RESEARCH ARTICLE OPEN ACCESS

MODELING AND SIMULATON OF THREE STAGE INTERLEAVED BOOST CONVERTER BASED WIND ENERGY CONVERSION SYSTEM

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Abstract:

This paper deals with modeling and simulation of three stage interleaved boost converter (ILBC) based induction motor drive fed from wind generator. The output of wind generator is converted into DC using a three phase uncontrolled rectifier. This voltage is boosted by using ILBC with reduced current ripple with three stages ILBC is proposed for this purpose. The output of the ILBC is converted into three phase balanced ac using a three phase inverter, which feeds a three phase induction motor. The simulation results for single pulse width modulation (PWM), sine PWM and space vector modulation (SVM) are presented.

Keywords— **wind energy conversion system, interleaved boost converter, induction motor load.**

I. INTRODUCTION

In recent days, because of energy shortage and environmental contamination, the renewable energy is increasingly valued and it has been employed worldwide. A typical renewable energy system has renewable energy sources, such as wind power generation, fuel cells, and solar systems, convert sources energy into electrical energy, which generate low output voltage. Because of low output voltage, this system required high DC/DC convertor which convert low voltage into high voltage, that commonly used in many renewable energy system. Thus high step up conversion is most important in renewable energy sources system because of its high efficiency with sufficiently high step up conversion.

In all over the world, wind energy becomes a research focus and it has more priority among various types of renewable energy. Wind energy is one of the fastest growing energy because of free availability, friendly environment and the development of turbine techniques, is becoming the key part among the serious energy sources [1], [2]. In wind energy conversion system (WECS), the doubly fed induction generator (DFIG) – based WECS and the direct drive permanent magnet synchronous generator (PMSG) – based WECS are regularly used turbine structure for variable speed wind turbine.

This block diagram shown in Fig 1.1 represents the proposed method of ILBC. The three phase input voltage which is produces by wind generator is fed to three phase diode rectifier and in turn it converts into a dc source.

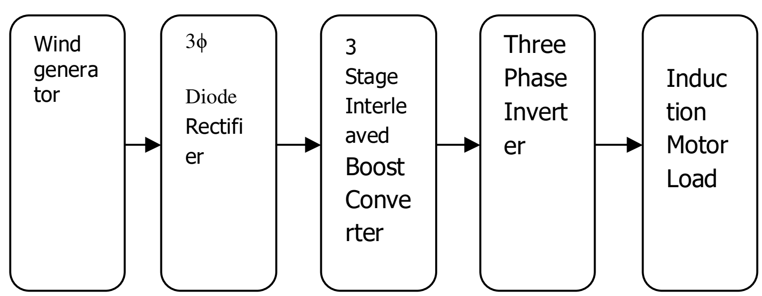

Fig 1.1

The interleaved DC – DC converter will have three stage interleave boost converter, which will regulate the noisy, less ripple, improve efficiency and decrease the total harmonic distortion for the system. A three phase inverter takes the constant output voltage from three stage ILBC and it connected to the induction motor load.

II. PROPOSED POWECONVERTERS.

In wind energy conversion system, the power converters are widely used for fixed speed WECS, in which converter reduce the inrush current and during system start up, it reduce the torque oscillations. In variable speed WECS, the converter control the active/reactive power to the grid and also control the speed/torque of the generator. For optimal control of wind energy system, a variety of power converter configurations are available according to the system power ratings.

