Design of Agricultural based water pumping drive system using Bridgeless Buck-Boost converter

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Abstract – *This paper proposes novel agricultural based water pumping drive system encompassed with a Bridgeless buck-boost converter and a Three level neutral clamped inverter employing Total Harmonic injected Pulse width modulation technique. The proposed topology permits to reduce the no of switching components in addition to the rectifier switch currents, the harmonic distortion at the input converter side when compared to the conventional topologies. With the reduced number of switches it is shown that the complexity and the switching losses reduces so that it can be easily incorporated in agricultural water pumping applications. The model is developed and designed using Matlab/Simulink and the results are validated.*

***Key Words*: Bridgeless Buck-boost converter, Total harmonic injection pulse width modulation, three level neutral point clamped inverter, Water pumping drive system, Harmonics.**

1. INTRODUCTION

Power electronic converters have received an augmented interest for major industrial applications. Any electronic converters needs a power supply for its operations. Although single phase supply are easily available but to run heavy loads three phase supply is more preferable because power is limited in single phase supply and it does not efficiently gives a good starting torque[1]. So there is a requirement of single phase to three phase conversion.

Three phase gives rigidity to distribute the load in a set up on three phases. If one of the phases fail due to fault at the distribution point, there are other two phases that keeps running. This prevents a condition of complete black out hence decreasing collapse of electrical equipment.

Earlier for conversion, ac supply was rectified by using diode bridged rectifier and the output obtained was pulsating dc[4]. The pulsating dc was then fed to a boost converter converting the output from variable dc to fixed dc. The designed circuit was provided with inverter configuration which helped in converting variable dc to ac. This multi stage conversion process is reduced to two stage conversion process by using bridgeless configuration. Bridgeless alignment condenses the complication of multi stage conversion process. The reduction of conversion process reduces harmonics and makes it a cost effective method and increases customers' satisfaction level. In order to reduce harmonics and to get ripple free output we preferred third harmonics injection pulse width modulation technique [2,3].

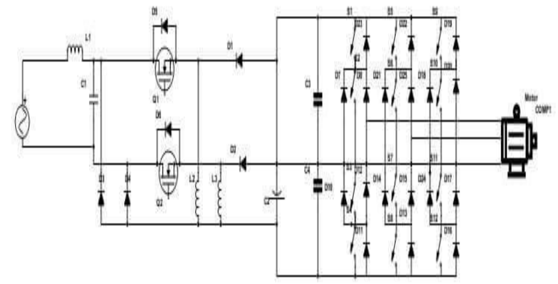

Figure 1 Equialent model of considered system

2. DESIGN OF BBC

Bridgeless buck boost converter is a converter which unlike conventional bridged converter uses less number of semiconductor devices which makes it highly cost efficient and reliable to use[5,6]. The design of bridgeless buck boost converter is given below in figure 2. When a 230v single phase ac supply is fed to a buck boost converter, the supply voltage gets continuously boosted up by the supply current and discharge of inductor charges the capacitor simultaneously. The boosted voltage reach up to 440V variable dc. Here diodes are used which works as fly back or freewheel[7,8,9].

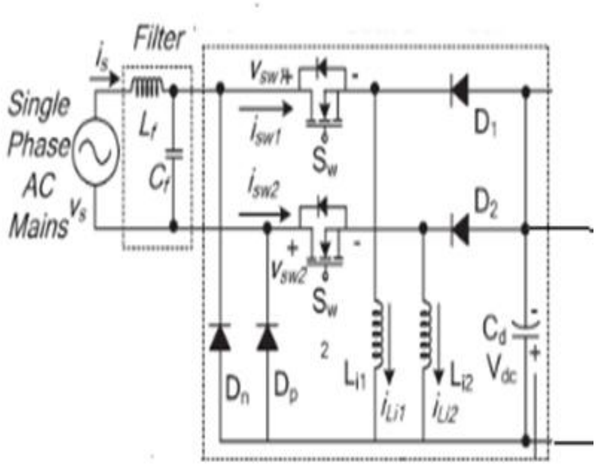

Figure 2 : Bridgeless Buck-Boost connverter

The anticipated configuration of the Bridgeless buck–boost converter takes the smallest number of components and minimum number of conduction devices during each half cycle of supply voltage.

