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Comparison of Boost and Interleaved Boost Converters for Wind Energy System

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Abstract—From the past literature survey, it is witnessed that there is remarkable growth in the Wind power capacity in the recent years. The advancement of converters used in wind power technologies led to maximum extraction of wind energy. In this paper, a comparison of Single Boost converter (SBC) with Interleaved Boost Converter (IBC) used in small-scale wind turbine systems. It utilizes the AC-DC-AC power converter to deliver high power from PMSG to Load. The Performance of Boost Converter System is compared with that of Interleaved Boost Converter System in terms of the ripple content and THD parameters. The design and Simulation results with three phase Resistive load and Permanent Magnet Synchronous Motor are studied using MATLAB/ Simulink.

Index Terms— Interleaved Boost converter, Wind Energy, Converters.

I. INTRODUCTION

The nuclear and fossil fuels have been consumed a lot so far and it has lead to world attention to switch from conventional energy sources to renewable energy technologies. In countries which are developed such as USA, European, countries, wind energy has been the fastest growing energy sector for the previous decade, thanks to its attractive package, its substantial presence of environmental supportive power policies. However, in case of developing countries that wind generation system and other renewable energies will play an important role to increase the quality of life of the people in the immediate future. People who live in countries like India, Bangladesh, Africa, live in very remote areas i.e. far from the main power utility grid. The incapability of the electrical utilities to meet their needs is taken as a serious concern right from small rural based schools and all other industries [1]. Internationally, research has become the central point of focus in the field of wind energy conversion systems (WECS). The improvement with the design of blades, and the material used forthe blade and the invention of advanced closed loop control system into the WECS is one of the major changes of technology that has transformed to decrease in costs of energyproduction, high efficiency and latest development of control strategies for WECS.

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At present, such challenge of closed loop control system shall be easily tackled due to the improvement of power semiconductors, cost reduction; development of AC drives control and microprocessors. In spite of huge initial investment, the development of electrical control system allows a very high flexibility and so more and more complex goals can be achieved easily in a variable speed control operation [4]-[7].With latest technological ,the traditional controllers for WECS shall be updated by more efficient control strategies such as fuzzy logic control, etc. Among them sliding mode(SM) control becomes as an excellent option to deal with speed operating WECS. This method of control has been popular by exhibiting very robust with respect to variations in system parameters as well as external disturbances.

By the above investigations which clearly reveals that the new control strategies for the both grid-connected and stand alone WECS is a very promising area of research to deal with plenty of challenging problems from the control design of power electronics to obtain a quality output.

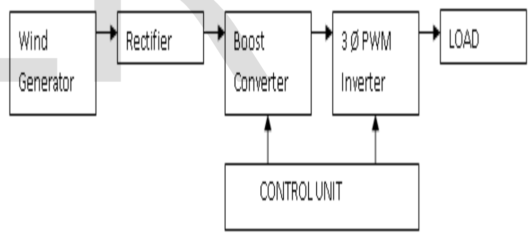

Figure.1.Wind Energy Conversion System.

II. BOOST CONVERTER

The schematic in Figure.2 shows traditional boost converter.

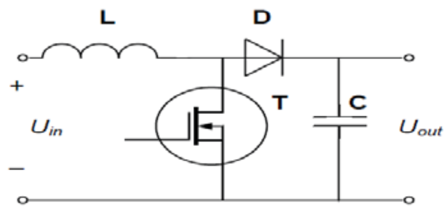

Figure.2. Structure of a Boost Converter.

The circuit is used when a higher output voltage than the input is required. When the MOSFET is ON Vx = Vin and OFF state the inductor current flows through giving Vx = Vo. The

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discontinuous conduction mode (DCM) is usually exists when the inductor current is huge enough and contains ripple in a converter which works with light load. Since it is usually happens in wind energy conversion system, converters operate with their loads on and off, DCM is the most appropriate method used.

III. SIMULATION RESULTS

Wind Generation system is simulated using the elements of Simulink and the results are presented. The circuit diagram of AC-AC Converter employing Boost converter is shown in Figure. 3a.It consists of three phase diode bridge rectifier. Each diode consists of RC snubber circuit in parallel to the diode body of 500 Ω resistances and 250e-9 μF. the output of the diode bridge rectifier is fed into the boost converter .The duty cycle (δ) controls the output of the boost converter and outputs the voltage to the three phase PWM inverter. The inverter consists of six MOSFETS. Each MOSFET with switching frequency of 3.33 msec converts variable DC Voltage into desired three phases AC Voltage. The Three Phase Inverter feeds a Balanced Resistive Load of 500 Ω per phase.

