ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Comparative Analysis of Wind Energy Conversion System under Steady and Dynamic Wind Speeds with Single-Stage AC/AC Converter

M. Shravani
M.Tech (Energy Systems)
Department of Electrical Engineering
JBIET, Hyderabad, Telangana, India.

K. Giribabu
Assistant Professor
Department of Electrical Engineering
JBIET, Hyderabad, Telangana, India.

Fatima Azra
Associate Professor & HoD
Department of Electrical Engineering
JBIET, Hyderabad, Telangana, India.

Abstract

In this paper, a new sensor-lesssix switches AC/AC converter based WES is proposed. Theproposed WES has cost advantages compared to otherconfigurations since it has the lowest number of active switchesand also does not require to rotor speed sensor.The generatorspeed is estimated through an observer technique.Single independent control strategyis utilized for of the proposed system. In this paper a single-stage converter was proposed for integrating Wind system with Grid by reducing the number of switches. Due to incident wind speed, maximum output power of windturbine is obtained in different speed of the turbine. The generatorspeed must be adjusted according to instantaneous wind speed toobtain incident maximum power.Tip speed ratio (TSR) technique is used for MPPT. This MPPT method willgenerate the reference speed for speed controller of PMSG. The comparative analysis has been done for steady and transient state wind speeds. The validation of proposed converter is verified with MATLAB/Simulink under simupowersystems toolbox.

INTRODUCTION

Wind energy has continued the worldwide success story asthe wind power development is experiencing dramatic growth. According to statistical data the cumulative installed wind power capacity in 2006, 2009 and 2012 were 74.0, 158.86 and 282.43 GW respectively; almost doubled in every three years. The dynamic growth of wind power directly pushes the wind technology into a more competitive area. Therefore, it is essential for scientists and researchers to find out the effective technologies for the wind power generation systems. The variable nature of wind energy sources (in terms of the real power, reactive power, output voltage, and frequency) is a major challenging issue.The conversion of an input AC power at a given frequency and voltage to an output power at different frequency and voltage can be obtained with static circuits called power converters, containing controllable power electronic devices. Various power converters have been developed to fulfill the requirements of the wind power generation. Each of them has some advantages and some disadvantages. The traditional converter voltage level is in the range of 380–690 V due to the low generator voltage rating and the use of two-level converter topology. To reduce the electrical losses, a power frequency (50/60 Hz) power-transformer is commonly used in wind power generation system (usually installed inside the turbine nacelle) to step-up the voltage to medium voltage level (e.g. 11–33 kV), as shown in Fig. 1. This heavy and bulky transformer significantly increases the weight and volume of the nacelle as well as mechanical stress of the tower. Nowadays components can handle higher current and voltage ratings, the power loss decreases and the devices become more reliable for the control of megawatt scale power thanks to the power electronics as a rapidly developing technology. The price is still decreasing, and power converters are becoming

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

more and more attractive which means improving the performance of wind power generation systems.

With the advent of new power semiconductor devices, different soft magnetic materials with high magnetic saturation flux density and low specific core loss are conceived to reduce the weight and volume of medium or high frequency-link [1]. These recent advances have led to thedevelopment of new medium voltage converter system, which would be a possible solution to eliminate the transformer of the wind turbine generator systems. This chapter aims to a comprehensive study of traditional converter technologies for wind turbine generator systems. In addition the challenges, current research and development trends, possible future directions of the research to develop new converter topology for future wind turbine are also considered in this chapter.