2.1 MODES OF OPERATION OF BRIDGELESS BUCK BOOST CONVERTER

Three modes of operation during the complete switching cycle has been discussed for the positive half cycle of supply voltage as shown here in fig 3.

Mode I: In this mode, switch S_{w1} is in conduction towards the charging of inductor L_{i1}; henceforth, the inductor current i_{Li1} growths in this mode. Diode D_p finishes the input side circuitry, while the dc link capacitor C_d is discharged by the 3-level VSI-fed Induction motor.

Mode II: In this mode of set-up, switch considered S_{w1} is crooked off, so the stored charge in inductor L_{i1} is transported to dc link capacitor C_d till the inductor is fully discharged. The current in inductor considered L_{i1} decreases and scopes zero.

Mode III: In this type, inductor L_{i1} arrives discontinuous conduction which capitals no energy is leftward in the inductor; henceforth, current i_{Li1} turn out to be zero for the respite of the switching period. Not any of the switch or diode will be accompanying in this kind and dc link capacitor C_d foods this energy to the load; henceforth, voltage V_{dc} across dc link capacitor C_d starts declining. The process is repeated once switch labelled S_{w1} is turned on another time after one complete switching cycle.

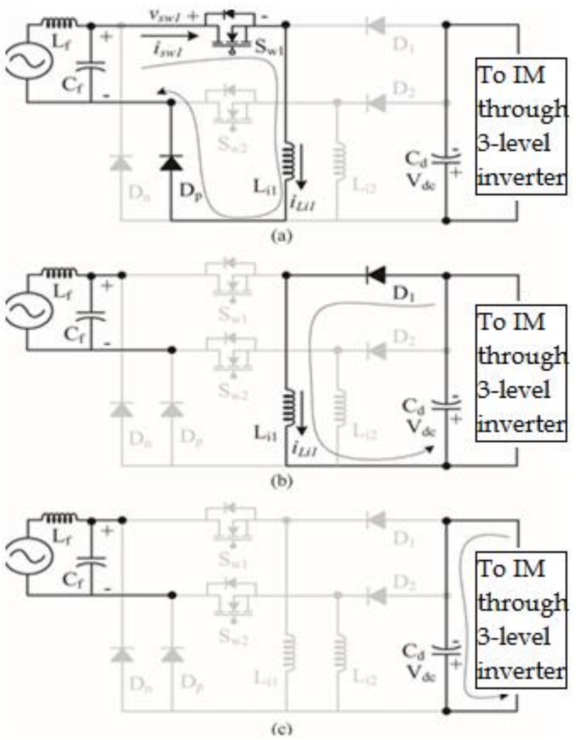

Fig -3: Operation of the planned converter in various modes (a)–(c) for a positive half cycle of supply voltage

3. WHY THREE LEVEL INVERTER

The three level inverter proposals numerous advantages over the more shared two level inverter. As likened to two level inverters, three level inverters consume reduced output voltage steps that lessen motor issues owing to extended power cables amongst the inverter and the motor[8]. These subjects include surge voltages and rate of voltage rise next to the motor terminals and motor shaft bearing currents. In totaling, the cleaner yield waveform delivers an effective switching frequency double that of the real switching frequency[9]. Utmost often the NPC inverter is cast-off for greater voltage ratings as the IGBTs are only exposed to half of the bus voltage, lower voltage IGBT modules can be used. Nonetheless the only difficulty of NPC is the mechanism for constancy of the DC-Link capacitor's voltage are limited.Inorder to overawed this restraint a THIPWM is used which will be discussed after[10].

Figure (4) shows the circuit formation of the NPC inverter and its particular switching modes. Every leg has four IGBTs associated in series. The serviceable voltage on the IGBT is half of the predictable two level inverter. The bus voltage is riven in dual by the connection of equivalent series capacitors. Each leg is accomplished by the addition of two clamp diodes.