In proposed wind energy conversion system, the interleaved boost converter is used. One of the converter topologies often used in WECS is DC – DC boost converters. In power conversion system, in between the diode rectifier and the inverter, the converter is placed. The current and voltage rating of one switching device may easily go beyond the range, in high power megawatt wind energy system. Parallel and series connection of multiple switching devices can be a solution. Anyhow additional measures should be taken among the parallel (or) series connection of devices, in order to provide the equal sharing of the current and voltage. Cascading power converter (or) paralleling is another valid solution, instead of parallel (or) series connection of switching devices. To handle high currents in the low voltage megawatt wind energy system, the multichannel interleaved boost converter are often used. An interleaved boost converter can be performed by interleaving (phase shifting) the gating signals for each of the parallel converters. The main advantage of interleaved converter is, equivalent switching frequency of converter is increased over the single converter. When compare to a two channel converter, the equivalent switching frequency of the converter can twice of the device switching frequency. The main benefits of interleaved converter increase in the equivalent switching frequency over the single channel converter and also it offers a number of advantage such as input current ripple and output voltage ripple, faster dynamic response and better power handling capability.

III. INTERLEAVED BOOST CONVERTER

Commonly used switching devices in interleaved boost converter in the WECS are IGBT and MOSFET. IGBT operates at low switching frequencies of a few hundred hertz to a few kilohertz and to reduce the switching losses. MOSFET often act at much higher switching frequencies.

A. *Single Channel Boost Converter:*

Among the power converter, boost converters have output dc voltage greater than its input dc voltage and it shown in Fig1.2. It consists of switch S_1, a dc inductor L_1, a diode D_1 and a filter capacitor. Diode D_1 is reverse biased, when switch S_1 is turned ON and the output is withdrawn from input. The inductor L_1 gets energy from the input supply. Diode D_1 is forward biased, when the switch is turned OFF and the load draws energy from the inductor L_1 through the diode. At this time, the converter makes the output voltage V_0 higher than its input voltage V_i by having the sum of the input voltage V_i and the inductor voltage $V_{L1.}$ Operation of the converter can be divided into two operating modes depending on the continuity of the DC inductor current i_{L1}: Continuous Current Mode (CCM) and Discontinuous Current Mode (DCM). The inductor current i_{L1} never fall to zero when converter operates in CCM. In steady – state operation, the integral of the inductor V_{L1} over time period T_S must be zero. The average voltage across the inductor L_1 over T_S is zero.

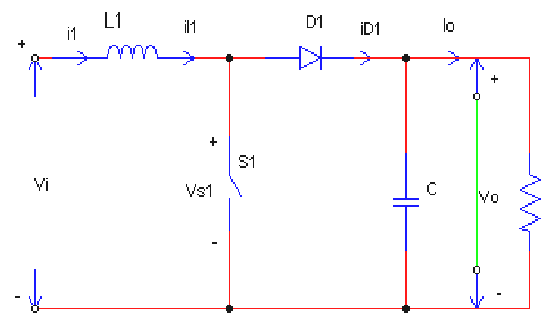

Fig 1.1 SINGLE CHANNEL BOOST CONVERTER

$$V_i t_{on} = (V_0 - V_i) t_{off} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

From which

$$\frac{V_0}{V_i} = \frac{1}{1-D} \; for \; 0 < D < 1 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where converter duty cycle is D and defined by $= \frac{t_{on}}{T_s}$; T_S is the switching period and the switch s, turn on and turn off times are defined by t_{on} and t_{off} respectively. The mention above equation indicates that input voltage of the converter always lower than the output converter voltage. The converter input current I_i and output converter current I_0 can be related by

$$V_i I_i = V_0 I_0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (3)$$

From which

$$\frac{I_0}{I_i} = 1 - D \; for \; 0 \le D \le 1 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

B. ***Two Channel Interleaved Boost Converter***

Two channel converter topology is shown Fig 1.3. In this circuit, there are two channel parallel converters. In two converter channel, they connected in parallel but operate in an interleaved mode. While design the ILBC the gating signals V_{g1} and V_{g2} for S_1 and S_2 are identical but displaced by$\frac{360°}{N} = 180°$, where N is the number of parallel converter channel. The operation and waveforms of this individual must be same as single channel converter but, the total input current i_1 is the addition of two inductor current i_{L1} and i_{L2}.

