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Single Phase Interleaved Bridgeless Boost Front End Converter for Three Phase Induction Motor Drive

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ABSTRACT: In many countries single-phase power is used for rural power distribution which limit the use of three-phase motors. Three-phase induction motors are preferable for high power applications as they are highly efficient, have smooth torque and good starting torque. So as to overcome this problem, three-phase induction motor drives are often required to operate three phase motors from a single-phase ac source.The aim is to design and implement three phase induction motor drive operating from single phase ac source.The main applications are in fans, pumps, air conditioners and can also be employed for electric traction. The entire performance has been evaluated using MATLAB/SIMULINK.

KEYWORDS: Bridgeless Interleaved(BLIL)Boost Converter, Variable Frequency Drive(VFD),Drives for rural applications, single phase to three phase converter.

I. INTRODUCTION

Systems employed for motion control are called drives and drives employing electrical motors are called electrical drives. The major parts of electrical drives are source, power modulator, control unit, load, and motor. Most of the electric power is consumed by motor loads, mainly induction motors which are used in fans, blowers, pumps, compressors as well as motor driven equipments. A three-phase motor is less expensive than a single-phase motor of the same voltage and rating.The operation of three-phase induction motor drives from single-phase ac source requires addressing many issues such as higher ripple voltage across the dc bus capacitor, higher peak input current, higher input current distortion, lower power factor, and poorer system efficiency.

The induction motor, has well-known advantages of simple construction, reliability, ruggedness and low cost. While comparing with dc motor, it can be used in hazardous environment since there are no problems with spark and corrosion. In the past Induction motors and synchronous motors are employed mainly for constant speed applications because variable speed application of this drives are either too expensive or had very poor efficiency. But with development of semiconductor converters employing thyristors,power transistors, IGBTs and GTOs they are widely used now a days.

Thepresent proposal aims at minimizing ripples in DC bus voltage and the peak current flowing through the rectifier diodes by interleaving of bridgeless converters. The converter improves power factor and VFD employed will reduce the power consumption. It can be employed in applications requiring operation at variable speeds ranging from small appliances to the medium power applications.

The Active Front End Inverter refers to the power converter system consisting of the line-side converter with active switches such as MOSFETs, the dc link capacitor bank, and the load-side inverter.An improved front end converter was proposed in [1].But this converter is being replaced by interleaved bridgeless boost converter. The line-side converter

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normally functions as a rectifier alsoknown as PWM rectifier, since it can be switched using a suitable pulse width modulation technique.

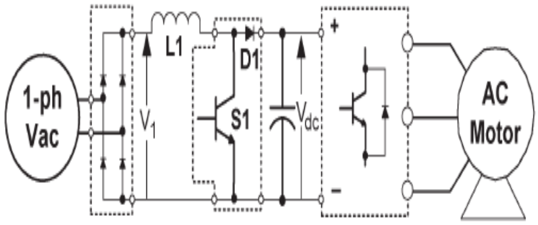

Fig.1 Conventional single phase boost converter fed three phase induction motor

The PWM rectifier basically operates as a boost chopper.The input to the converter is single phase AC. The required dc-link voltage needs to be maintained constant during rectifier as well as inverter operation of the line side converter. The ripple in dc-link voltage can be reduced using an appropriately sized capacitor bank.The conventional boost topology is the most popular topology for power factor correction(PFC) applications. In PFC applications, a dedicated diode bridge is used to rectify the ac input voltage to dc, and this is followed by the boost converter but the output capacitor ripple current is very high. The diode bridge rectifier and boost converter are replaced by the interleaved bridgeless boost converter which is shown in Fig. 2. The DC link voltage can be controlled by adjusting the duty ratio of switches employed in front end converter.