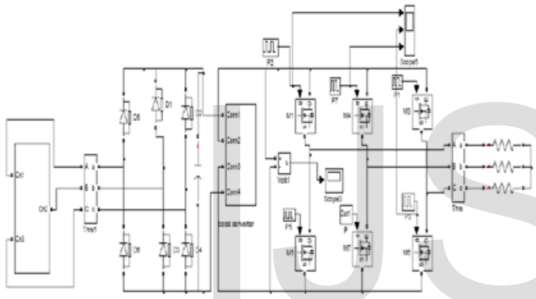

Figure. 3a. Circuit Diagram of Boost Converter

Using three phase VI measurement, the output voltage of wind generator per phase is shown in Figure.3b.

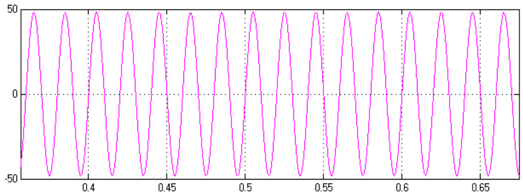

Figure. 3b. Output Voltage of Wind Generator

The Boost converter circuit alone is shown in Figure. 3c. The boost converter consists of MOSFET and series inductance of 10e-3 H and a diode of 0.8 forward voltage and output capacitance of 5000μF.When gate signal of 1 amplitude of 1msec time period with no delay in phase angle is applied, the MOSFET in the boost converter conducts and outputs the voltage to the three phase inverter.

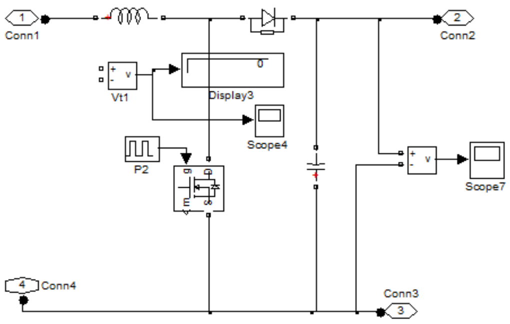

Figure. 3c. Boost Converter

The output voltage of Boost converter per phase is shown in Figure. 3d.The output voltage settles at 300 volts within 3ms time period.

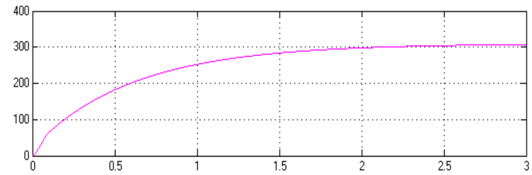

Figure. 3d. Boost Converter Output Voltage

The ripple content in the output voltage of Boost Converter is shown in Figure. 3e. The Peak-Peak ripple is 0.8 volts.

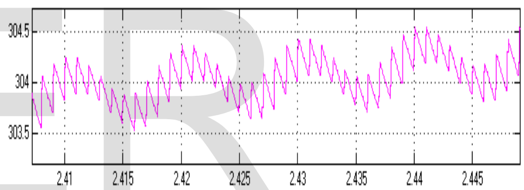

Figure. 3e. Ripple Voltage

FFT Analysis is done for the output voltage of the Boost Converter and their spectrum is shown in Figure.3f. The Total Harmonic Distortion (THD) is 69.9%.

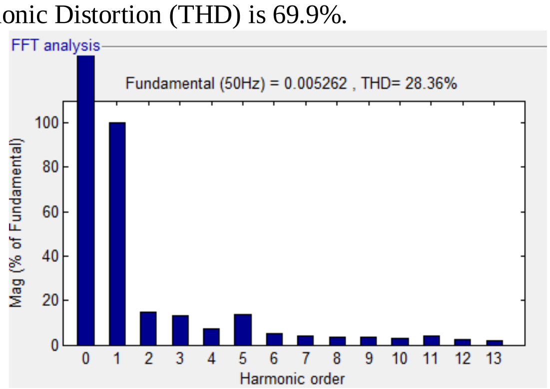

Figure. 3f. Total Harmonic Distortion

The output voltage of each phase waveform of the three phase inverter is shown in Figure.3g. Each phase voltages are displaced with each other by 120º. The output voltage is not sinusoidal.

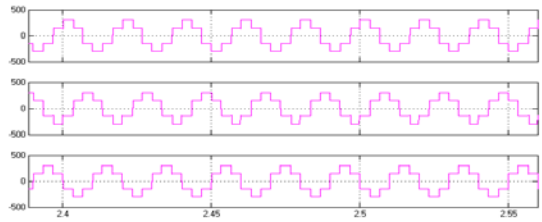

Figure. 3g. Inverter Phase Output Voltage

The output current of each phase waveform of the three phase inverter is shown in Figure.3h. Each phase currents are displaced with each other by 120º. The currents are balanced.

