A High Efficiency Wind Energy System

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Abstract—**In this paper a wind generator system that employs a Four phase Interleaved Bi-directional DC / DC Converter, a Selective Harmonic Elimination Sinusoidal Pulse Width Modulation (SHE SPWM) based Inverter and a Permanent Magnet Synchronous Generator (PMSG) is studied. The merits of using the topologies and PMSG are described. Finally, MATLAB based simulation results as well as practical results from a prototype are described**.

Index Terms—**Energy, Wind Turbine, Converter, PMSG, Synchronous Generator, SHE SPWM.**

I. Introduction

Due to rapid depletion of fossil fuels that have been the traditional energy source and vast amount of greenhouse gas emissions due to their use and the resultant global warming, emphasis is now being made to use alternative renewable energy sources like Photo Voltaic (PV) Arrays, Geothermal, Ocean Waves, Fuel Cells and Wind Energy. This paper discusses the use of wind energy for efficient electricity generation. From the last couple of years wind power has established its place in the power generation market and it is traded in a similar manner like any other product in the market. The use of wind power is also attractive considering additional benefits like impact on the environment however, issues like cost, efficiency, power quality and integration into the grid are very important to consider when new wind forms are planted. There are many aspects which have been taken up by different researcher for example induction motor dynamics using machine models of different orders, power quality impact for stall regulated fixed speed wind turbines and electrical characteristics of wind turbines are performed in these references respectively [1–5].

II. Components of Wind Energy System

The main component of the proposed wind energy system is depicted in figure 1 [6]. A step-up gear box and a suitable coupling connect the wind turbine to the PMSG. An induction generator with the advantages of robustness, low cost and maintenance-free operation could have been employed. However, it has the drawbacks of low power factor and needs an AC excitation source. The PMSG is chosen so as to eliminate the drawbacks of induction generator. Other merits / demerits of PMSG and its comparison with other types of generators are explained in [7, 8].

The output voltage as well as frequency of PMSG varies with wind velocity [9, 10]. Therefore, the varying PMSG output is rectified into uncontrolled DC using a diode bridge. The variable DC voltage output from the diode bridge is fed to the DC - DC Converter that regulates the voltage to a constant value. Finally, the constant DC is fed to the SHE SPWM based Inverter that generates the desired AC Voltage at the required frequency. The strategy employed for the DC - DC Converter is Four-phase Interleaved Bi-directional DC - DC Converter [11]. In renewable energy applications, a bidirectional DC-DC Converter is used to transfer renewable energy to energy storage (if employed) when the DC bus voltage is high, while delivering energy to the load when DC bus voltage is low. The non-isolated Converter employed basically combines a buck converter with a boost converter in a half bridge configuration. The main advantages of this bidirectional converter are zero-voltage soft switching for switching loss reduction, interleaving phase-leg currents for conduction loss reduction and coupled inductor for core loss reduction, resulting in ultrahigh efficiency. It is pertinent to note that in [8], the author is using the topology to step down from a high to a low voltage level (Buck mode). In the set up under discussion, the low and variable DC voltage of the diode rectifier is step up (Boost mode) to the required level by the Inverter.

Figure 2 depicts the circuit diagram of the converter used. The coupled inductors have been designed to pass 3.5 kW at 25 kHz, at an initial stage. Research is currently being conducted to design the converter for frequencies up to 500 kHz, thereby, achieving efficiency of up to 99%.

The Inverter (DC-AC Converter) employed is based on SHE SPWM [12]. The Inverter uses six IGBTS and micro-controller generated SHE SPWM sequences to generate the AC outputs. Gate Driver is required for isolation between the power semiconductor devices and digital logic of the PWM generator. Figure 3 depicts the block diagram of the Inverter. The reason for selecting SHE SPWM as compared to other PWM control strategies [13] is that for a given fundamental frequency of say 50 Hz (grid frequency), this strategy has lesser number of switching per cycle as compared to other schemes, resulting in low switching losses. Figure 4 shows the SHE SPWM pattern. Other advantages include elimination of lower order harmonics and possibility of filter less operation. By use of this strategy, efficiency greater than 90% has been achieved. Figure 5 shows the frequency spectrum for SHE SPWM and

