating and voltage limitation of power electronics devices. Therefore, the power converter is connected to the grid via a step-up transformer to match the grid voltage level (10.5 ≈ 35 kV) in the wind farm collection system. In the low voltage (690 V) system, when wind turbine power is larger than 500 kVA, several power converters are connected in parallel to handle the increasing current. The large current transfer also results in a parallel connection of multiple cables and causes substantial losses, voltage drop as well as high cost of cables and connections. This disadvantage can be avoided by placing the step-up transformer into the nacelle. However, the bulky and heavy transformer significantly increases the mechanical stress of the tower. Instead of paralleling converters and cables, another alternative to transfer high power is to use medium voltage transmission, where the current is reduced and the step-up transformer may not be needed if the converter output voltage level can reach the grid voltage (10.5 kV ≈ 35 kV) Since the system current rating can be a good indicator for the cable and connection cost and losses.

The cascaded H-bridge Converter is recognized as more suitable for industrial product in the sense of modular structure, high reliability, and fault-tolerant ability. In addition, it is the only available and practical multilevel converter topology that may meet the voltage level of more than 10 kV subject to the voltage rating of power electronic devices. Whereas, in a wind power conversion system, the multiple generator coils can be used as the independent sources for the converter modules.

2.1 Schematic diagram

Proposed system presents a modular permanent magnet wind generator and medium-voltage converter system, aiming to reduce the system current rating by

International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013
ISSN 2229-5518

cascading converter modules. Each module is fed from separate DC voltage, and an H-bridge inverter. Where three HW converter blocks are connected in series .Each HW converter blocks consists on DC voltage source.

The sum of each HW converter block is connected to load. Here the output voltage is measured by using 3phase resistive load.