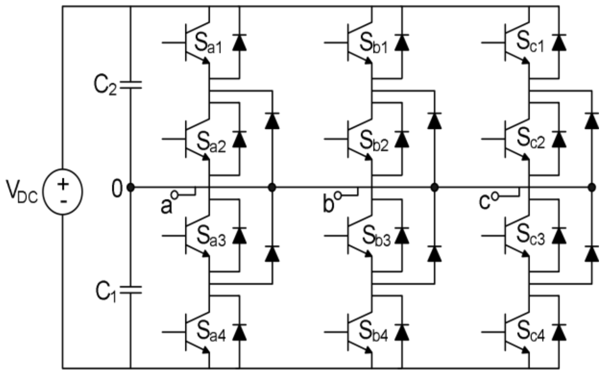

Figure 4 Three Level NPC

S_1	S_2	S_3	S_4	V_{ph}
ON	ON	OFF	OFF	$V_{DC}/2$
OFF	ON	ON	OFF	0
OFF	OFF	ON	ON	$-V_{DC}/2$

Table-1: switching modes

4. DC-LINK CAPACITORS VOLTAGE BALANCING

In many documents diverse approaches for DC link capacitor voltages harmonizing were elucidated. Countless of them have drawbacks such as need of additional sensor or more switching frequency. And the tranquil modulation method sinusoidal PWM itself is consuming a difficulty for a complete submission in as long as the essential DC bus supply voltage[11]. Since this issue, the third-harmonic injection pulse-width modulation (THIPWM) technique was employed to advance the inverter concert. This technique contains the third harmonic voltage in the DC-link to harvest a current to the line currents and benefits in providing the identical voltage among the capacitors with lesser harmonics[12]. The operation of choosing the reference wave is explained below in figure(4) and the simulation circuit is also shown in figure (5).

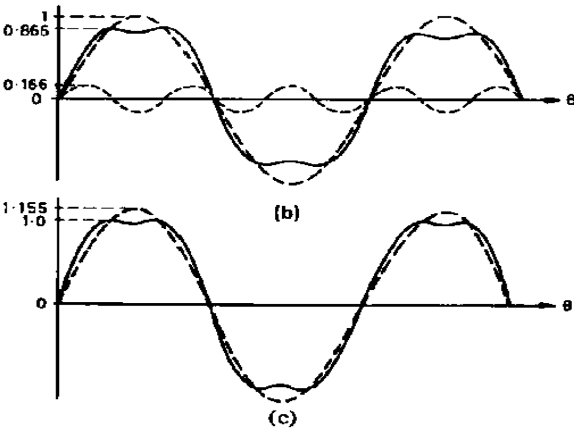

Figure 1 Reference wave generation of THIPWM

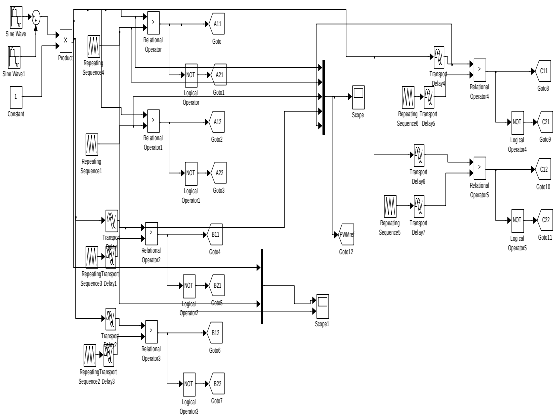

Figure 5 DC-Link balancing of two capacitors of MLI

5. SIMULATION RESULTS

The below shown results gave the complete performance of the considered circuit with expected results. As discussed the bridgeless buck-boost converter designed here should be able to boost up the voltage from 230V ac to 440V DC. The voltage stored in the capacitor 1 shows the result is fulfilled and shown in figure(6).Later the stored voltage in Capacitor1 has to be balanced equally in the DC-link capacitors of NPC,and it is also shown in figure(7).later the three level MLI has successfully inverted the stored dc voltage to required voltage and frequency which is shown in figures(8) and (9) and with lesser THD as shown in figure (12).Now this voltage was successfully applied to a 3-ph Squirrel cage IM whose speed is 1500rpm and Torque is 5 N-m and results including stator currents are shown in figure (10) and figure (11).