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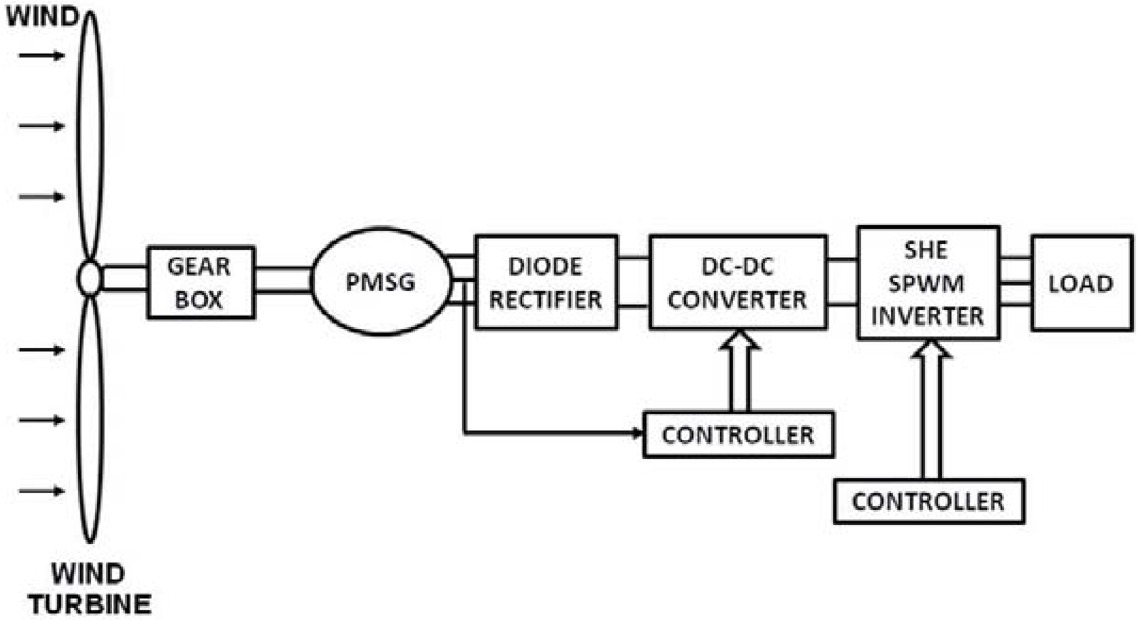