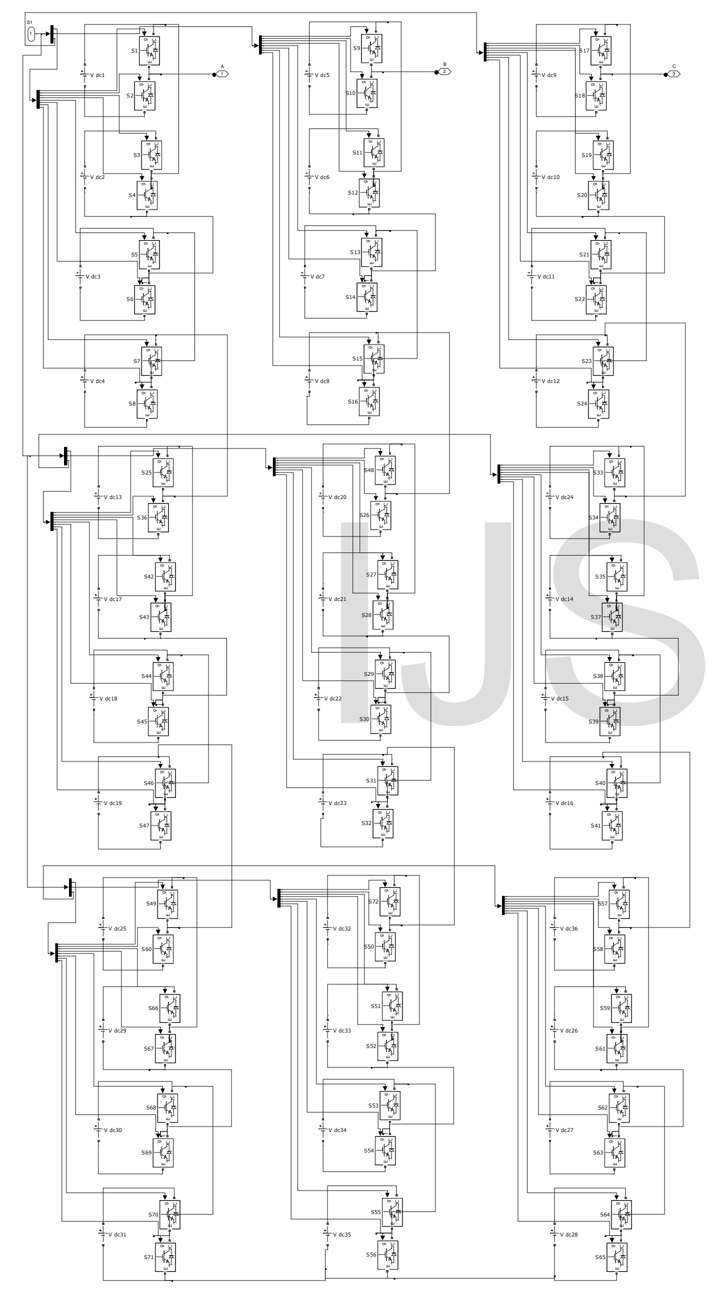

Fig 1 Simulation Circuit Model of Half H Bridge Converter

At the generator side, each converter module requires a stable voltage source input, where diode rectifier is used to give the input to the inverter.

Each Converter block consists of two switches. The converter blocks are connected in series to increase the output voltage. The output of the Rectifier circuit is given to Cascaded H-bridge inverter. Where, 3 HWR blocks are connected in series to increase the output.

2.2 Phase Shifted Carrier Pulse Width Modulation Technique (PSCPWM)

Fig.2 shows the Phase shifted carrier pulse width modulation. Each cell is modulated independently using sinusoidal unipolar pulse width modulation and bipolar pulse width modulation respectively, providing an even power distribution among the cells.

A carrier phase shift of 180°/m for cascaded inverter is introduced across the cells to generate the stepped multilevel output waveform with lower distortion.

The Phase Shifted Carrier PWM (PSCPWM), Figure 3, is a multicarrier modulation strategy that has all carrier waves phase shifted from each other. It is the standard modulation strategy for the CMCI topology but is not exclusively for that topology.

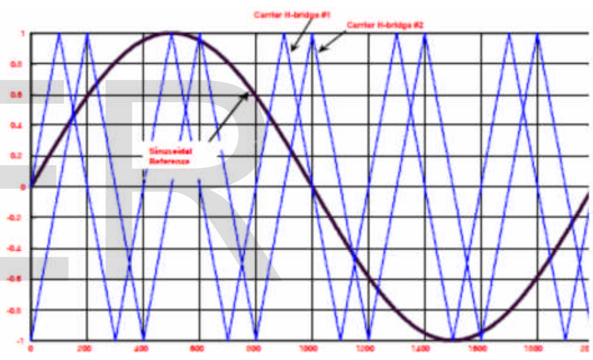

Fig 2 Phase shifted carrier

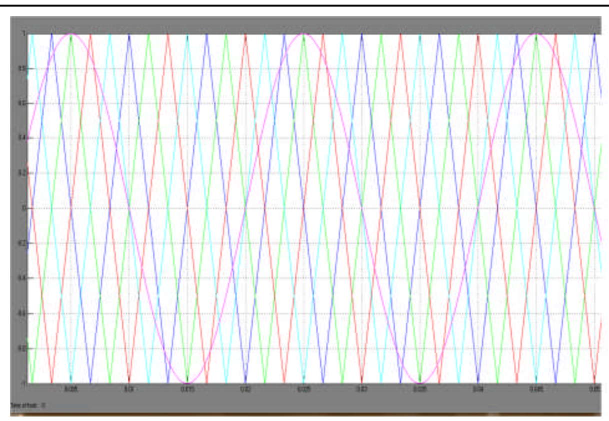

Fig 3 Phase Shifted carrier and Reference Signal

For a CMCI with n number of full-bridge modules in each phase-leg there are also n number of triangular carrier waves. There is one trian-

International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013
ISSN 2229-5518