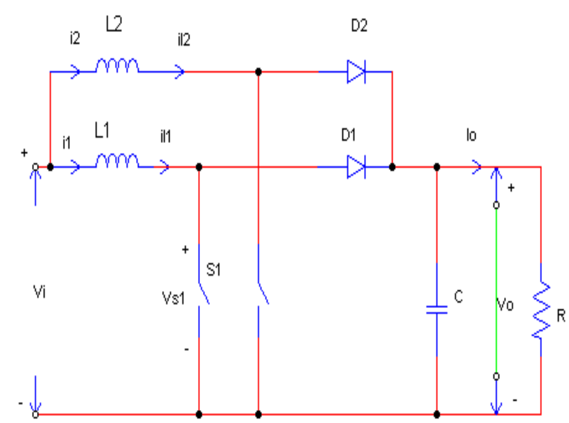

Fig 1.3 Two Channel Interleaved Boost Converter

C. ***Three Channel Interleaved Boost Converters***.

Three channel converter topology is shown Fig 1.4 Three channel boost converter topology can be interleaved by$\frac{360°}{N} = 120°$. It is composed of three parallel converters and operating in the interleaving manner. The input current converter frequency i_i is three times of the individual converters and inductance of the each channel converter is $L = L_1 = L_2 = L_3$

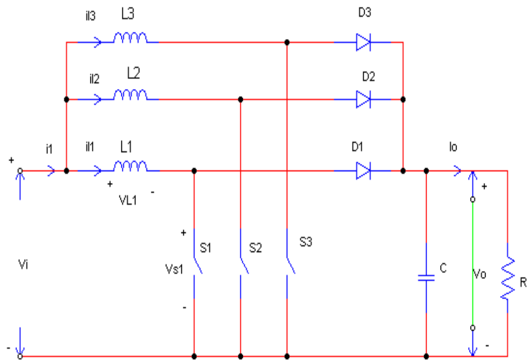

Fig 1.4 Three Channel Interleaved Boost Converter

The main charactertics of the input current i_i

1) Due to interleaved technique, the peak to peak input current ripple ΔI_i is smaller than individual channel.
2) The equivalent switching frequency of ILBC is twice times of the each channel.

SIMULATION RESULTS

The simulink diagram of single PWM based AC – AC converter fed induction motor system is shown in Fig 2.1. Output voltage of wind generator is shown in Fig 2.2. The output voltage of boost converter is shown in Fig 2.3 and its value is 395 volts. The speed increases and settles at 1400 rpm as shown in Fig 2.4. The torque response is shown in Fig 2.5. The torque settles at 2NM. The inverter is controlled by using single PWM method.