Fig. 1. Components of Wind Energy System

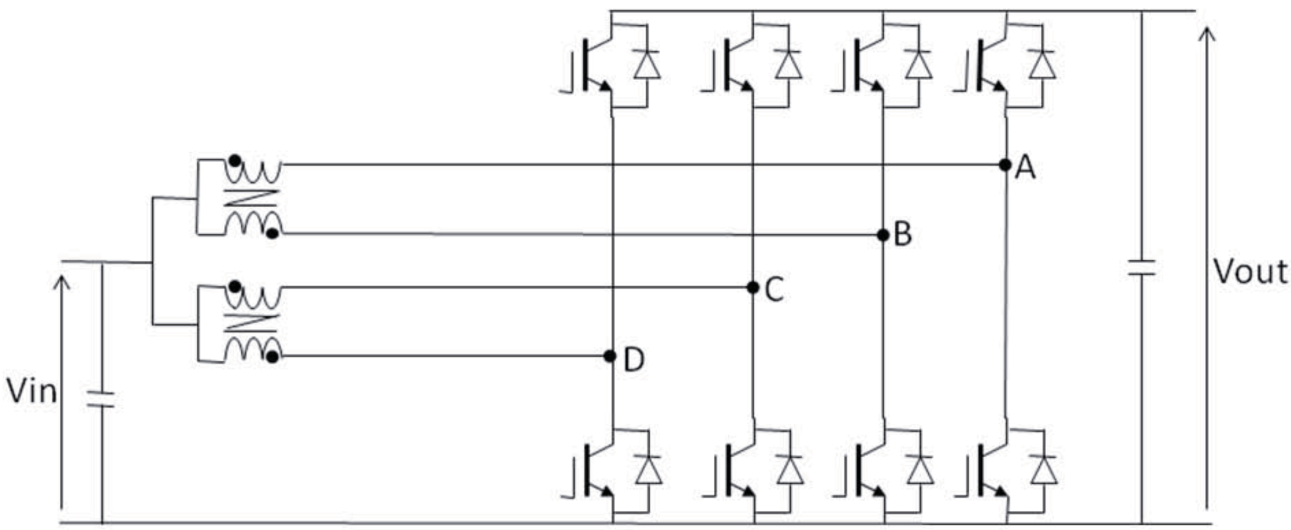

Fig. 2. Four Phase Interleaved Bi-Directional DC – DC Converter

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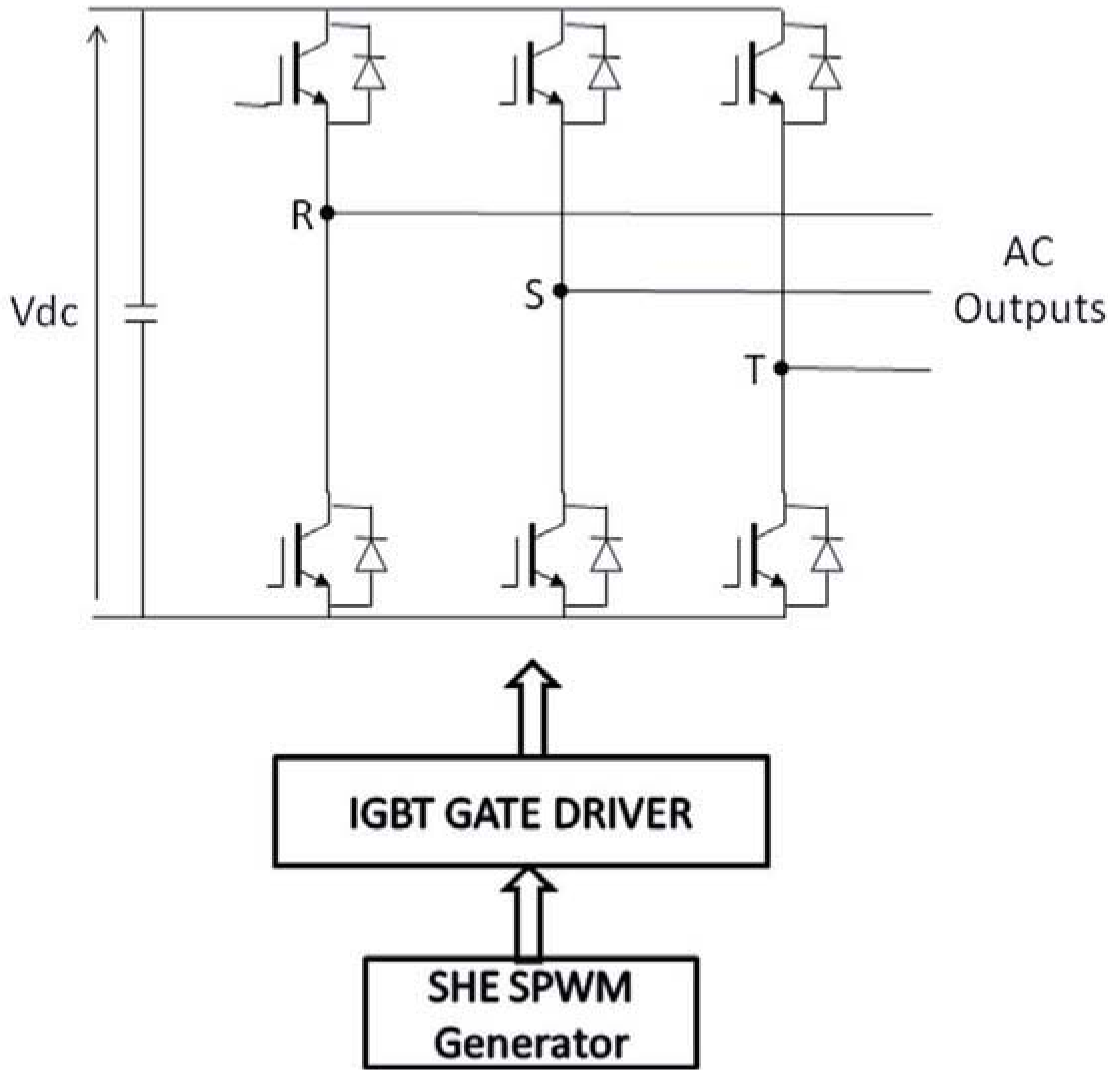