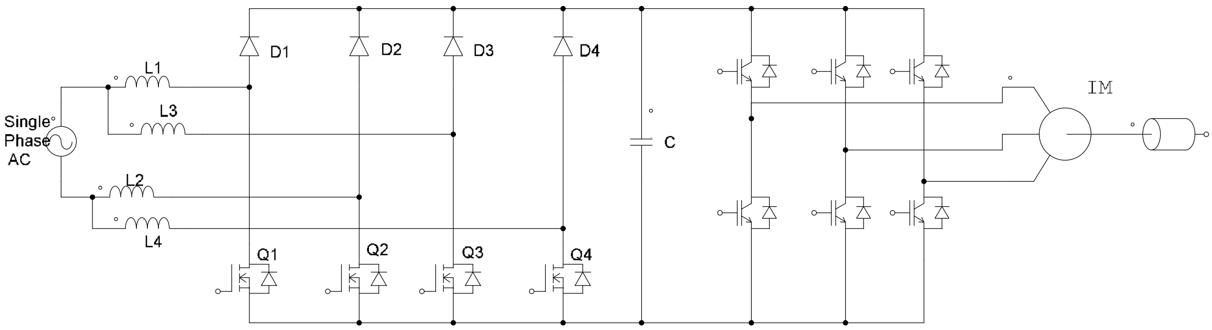

Fig. 2 Proposed Three phaseInduction Motor drive

II. OPERATING PRINCIPLE OF BLIL CONVERTER

Interleaving is the method of paralleling converters inorder to improve the performance.The interleaved bridgeless boost converter is shown with different modes of operation in positive half cycle in Fig. 3 .The switching frequency of the converter is higher than frequency of input line voltage.So the input voltage will be constant during one switching period.The Modes I,II,III and IV are repeated in the positive half cycle and V,VI,VII and VIII are repeated in negative half cycle.The different modes are explained below

Mode I:The switch Q1 is turned ON, and all other switches are off, as shown in Fig. 3(a). During this interval, the current in series inductances L1 increases linearly and stores the energy through Q1,body diode of Q2 and L2. The ripple currents in Q1 are the same as the current in series inductances L1 and L2. The current in series inductances L3 and L4 decreases linearly and transfers the energy to the load through D3, Cand body diode of Q4.

Mode II and IV:The switch Q3 is turned ON, keeping Q1 in ON condition, as shown in Fig. 3(b). During this interval, L1 and L2 get charged through L1-Q1-body diode of Q2-L2 path. Similarly L3 and L4 get charged through the path L3-Q3-body diode of Q4-L4.All the four inductors are in charging condition.

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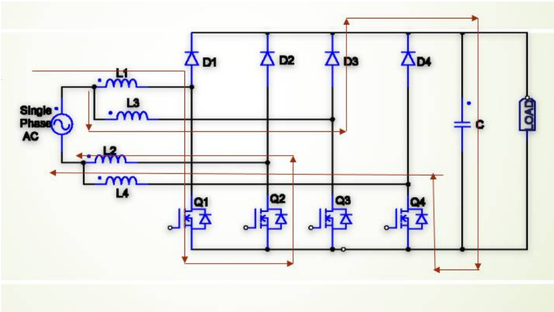

Fig. 3 (a) Mode I

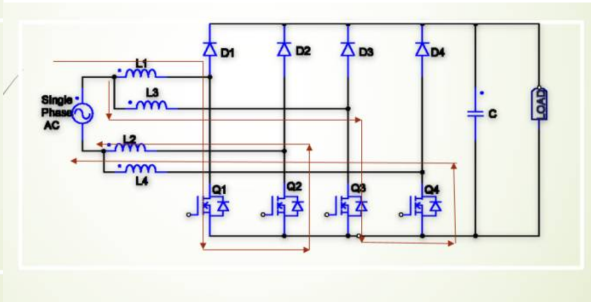

Fig. 3(b) Mode II

Mode III:The switch Q1 is turned OFF, and keeping Q2 in ON condition, as shown in Fig. 3(a). During this interval, the current in series inductances L1 decreases linearly and discharges the energy through D1 to the capacitor. The ripple currents in Q1 are the same as the current in series inductances L1 and L2.