TABLE 1
GENERATOR AND CONVERTER PARAMETER IN SIMULATION

Symbol	*Quantity*
Vdc- DC input Voltage	*848V*
R -Load Resistance	*100Ω*
f -Frequency	*50Hz*
Switching Frequency	*12KHz*

gular carrier wave for each full bridge module, phase shifted with 180/n in betweens them, with amplitudes the magnitude of the total DC voltage. The magnitudes for the carrier waves are modulated by the actual voltage level in the appropriate module. For the _ve-level CMCI with two modules there are two triangular carrier waves, one for each module. The modules create the two voltages with PSCPWM modulation. There are also two reference waveforms for the two legs in each inverter modules that are phase shifted 180° from each other, as can be seen in Figure 4. Both reference waves are compared with both carrier waves, one reference wave is for modulation of the left full-bridge module leg switches (dashed reference wave) and the other reference wave to modulate the right full-bridge module leg switches (solid reference wave). The triangular wave in Figure 3 is compared with the upper output voltage plot in Figure 3 (and the second triangular with the lower voltage plot). Close to 2ms in the plots it can be seen that the triangular wave crosses one reference wave downwards, controlling the right leg switches.

Figure 3 shows the carrier and reference waves for a _ve-level CMCI with PSCPWM, two reference waves and two triangular waves (one for each module) of the modules, turning that modules output voltage from 0 kV to □0:5 kV. Closely after the second carrier wave crosses the same reference wave (the one that controls the right leg switches in the modules) upwards turning the output voltage from 0 kV to 0.5 kV Comparisons with the other reference wave works in the same wave, but then controlling switches in the modules left legs. As the plots suggest the two modules share the workload for all levels, no module is strictly connected to one voltage level in the output. For the CMCI this strategy cancels all carrier and sideband associated harmonics up to the 2nth carrier group.

3 SIMULATION RESULTS

The simulation is done by MATLAB/SIMULINK software. Following Fig 4, 5, 6 and 7 shows the output of simulation of proposed system. Phase shifted PWM technique is used to control the switching sequenc of MLI.

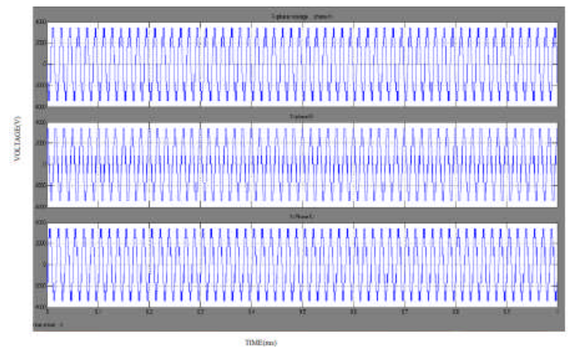

Fig 4 Simulation Output for HW Converter 3.39KV

Fig4 shows the simulation output of HW converter, phase voltage is 3.39KV. Phase shifted PWM technique is used to control the switching sequenc of MLI.

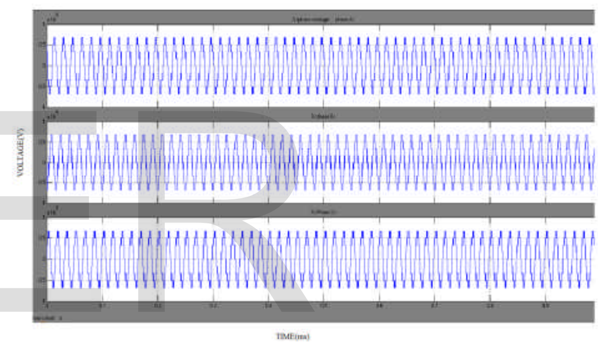

Fig 5 Simulation Output for HW Converter 6.78KV

Fig5 shows the simulation output of HW converter, phase volage is 6.78KV.

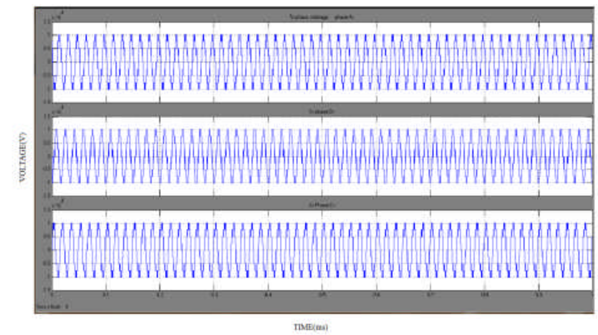

Fig 6 Simulation Output for HW Converter 10KV

Fig6 shows the simulation output of HW converter, phase volage is 10KV.