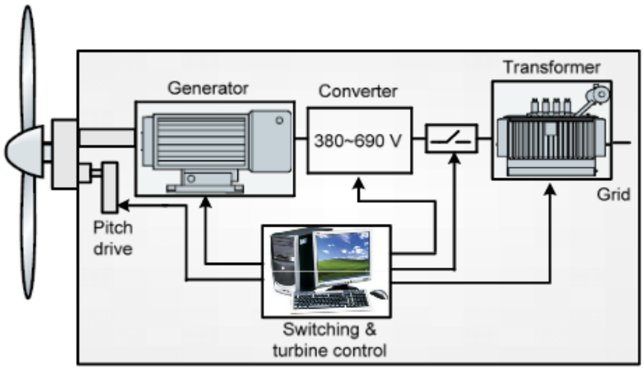

Fig. 1: Fully-rated converter based wind turbine generator system

Circuit Structure and Operation Principle

Fig. 2 shows the power circuit of the proposed three-phase AC/AC converter, whose operation mode is divided into two sections. Fig. 3 shows the on-off timing schedule of active switches. In mode 1, when SW5 and SW6 are both turned-on, the switches SW1, SW2, SW3, and SW4 are unipolar switching, and the converter is regarded as AC/DC rectifier. In mode 2, when both SW1 and SW2 are turned-on, the switches SW3, SW4, SW5, and SW6 are unipolar switching; the converter is regarded as DC/AC inverter.The core of the new converter control strategy can be roughly divided into two parts. The first part is dividing working area of the rectifier and inverter in the structure of main circuit by the ratio of capacitance.

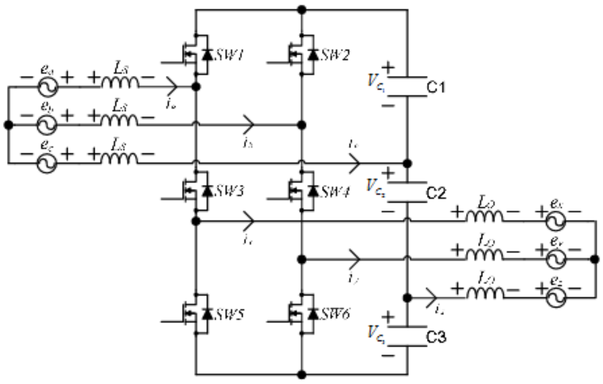

Fig 2: Power circuit of the proposed three-phase AC/AC Converter

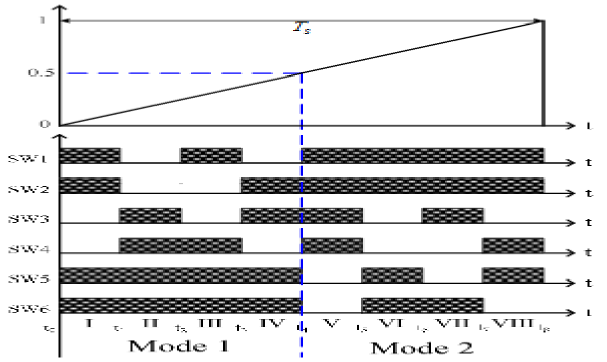

Fig 3: The on-off timing schedule of active switches

The core of the new converter control strategy can be roughly divided into two parts. The first part is dividing working area of the rectifier and inverter in the structure of main circuit by the ratio of capacitance. The second part is applying DSP to plan for the width of the sinusoidal pulse modulation signals, and then send signals to the switch via the logic combinational circuit switch in order to trigger the switch.

The sinusoidal pulse width modulation signal, planned by DSP, will be divided into three parts to be discussed. The first part, generated by rectifier modulation signal, is shown in Figure 3. After the voltage command value V*m passing through a gain G, the difference between DC voltage command value V*c and actual DC voltage CV is corrected by the PI controller. By multiplying corrected value and the unity sinusoidal wave, we'll get the current command value i*ac, i*bc, find the difference between the current command value and the actual currenti_{ac},i_{bc}, then revise it by the PI controller. After detecting the peak value of the corrected value, divide the PI controller correctionvalue by the peak value, and we'll get sinusoidal wave of a unit. Subtract this value by PI controllercorrection, and then we need to add constant 0.75 to the duty cycle of the rectifier, according to theprevious discussion. Finally, we get the required duty cycle duty1 and duty2 of the new converter.

The second part is the inverter modulation signal shown in Figure 3. The inverter duty cycle of the result value of multiplying Voltage command value V*m and the DSP of the two-phasesinusoidal wave needs to be reduced to 0.25 according to the discussion at the front. Finally, we get the duty cycle duty3 and 4duty of the new converter.

The third part is the pulse width modulation generator, shown in Figure 4. Add 0.5 duty cycle to 1duty, 2duty, 3duty and duty4, got from the first part and second part; pass the signal we get to the external compositional logic circuit after passing through the PWM controller. Then, the composed signal is sent to the gate of every power switch.