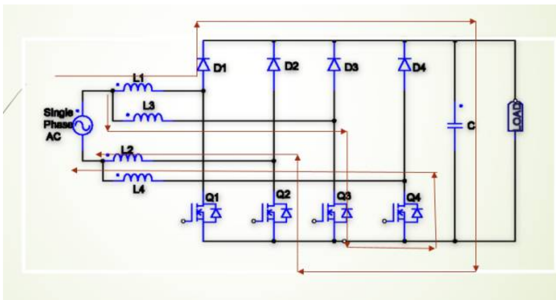

Fig. 3(c) Mode III

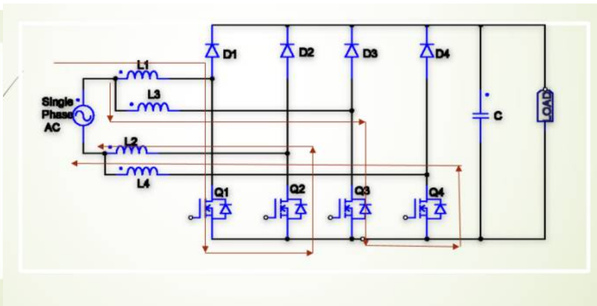

Fig. 3(d) Mode IV

Fig. 3 Modes of operation of BLIL Boost Converter in positive half cycle

Mode V: The switch Q2 is turned ON, and all other switches are off, as shown in Fig. 4(a). During this interval, the current in series inductances L2 increases linearly and stores the energy through Q2,body diode of Q1 and L1. The ripple currents in Q2 are the same as the current in series inductances L2 and L1. The current in series inductances L3 and L4 decreases linearly and transfers the energy to the load through D4, Cand body diode of Q3.

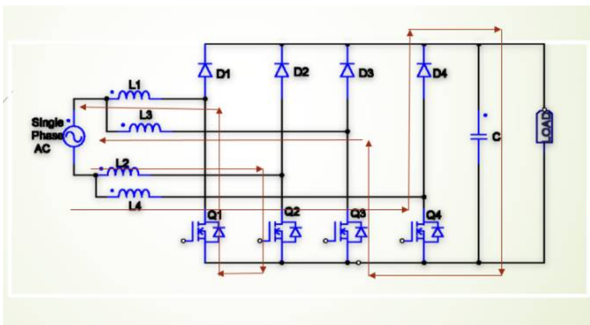

Fig. 4 (a) Mode V

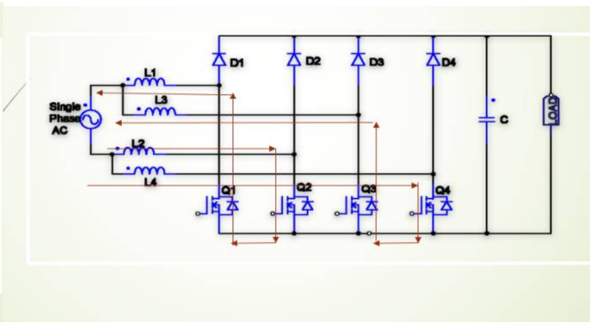

Fig. 4 (b) Mode VI

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Mode VI and VIII:The switch Q4 is turned ON, keeping Q2 in ON condition, as shown in Fig. 4(b). During this interval, L2 and L1 get charged through L2-Q2-body diode of Q1-L1 path. Similarly L3 and L4 get charged through the path L4-Q4-body diode of Q3-L3.All the four inductors are in charging condition.

Mode VII:The switch Q2 is turned OFF, and keeping Q4 in ON condition, as shown in Fig. 4(c). During this interval, the current in series inductances L2 and L1 decreases linearly and transfers the energy to the load through D2, Cand body diode of Q1.At the same time ,the inductors L4 and L3 in charging condition.