International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013
ISSN 2229-5518

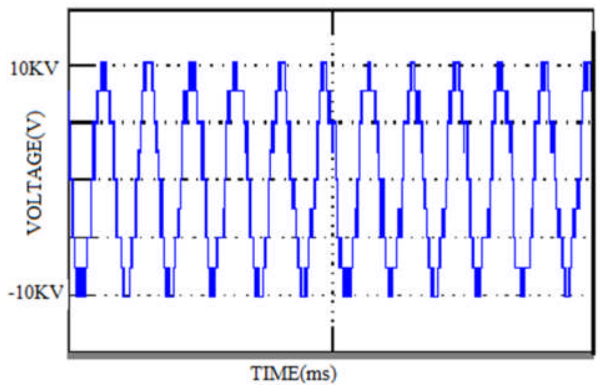

Fig 7 Zoomed View Simulation Outputs 10KV

4 CONCLUSION

Proposed System has presented a permanent magnet wind generator and high-power converter system, which increases the converter output voltage by cascading converter modules. This system can reduce the cable losses and associated cost for cables and connections by reducing the current, which provides a solution for the power conversion of large wind turbines. 3 phases Half H bridge Converters are used to increase the output level and the Phase Shifted vector-controlled cascaded H-bridge converter can successfully transfer power from the generator to the load with independent active power and reactive power control ability.

ACKNOWLEDGMENT

I am thankful to my Guide R.Nagarajan, Associate Professor, Department of EEE, Raja College of Engineering and Tech, Madurai for his valuable suggestion to complete my paper in time.

REFERENCES

[1] Xibo Yuan, Member, IEEE, Jianyun Chai, and Yongdong Li, Senior Member, IEEE "A Transformer-Less High-Power Converter for Large Permanent magnet wind generator systems "IEEE transactions on sustainable energy, vol. 3, no. 3, july 2012

[2] C. Ng, M. Parker, and P. Tavner, "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.

[3] A Faulstich, J.K Stinke, and F. Wittwer, "Medium voltage converter for permanent magnet wind power generators up to 5 MW," in Proc.EPE

[4] J. Rodriguez, S. Bernet, and B. Wu et al., "Multilevel voltage-source converter topologies for industrial medium-voltage drives," IEEE Trans. Ind. Electron., vol. 54, no. 6, pp. 2930–2945, Dec. 2007.

[5] H. Li and Z. Chen, "Design optimization and valuation of different wind generator systems," in Proc. IEEE ICEMS'08 Conf., Oct. 2008,vol. 2, pp. 2396–2401.

[6] L. Liu, Y. Ma, J. Chain, and X. Sun, "Cascaded single phase PFC rectifier pair for permanent magnet wind generation system," in Proc. IEEE IPEMC'08 Conf., Oct. 2008, vol. 1, pp. 2516–2520.

[7] M.A. Parker, Ng. Chong, and Ran Li, "Fault-tolerant control for a modular generator converter scheme for direct drive wind turbines," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 305–315, Jan. 2011

[8] K.S. Khan,W.M. Arshad, and S. Kanerva, "On performance figures of multiphase machines," in Proc. ICEM'08 Conf., Sep. 2008, vol. 1, pp.1–5

[9] Y. Lo, S. Ou, and H. Chiu, "On evaluating the current distortion of the single-phase switch-mode rectifiers with current slop maps," IEEE Trans. Ind. Electron., vol. 49, no. 5, pp. 1128–1137, Oct. 2002.

[10] V. Kaura and V. Blasko, "Operation of a phase locked loop system under distorted utility conditions," IEEE Trans. Ind. Appl., vol. 33, no. 1, pp. 58–63, Jan. 1997.

- *C.Mallika Devi is currently pursuing master's degree program in Power Electronics and Drives, Raja College of Engineering and Technology in Anna University, Madurai, India. E-mail: cmallikadevi@yahoo.coin*
- *R.Nagarajan is currently working as Associate Professor in Electrical and Electronics Engineering Department, Raja College of Engineering and Technology in Anna University, Madurai, India. E-mail: knaga71@yahoo.com*