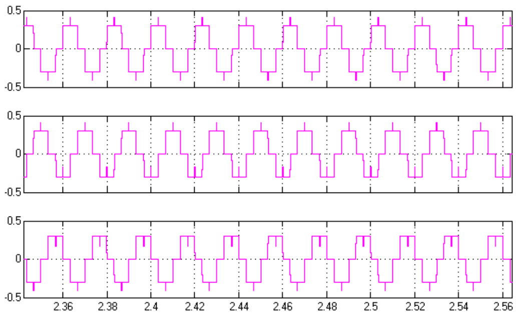

Figure. 3h. Inverter Phase Output Current

AC-AC Converter system with interleaved Boost converter (IBC) is shown in Figure. 4a.

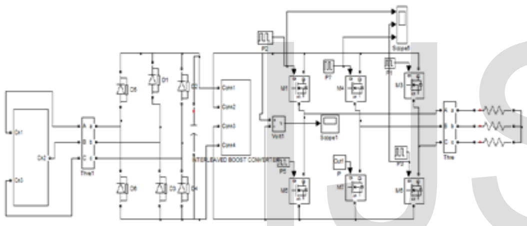

Figure. 4a Circuit Diagram With Interleaved Boost Converter

The single boost converter (SBC) in the Figure..3a is now replaced by inter-leaved boost converter (IBC) in order to reduce the ripple content in the output voltage.

Using three phase VI measurement, the output voltage of wind generator is shown in Figure. 4b.

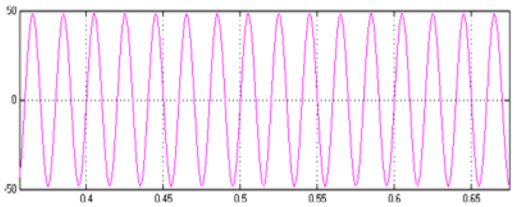

Figure. 4b. Output Voltage of Wind Generator

The circuit of inter-leaved boost converter is shown in Figure.4c. It consists of three phase bridge rectifier, two normal boost converters but interleaved by 180 º phase angle difference with each other, two inductors of 20e-3 H and two diodes of 0.8 forward voltages each and output capacitance of 1200μF.

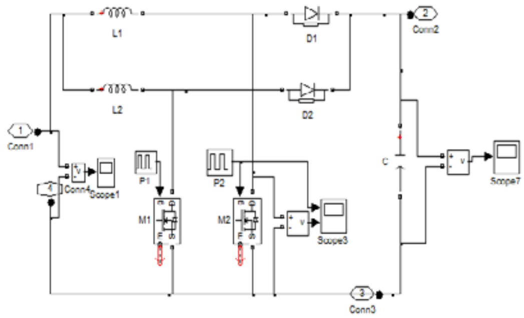

Figure. 4c. Interleaved Boost Converter

The PWM pulses given to the switch in M2 are displaced by 180º with respect to M1. The output voltage of IBC is shown in Figure. 4d.

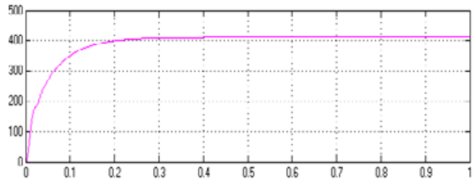

Figure. 4d. Interleaved Boost Converter Output Voltage

The ripple voltage in the output is shown in Figure. 4e.The DC Output voltage is around 400 volts.

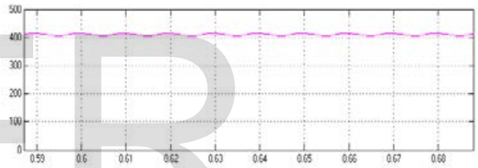

Figure. 4e. Ripple Voltage

FFT Analysis is done for the output voltage of IBC and the spectrum is obtained as shown in Figure. 4f. The Total Harmonic Distortion (THD) is 8.5%.

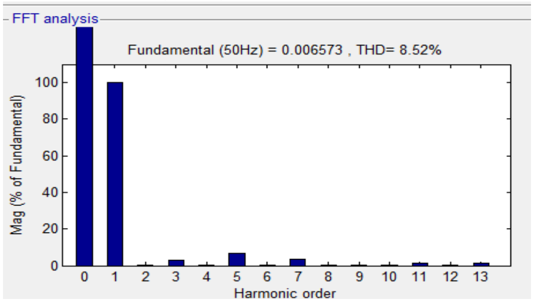

Figure. 4f. Total Harmonic Distortion

The PWM pulses given to switches M1, M3 and M5 are shown in Figure. 4g.