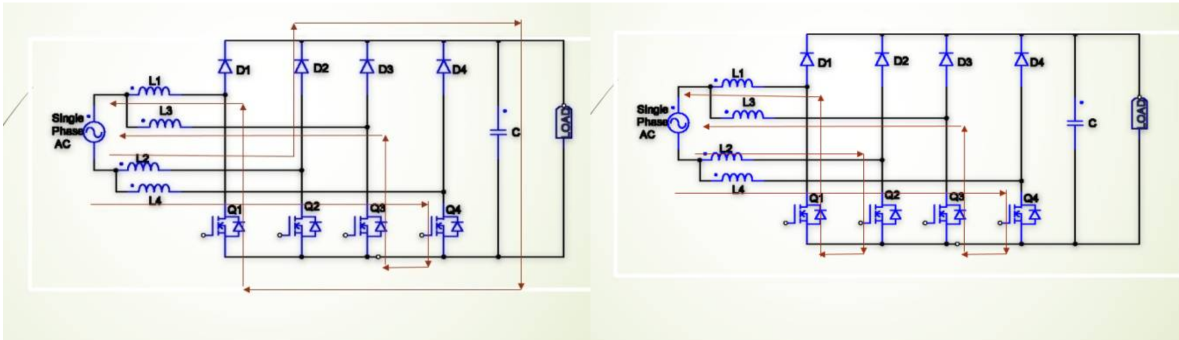

Fig. 4 (c) Mode VII

Fig. 4 (d) Mode VIII

Fig. 4 Modes of operation of BLIL Boost Converter in the negative half cycle

III. SIMULATION

The three phase induction motor drive with an interleaved bridgeless boost front end converter is simulated using MATLAB/ SIMULINK. The input voltage given is 230 V,50 Hz single phase AC supply .The DC link voltage is to be maintained constant in order to a get a three phase sinusoidal voltage at inverter output.