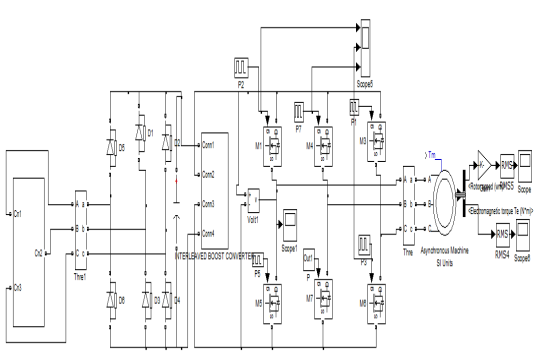

Fig 2.1 Circuit Diagram For Single PWM Pulses With Motor Load

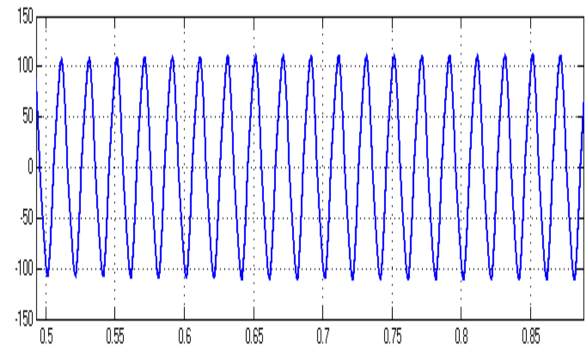

Fig 2.2 Wind Output Voltage

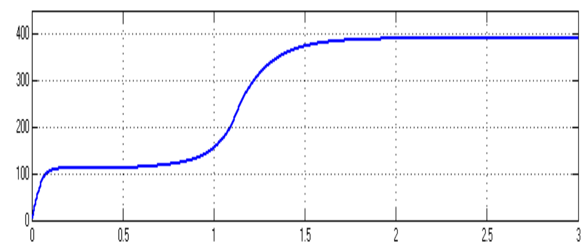

Fig 2.3 Interleaved Boost Output Voltage

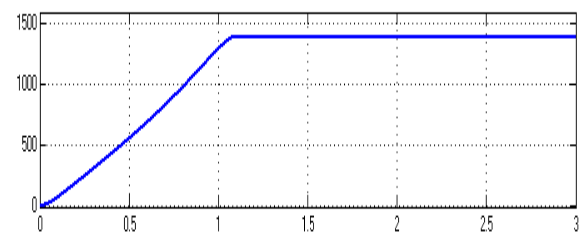

Fig 2.4 Motor Speed

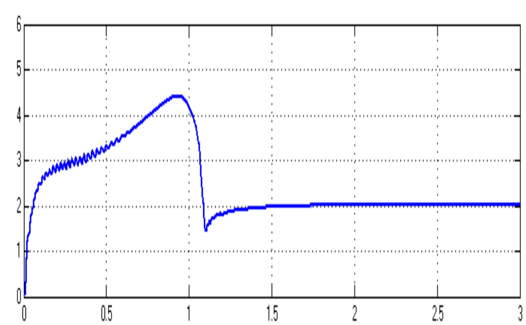

Fig 2.5 Torque

AC – AC converter fed induction motor with sine PWM is shown in Fig 3.1. The inverter is controlled using sine PWM pulse. The output of the ILBC is shown in Fig 3.2 and its value is 400V. The three phase voltage applied to the induction motor is shown in Fig 3.3 and they are displaced by 120˚. The speed and torque curves are shown in Fig 3.4 and Fig 3.5 respectively. The torque settles at 2.5NM.