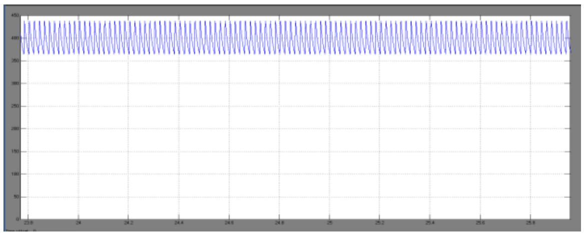

Figure 6 Voltage across capacitor1

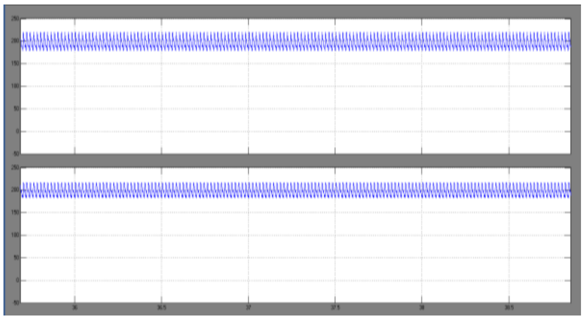

Figure 7 DC-Link balancing of two capacitors of MLI

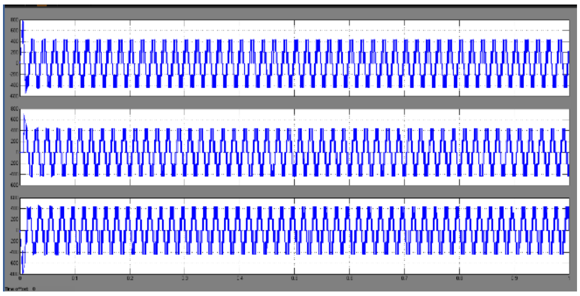

Figure 8 Line voltages of MLI

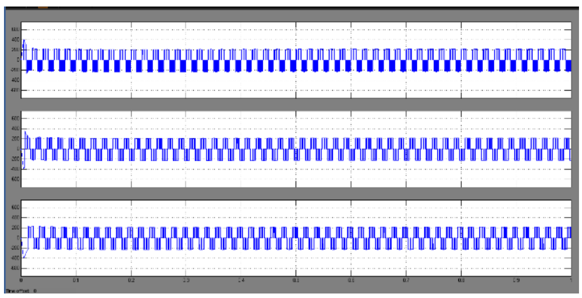

Figure 9 Phase voltages of MLI

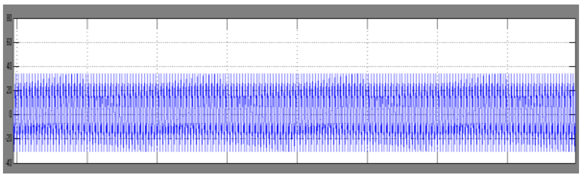

Figure 10 Stator currents

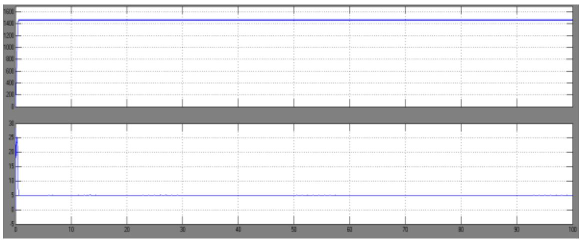

Figure 11 Speed and Torque of IM

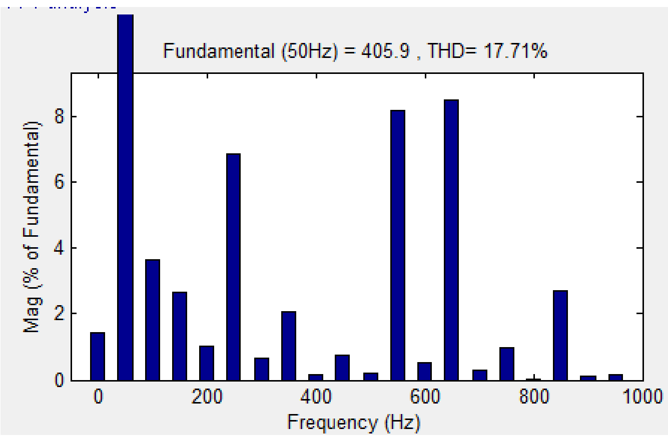

Figure 12 Total Harmonic Distortion of inverter o/p voltage

3. CONCLUSIONS

The simulation results prove that the bridgeless buck-boost converter is stepping the voltage to a required value with less utilization of semiconductor Switches. The multi-level inverter is showing the less harmonic distortion and the dc-link voltage balancing across the capacitors is maintained equally. Finally the acquired ac voltage is fed to the induction motor used in water pumping drive system and the performance of induction motor is observed. This induction motor can be easily utilized in agricultural applications.

REFERENCES

[1] "Power Factor." Wikipedia. Wikimedia Foundation, Inc. April 20, 2011. Creative Commons Attribution-ShareAlikeLicense <http://en.wikipedia.org/wiki/Power_factor>.

[2] "Apparent Power." Repair and Maintenance Manuals - Integrated Publishing. Integrated Publishing, Inc., 1998. Web. Feb.-Mar. 2011.

[3] "PFC Decoded." Dan's Data - PC Hardware and Gadget Reviews! Atomic: Maximum Power Computing, 2003. Web. 15 Feb. 2011.

[4] Prasad, A.R.; Ziogas, P.D.; Manias, S.; , "An active power factor correction technique for three-phase diode rectifiers," Power Electronics, IEEE Transactions on , vol.6, no.1, pp.83-92, Jan 1991