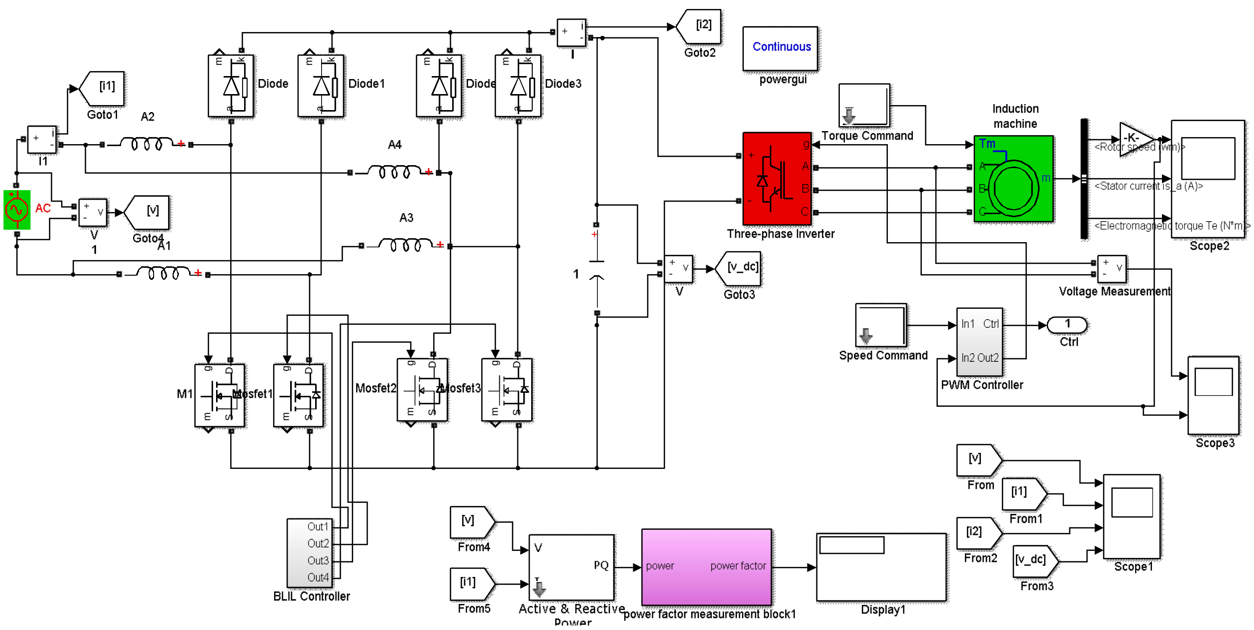

Fig. 5 Simulation diagram

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For maintaining the voltage constant the switching frequency of the converter is given as 50 k Hz while the input supply frequency is 50 Hz.The set of four modes are repeated 1000 times in their respective half cycles i.e. Modes I,II,III and IV in the positive half cycle and V,VI,VII and VIII in negative half cycle.The Simulation results are given below

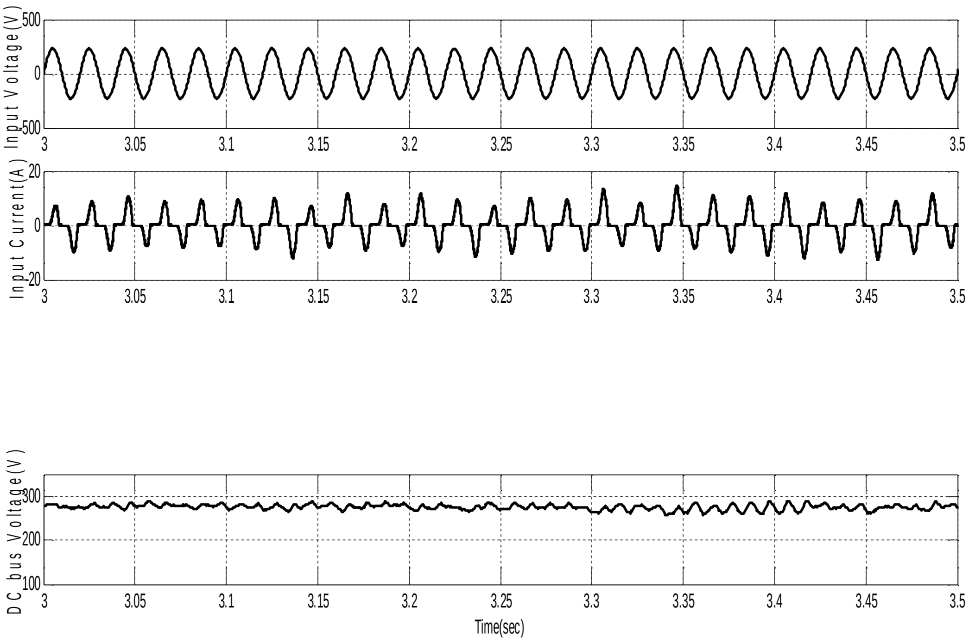

Fig 6 (a) Input Voltage (b)Input Current (c)DC Link Voltage

The input power factor is obtained as 0.825.The input current and input voltage are obtained to be in phase. The DC link voltage shown in Fig. 6 (c) obtained is 280 V ripple less.