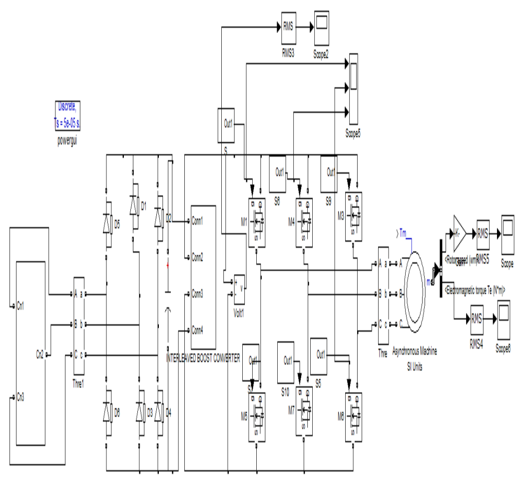

Fig 3.1 Circuit diagram for Sine PWM pulses with motor load

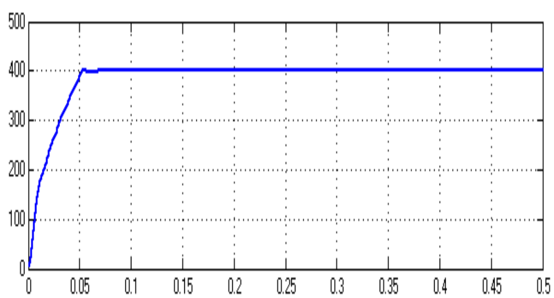

Fig 3.2 Interleaved boost output voltage

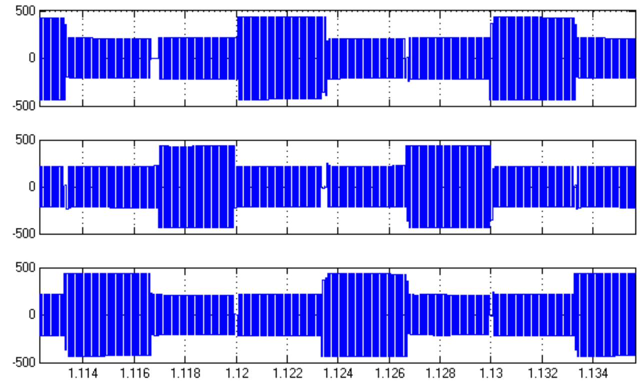

Fig 3.3 Output voltage

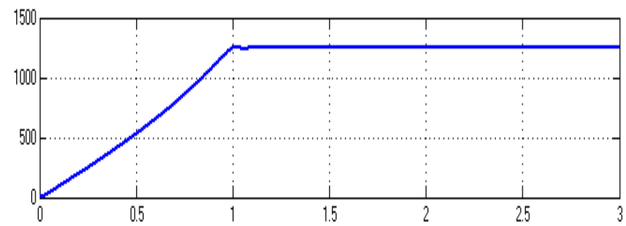

Fig 3.4 Motor speed

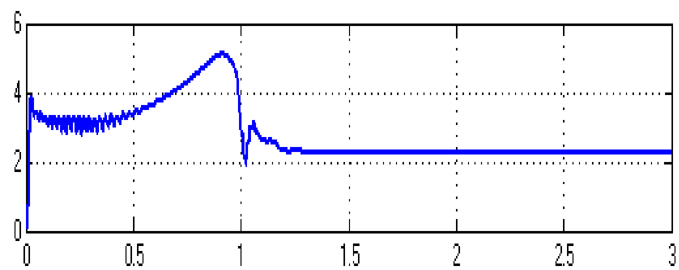

Fig 3.5 Torque

AC – AC converter with SVM control is shown in Fig 4.1. The pulses are generated by comparing trapezoidal voltage with triangular voltage. The output voltage of the boost converter are shown in Fig 4.2 respectively. The three phase output voltage are shown in Fig 4.3. The speed increases and settles at 1490 rpm in shown in 4.4. The torque response is shown in Fig 4.5. The torque settles at 3.8NM and THD in Fig 4.6. Summary of THD, speed and output voltage of ILBC are given in table1.