Fig. 3. Block Diagram of Inverter Stage

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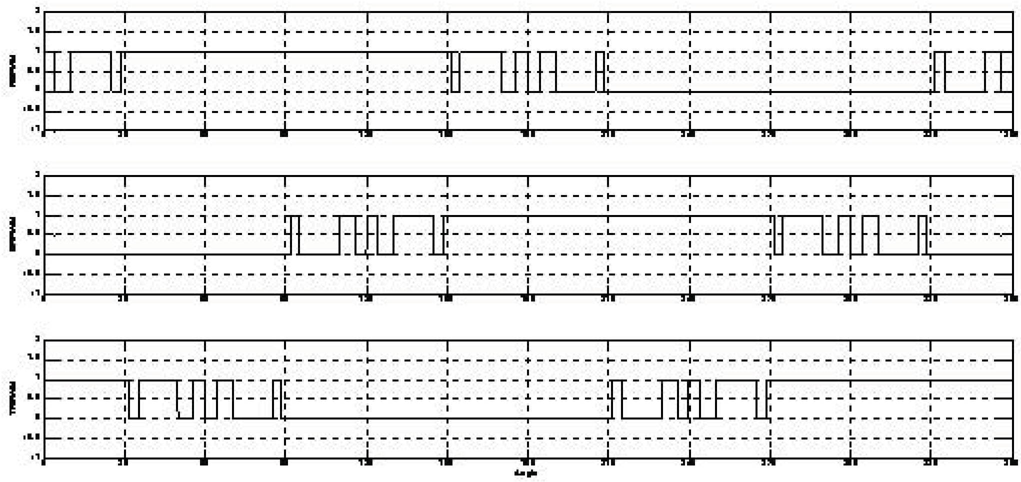

Fig. 4. Switching Pattern of SHE SPWM

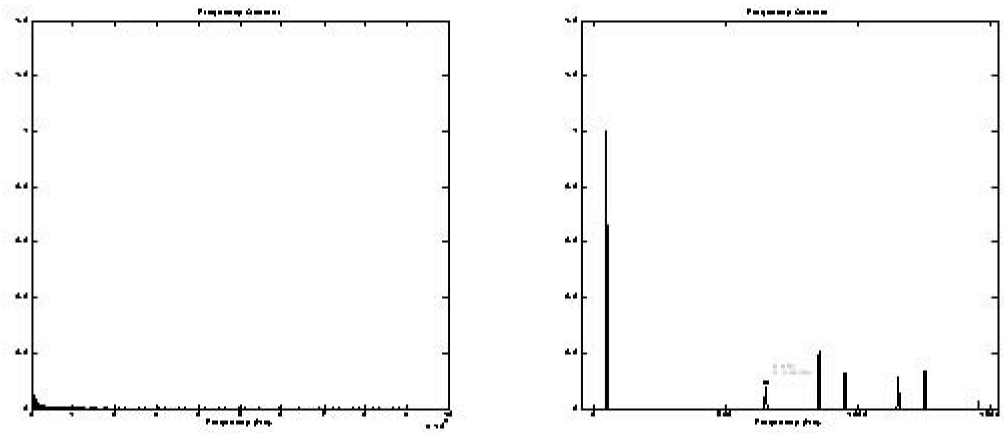

Fig. 5. Frequency Spectrum of SHE SPWM

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the spectrum have also been expanded to show elimination of the lower order harmonics. With fundamental of 50 Hz, the first harmonic that is visible is 650 Hz (13th).

III. Conclusion

We have demonstrated in this research that employing SHE SPWM is a better strategy compared with other similar techniques due to two significant benefits. Research results obtained demonstrates that by combining a PMSG wind turbine, four-phase interleaved bi-directional DC - DC converter and SHE SPWM based inverter, a high efficiency wind energy generation system can be realized. Due to the use of the bi-directional converter, inverter output will remain constant under varied wind velocity. The use of SHE SPWM results in almost free of harmonics distortion (figure 5), reduction in switching losses and output filtering requirement is minimized.

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