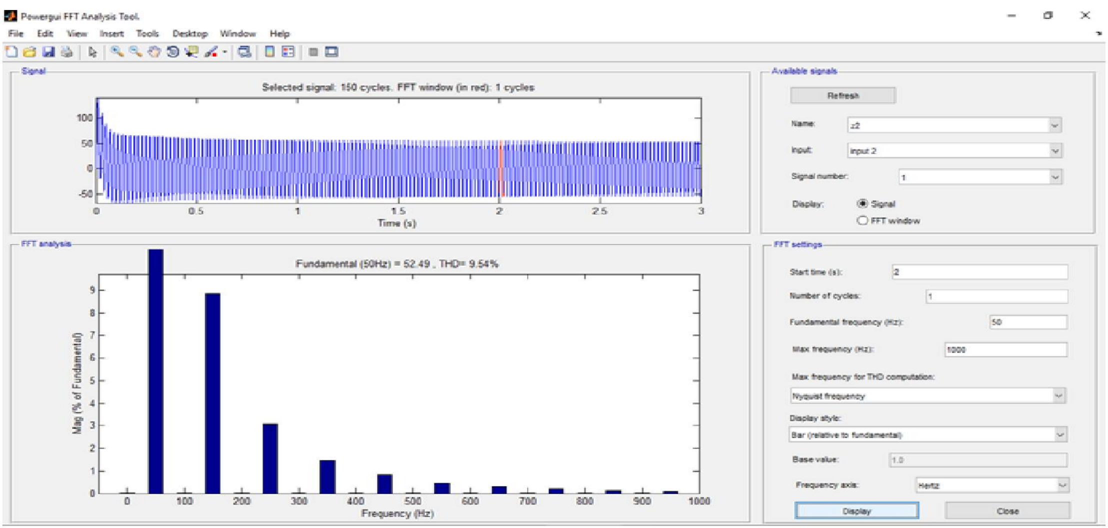

Fig 7 FFT analysis of input current

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The input current waveform shown in Fig 6(b) is analysed by Fast Fourier Transform.The third harmonic component of current is about 8.5% of fundmental component.The fifth and seventh component is 3.5% and 1.5% of fundamental component.The input current THD obtained is about 9.54 %.

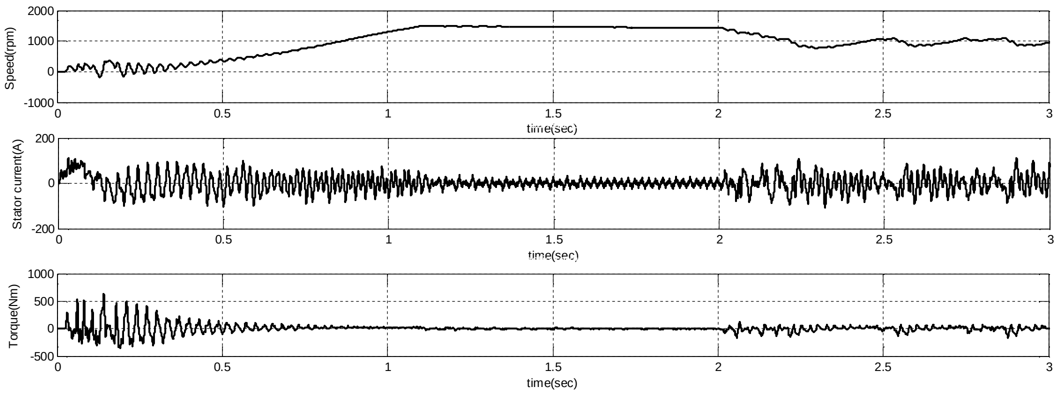

Fig 8 (a) Speed in rpm (b)Stator Current (c)Torque

The speed command is given as 1400 rpm at 1 sec and 1000 rpm at 2 sec.At 1.1 sec the speed of the motor approaches 1400 rpm and after 2 sec the speed remains around 1000 rpm.The actual speed obtained seems to be close to the reference speed command.The stator current and torque variations are in accordance with the speed variations.

V. CONCLUSION

A novel BLIL boost PFC topology has been presented in this paper for application in the front-end ac–dc converter in three phase induction motor drives. The proposed topology has been analyzed and its performance characteristics have been presented. The proposed topology introduces an effective way to drive three phase induction motor from single phase supply. The main disadvantage is the increase in the number of power electronic devices.The input current THD and powerfactorare improved as compared to that of conventional diode bridge rectifier.The variable frequency operation extends the application of the drive to household appliances and in traction drives.

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