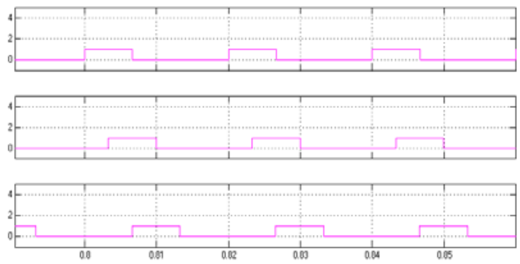

Figure. 4g. Switch Pulse for Inverter (M1, M3, M5)

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The output voltage of each phase waveform of the three phase inverter is shown in Figure.4h.

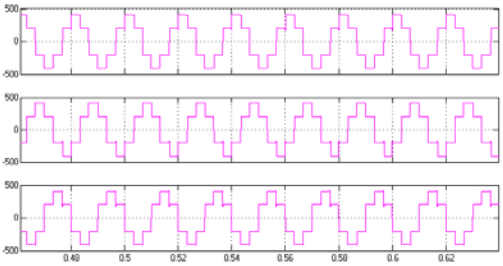

Figure. 4h. Output Voltage

The output current of each phase waveform of the three phase inverter is shown in Figure.4i.

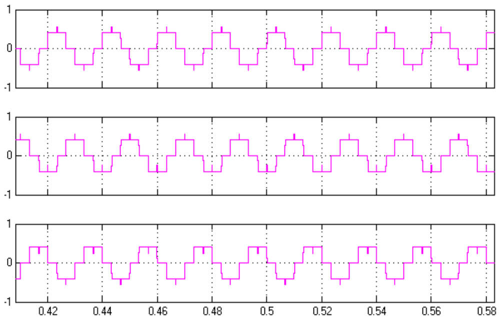

Figure. 4i. Output Current

AC-AC Converter with Synchronous Motor (SM) is shown in Figure. 5a.It consists of interleaved boost converter, a three phase inverter and Synchronous Motor as a Load.

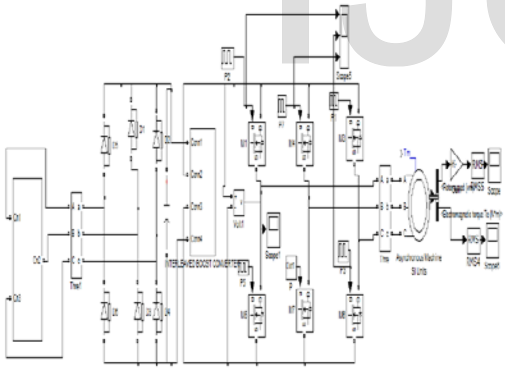

Figure. 5a. Circuit Diagram With Synchronous Motor Load

Using three phase VI measurement, the output voltage of wind generator is shown in Figure.5b.

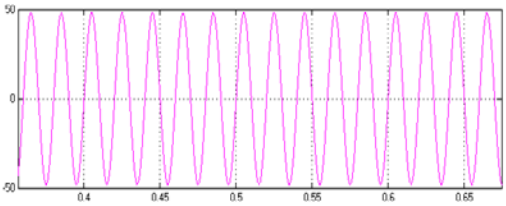

Figure. 5b. Wind Output Voltage

The output voltage of inter-leaved boost converter per phase is shown in Figure. 5c.

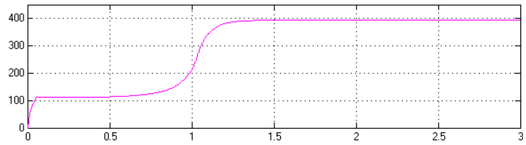

Figure. 5c. Interleaved Boost Output Voltage

The speed response curve of Permanent Magnet Synchronous Motor (PMSM) is shown in Figure.5d. The speed settles at 1500 RPM with in 1msec.

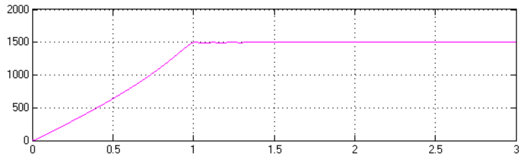

Figure. 5d. Motor Speed

The torque response curve is shown in Figure. 5e. The torque settles at 2.5N-m within 1msec.

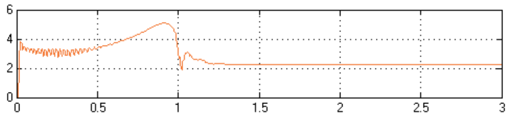

Figure. 5e. Motor Torque

IV.CONCLUSION

AC-AC Converters employing SBC & IBC for Wind Energy System are successfully modeled & simulated using the blocks of Simulink. The simulation results of the above mentioned systems are compared. It is observed that IBC system produces higher output voltage with reduced ripple. Wind generated based AC-AC Converter fed PMSM Drive system is also modeled and simulated. The main advantage of the system is reduced ripple and Total Harmonic Distortion (THD).

The scope of this paper is the modeling and simulation of wind based AC–AC Converter system. The hardware will be implemented in future.

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