[5] Jovanovic, M.M.; Jang, Y.; , "State-of-the-art, single-phase, active power-factor correction techniques for high-power applications - an overview," Industrial Electronics, IEEE Transactions on , vol.52, no.3, pp. 701- 708, June 2005

[6] Daqing Wang; Hongqi Ben; Tao Meng; , "A novel three-phase power factor correction converter based on active clamp technique," Electrical Machines and Systems, 2008. ICEMS 2008. International Conference on , vol., no., pp.1896 1901, 17-20 Oct. 2008

[7] Prasad, A.R.; Ziogas, P.D.; Manias, S.; , "A new active power factor correction method for single-phase buck-boost AC-DC converter," Applied Power Electronics Conference and Exposition, 1992. APEC '92. Conference Proceedings 1992., Seventh Annual , vol., no., pp.814-820, 23-27 Feb 1992

[8] Ekemezie, P.N.; , "Design of a power factor correction ac-dc converter," AFRICON 2007 , vol., no., pp.1-8, 26-28 Sept. 2007

[9] Wang Wei; Liu Hongpeng; Jiang Shigong; Xu Dianguo; , "A novel bridgeless buck boostPFC converter," Power Electronics Specialists Conference, 2008. PESC 2008. IEEE , vol., no., pp.1304-1308, 15-19 June 2008

[10] Kanaan, H.Y.; Al-Haddad, K.; , "A comparative analysis of nonlinear current control schemes applied to a SEPIC power factor corrector," Industrial Electronics Society, 2005. IECON 2005. 31st Annual Conference of IEEE , vol., no., pp.6 pp., 6-6 Nov. 2005

[11] Hysteresis Current Controller based Transformer less Split Inductor-NPC - MLI for Grid Connected PV-System; R.latha*, C.Bharatiraja, R.Palanisamy, sudeepbanerji, Subhransu Sekhar Das, International Conference on DESIGN AND MANUFACTURING 2013 (IConDM 2013), Procedia Engineering 64 (2013) 224 – 233

[12] Multilevel Inverters: A Survey of Topologies, Controls, and Applications; José Rodríguez, Senior Member, Jih-Sheng Lai and Fang Zheng Peng; IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 49, NO. 4, AUGUST 2002; Page(s):724-738.