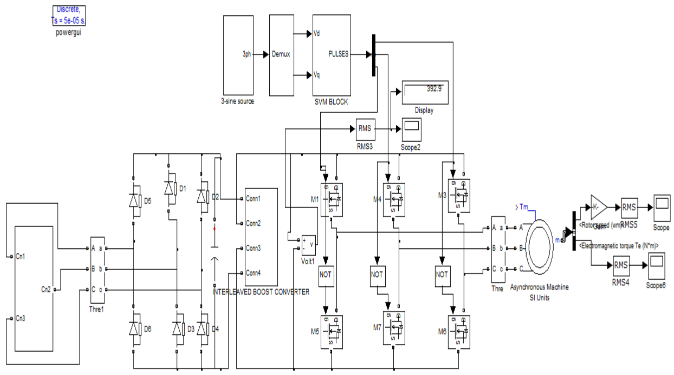

Fig 4.1 Circuit diagram for SVM PWM pulses with motor load

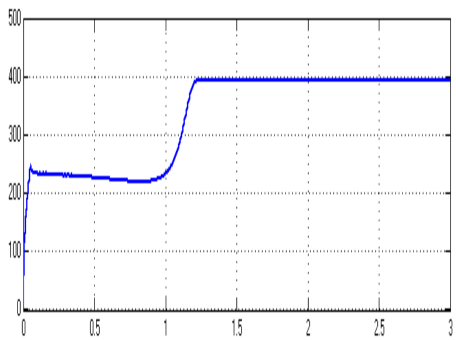

Fig 4.2 Interleaved boost output voltage

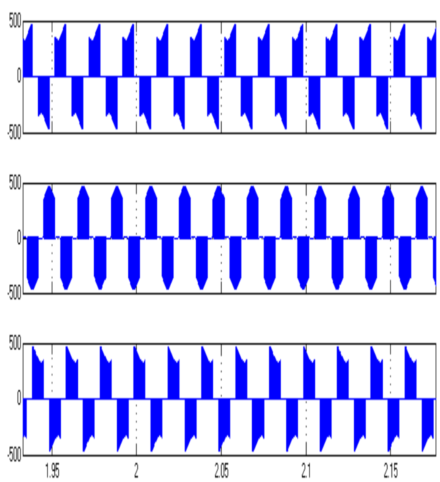

Fig 4.3 Output voltage

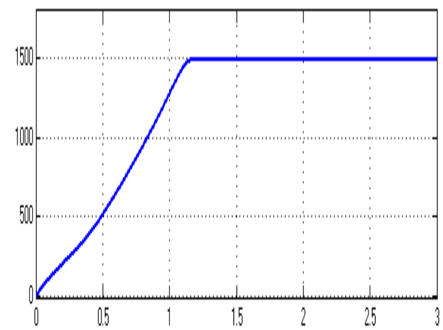

Fig 4.4 Motor speed

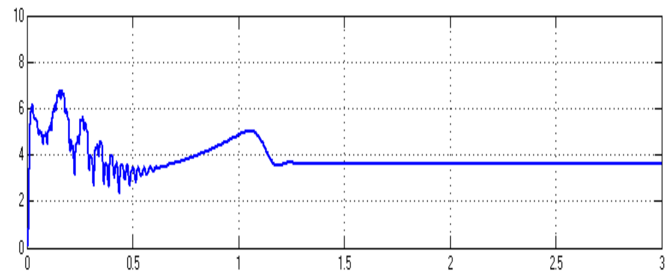

Fig 4.5 Torque

PULSES	THD	SPEED (RPM)	ILBC VOLTAGE (V)	TORQUE (NM)
Single pulse	8.43 %	1421	398	2
PWM pulse	7.0%	1434	405	2.2
SVM pulse	6.67 %	1447	438	3.5

Table 1

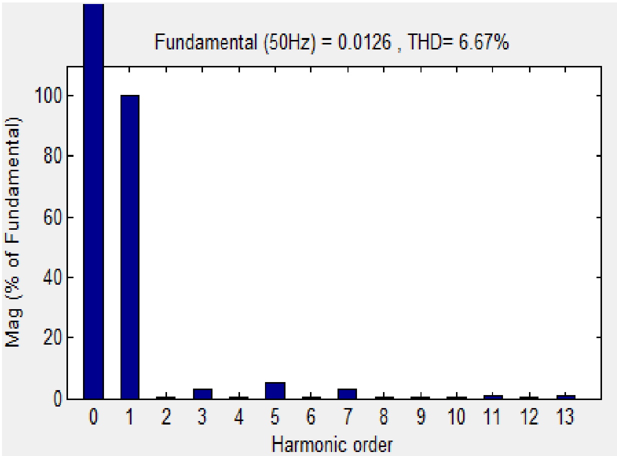

Fig 4.6 THD

CONCLUSION:

Wind generation based AC – AC conversion system is successfully designed , modelled and simulated using blocks of simulink. The results of the proposed system are demonstrated with single PWM,Sine PWM and SVM methods. The results indicated that SVM based system produces higher torque and lower THD than other systems. The advantages of the proposed system are reduced THD, reduced current ripple and improved efficiency. The disadvantage of three phase ILBC is that it requires three switches and three inductors.The scope of the present work is the simulation of AC – AC converter system for wind generation. The hardware will be implemented in future.

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