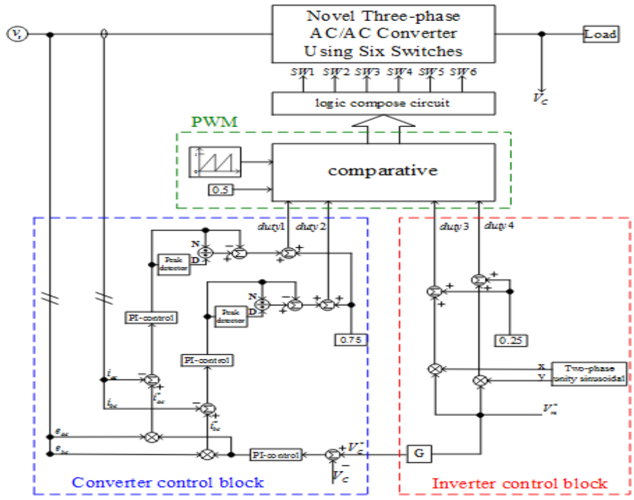

Fig 4: Block diagram of the control strategy

STMULATION RESULTS

In this section, simulation results are presented to verify thevalidity of operations of the proposed system under steady- stateand transient conditions.

Operation of Constant Wind Speed

In this section, the steady state operation of the proposed systemis verified through simulation results. For this purpose the windspeed is considered a constant value which is equal to 13 m/s.

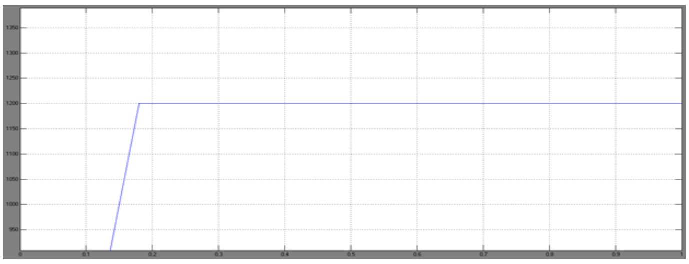

Figure 5: Rotor Speed of wind generator

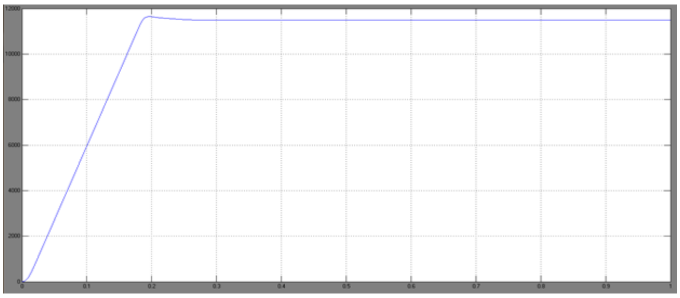

Figure 6: Mechanical power generated from Wind Turbine

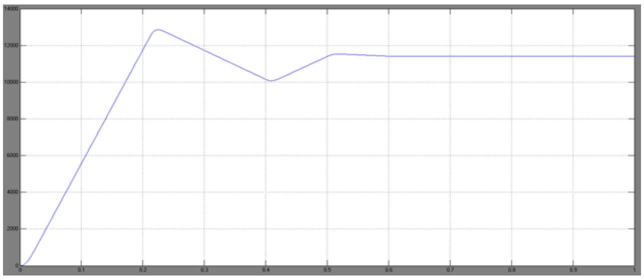

Figure 7: power delivered to grid from AC-AC converter

Operation of Variable Wind Speed

In order to examine the proposed system performance under the transient condition, wind speed has been

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

varied from 13 m/s to 9 m/s in t=0.6 sec and then from 9 m/s to 11 m/s in t=0.9 sec.

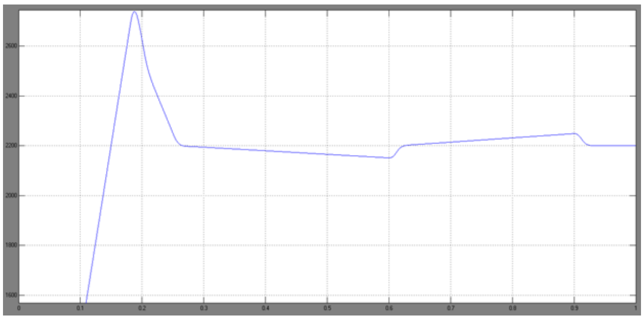

Figure 8: Capacitor voltage under variable wind speed

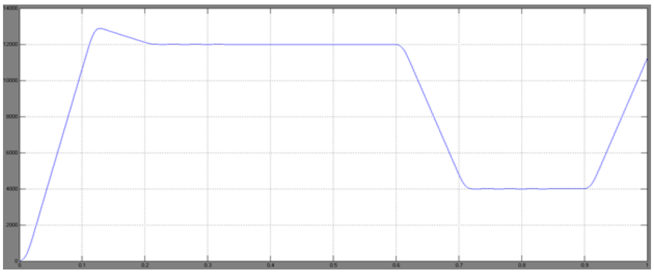

Figure 9: Power Delivered to grid under variable wind speed

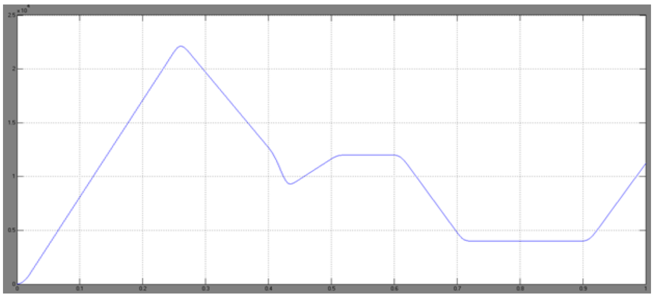

Figure 10: Mechanical Power generated formwind turbine under variable wind speed

AC-DC-AC Converter

Fig. 11 shows a schematic diagram of the proposed AC-DC-AC basedWECS with integrated active filter capabilities. In AC-DC-AC,the stator is directly connected to the grid as shown in Fig. 11.Two back-to-back connected voltage source converters (VSCs)are placed between the rotor and the grid. Nonlinear loads areconnected at PCC as shown in Fig. 1. The proposed AC-DC-AC works as an active filter in addition to the active power generationsimilar to normal AC-DC-AC. Harmonics generated by thenonlinear load connected at the PCC distort the PCC voltage.These nonlinear load harmonic currents are mitigated by GSCcontrol, so that the stator and grid currents are harmonic-free.RSC is controlled for achieving maximum power point tracking(MPPT) and also for making unity power factor at the statorside using voltage-oriented reference frame. Synchronous referenceframe (SRF) control method is used for extracting thefundamental component of load currents for the GSC control.

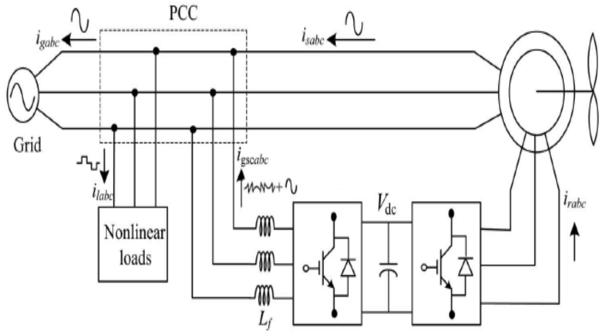

Figure11: Proposed system configuration

Control Technique of Converter

The main purpose of Rectifier is to extract maximum power with independent control of active and reactive powers. Here, the Rectifier is controlled in voltage-oriented reference frame. Therefore, the active and reactive powers are controlled by controlling direct and quadrature axis rotor currents (idr and iqr), respectively. Direct axis reference rotor current is selected such that maximum power is extracted for a particular wind speed. This can be achieved by running the AC-DC-AC at a rotor speed for a particular wind speed.

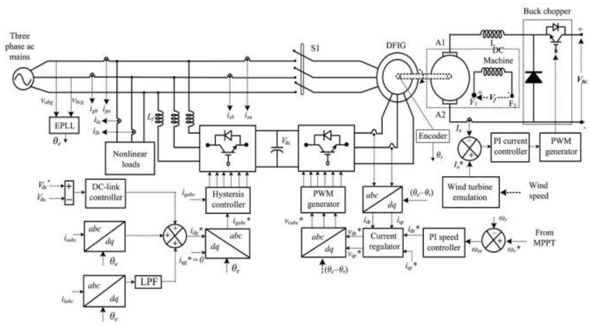

Figure12: Control algorithm of the proposed WECS.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

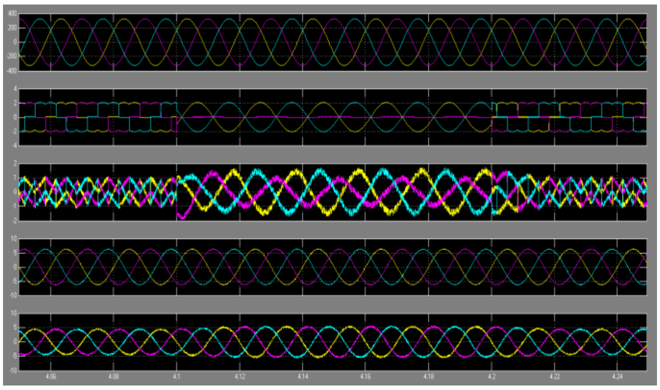

Figure13: Dynamic performance of DFIG-based WECS for the sudden removal and application of local loads

CONCLUSION

This paper proposes a novel three-phase AC/AC converter. The proposed converter consists of six power switches, three capacitors, three input inductors and three output inductors. By fixed capacitor ratio, the duty functions of converter and inverter are operated in optimum period for more stable control. Therefore, the converter has several advantages such as single stage control, input unity power factor, sinusoidal input/output current, adjustable output voltage and frequency, low costetc. Finally, some experimental results are presented to verify the feasibility of the proposed converter.

REFERENCES

[1] M. Heydari, A. Y. Varjani, and M. Mohamadian, "A novel variablespeedwind energy system using induction generator and six-switchAC/AC converter." in 3rd Power Electronics and Drive SystemsTechnology (PEDSTC), 2012, pp. 244-250.

[2] A. Bouscayrol, P. Delarue, and X. Guillaud, "Power strategies formaximum control structure of a wind energy conversion systemwith a synchronous machine," Renewable Energy, vol. 30, no. 15,pp. 2273-2288, Dec. 2005.

[3] S. M. Dehghan, M. Mohamadian, and A. Y. Vm:jani, "A NewVariable-Speed Wind Energy Conversion System Using PermanentMagnetSynchronous Generator and Z-Source Inverter," IEEETransactions on Energy Conversion, vol. 24, no. 3, pp. 714-724,Sep. 2009.

[4] I. A. Baroudi, V. Dinavahi, and A. M. Knight, "A review of powerconverter topologies for wind generators," in IEEE InternationalConference on Electric Machines and Drives, 2005, pp. 458-465.

[5] S. Morimoto, H. Kato, M. Sanada, and Y. Takeda, "OutputMaximization Control for Wind Generation System with InteriorPermanent Magnet Synchronous Generator," in Conference Recordof the IEEE Industry Applications Conference Forty-First lASAnnual Meeting, 2006, vol. I, no. C, pp. 503-510.

[6] W.-M. Lin and C.-M. Hong, "Intelligent approach to maximumpower point tracking control strategy for variable-speed windturbine generation system," Energy, vol. 35, no. 6, pp. 2440-2447, Jun. 2010

[7] M. Heydari, A. Yazdian, M. Mohamadian and H. Zahedi, "A NovelVariable-Speed Wind Energy System Using Permanent-MagnetSynchronous Generator and Nine-Switch AC/AC Converter" 1st Power Electronic & Drive System Technologies Conference(PEDSTC), 2010, pp.5 - 9.

[8] M. Heydari, A. Y. Varjani, and M. Mohamadian, "A Novel ThreePhaseto Three-Phase AC/AC Converter Using Six IGBTs," in 2nd International Conference on Electric Power and Energy ConversionSystems (EPECS), 2011, UAE, pp.I– 7.