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KALSEKAR TECHNICALCAMPUS, NEW PANVEL

PROJECT REPORT ON "EMBEDED CONTROL OF Z-SOURCE INVERTER"

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DEPARTMENT OF ELECTRICAL ENGINEERING

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PROJECT REPORT ON

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For the Degree of **Bachelor of Engineering in Electrical Engineering**

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ABSTRACT

Traditionally Voltage Source Inverter (VSI) and Current Source Inverter (CSI) fed induction motor drives have a limited output voltage range. Conventional VSI and CSI support only current buck DC-AC power conversion and need a relatively complex modulator. The limitations of VSI and CSI are overcome by Z-source inverter.

The Z-source inverter system employs a unique LC network in the DC link and a small capacitor on the AC side of the diode front end. By controlling the shoot-through duty cycle, the Z-source can produce any desired output AC voltage, even greater than the line voltage (i.e. 325V for 230V AC) regardless of the input voltage. The proposed Z-source inverter system provides ride-through capability during voltage sags, reduces line harmonics, improves power factor and reliability, and extends the output voltage range. Analysis, simulation, and experimental results were presented to demonstrate these features. This system reduces harmonics, electromagnetic interference noise and it has low common mode noise. Index Terms: current source inverter (CSI), voltage source inverter (VSI), Z-source inverter (ZSI), electro magnetic interference (EMI)

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CHAPTER 1

1.1 INTRODUCTION

The traditional inverters are Voltage source inverter (VSI) and current source inverter (CSI). which consists of a diode rectifier front end, dc link and inverter bridge. In order to improve power factor, either an ac inductor or dc inductor is normally used. The dc link voltage is roughly equal to 1.35 times the line voltage, and the V-source inverter is a buck converter that can only produce an ac voltage limited by the dc link voltage. Because of this nature, the V-source inverter based PWM VSI and CSI are characterized by relatively low efficiency because of switching losses and considerable EMI generation. Since switches are used in the main circuit, each is traditionally composed of power transistors and anti parallel diode. It provides bi-directional current flow and unidirectional voltage blocking capability.

Thus inverter presents negligible switching losses and EMI generation at the line frequency. The tackle which exists in the voltage inverter are an output LC filter needed to provide sinusoidal voltage compared with current source inverter. The LC filter causes additional power loss and controlled complexity.

To avoid short circuiting of damaging dead line is allowing which provides a delay time between gating signals but it causes waveform distortion. ASD system suffers the following common limitations and problems. Obtainable output voltage is limited quite below the input line voltage. The diode rectifier fed by the 415-V ac line produces about 560-V dc on the dc-link , which is roughly 1.35 times the line to- line input voltage under the assumption of heavy load and continuous “double –hump” input current for large (>50kW) drives that typically have an approximately 3% of inductance on the ac or dc side.Fig.1 Power conversion For light load operation or small drives with no significant inductance, the line current becomes discontinuous “double-pulse,” and the dc voltage is closer to 1.41 times the line –to-line input voltage 400-V motor, the low obtainable output voltage significantly limits output power that is proportional to the square of the voltage.

This is a very undesirable situation for many applications because the motor and drive system has to be oversized for a required power. Voltage sags can interrupt an ASD system and shut down critical loads and processes. Over 90% of power quality related problems are from momentary (typically 0.1-2s) voltage sags of 10-50% below nominal. The dc capacitor in drives is a relatively small energy storage element, which cannot hold dc voltage above the operable level under such voltage sags. Lack or ride through capacity is a serious problem for sensitive loads driven by drives. Vulnerability of a drives and the dc voltage under three phase and two phase voltage sag .Solutions have been sought to boost ride–through.

The drives industry provides options using fly back converter or boost converter with energy storage or diode rectifierCompared with the former inverter, the Z-source inverter has more advantages such as higher efficiency and lower cost, which is very promising for FC systems due to its novel voltage buck/boost ability. The interrelated literatures demonstrated the unique features of the Zsource inverter and its feasibility for the adjustable speed drive (ASD) systems with induction machines. .

This investigates the induction motor drive system fed by a Z-source inverter. Firstly, the configuration, operation principle and control method of proposed electric drive system are described. Then the statespace method is used for mathematical modeling. Finally, simulation results are carried out to verify the desired performance of the proposed drive systems.

A recently developed new inverter, the z-source inverter, has a niche for drives systems to overcome the aforementioned problems. A Z- source inverter based drives can.

* produce any desired output a voltage, even greater than the line voltage, regardless of the input voltage, thus reducing motor ratings.
* provide ride-through during voltage sags without any additional circuits.
* improve power factor reduce harmonic current and common-mode voltage.

1.2 LITERATURE SURVEY

- Traditionally Voltage Source Inverter (VSI) and Current Source Inverter (CSI) fed induction motor drives have a limited output voltage range. Conventional VSI and CSI support only current buck DC-AC power conversion and need a relatively complex modulator. The limitations of VSI and CSI are overcome by Z-source inverter. The impedance network used buck or boost the input voltage depends upon the boosting factor .This network also act as a second order filter .This network should required less inductance and smaller in size. Z source consist of two inductor and two capacitor. When the two inductors (L_1 and L_2) are small and approach zero, the Impedance source network reduces to two capacitors (C_1 andC_2) in parallel and becomes traditional voltage source. Similarly, when the two capacitors (C_1 and C_2) are small and approach zero, the Impedance Source Network reduces to two inductors (L_1 and L_2) in series and becomes a traditional current source. Therefore considering additional filtering and energy storage by the capacitors, the impedance source network should require less inductance and smaller size compared with the traditional current source inverters.[1] Z source inverter used to control the speed of an induction motor. The proposed Z source inverter (ZSI) can effectively reduce the voltage stress across the capacitors in the impedance network. This reduces the voltage range of the capacitors used, and also the cost of the proposed topology which is in turn used to control the speed of an induction motor which is used in many valuable industrial applications The Z source inverter is a single stage converter that can either buck or boost the ac output voltage from a dc supply. Z source inverter also allows two switches of the same leg to be gated in the circuit, thus eliminating the shoot through fault that occurs in traditional converters. Z source inverter is used, that can be used to drive an induction motor and to control its operating speed.[2] Impedance-source (or impedance-fed) power converter (abbreviated as Z-source converter) and its control method for implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. The Z-source converter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, thus providing unique features that cannot be obtained in the traditional voltage-source (or voltage-fed) and current-source (or current-fed) converters. Overcome the above problems of the traditional V-source and I-source converters, this paper presents an impedance-source (or impedance-fed) power converter (abbreviated as Z-source converter) and its control method for implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. The unique feature of the Z-source inverter is that the output ac voltage can be any value between zero and infinity regardless of the fuel-cell voltage. That is, the Z-source inverter is a buck–boost inverter that has a wide range of obtainable voltage. The traditional V- and I-source inverters cannot provide such feature. The Z-source inverter (ZSI) in is an emerging topology for power electronics DC-AC converters. It can utilize the shoot-through (ST) state to boost the input voltage, which improves the inverter reliability and enlarge its application field. In comparison with other power electronics converters, it provides an attractive single stage DC-AC conversion with buck-boost capability, reduced cost, reduced volume and higher efficiency due to a lower component number[3].

CHAPTER 2

2.1 LOAD FED FROM Z-SOURCE INVERTER

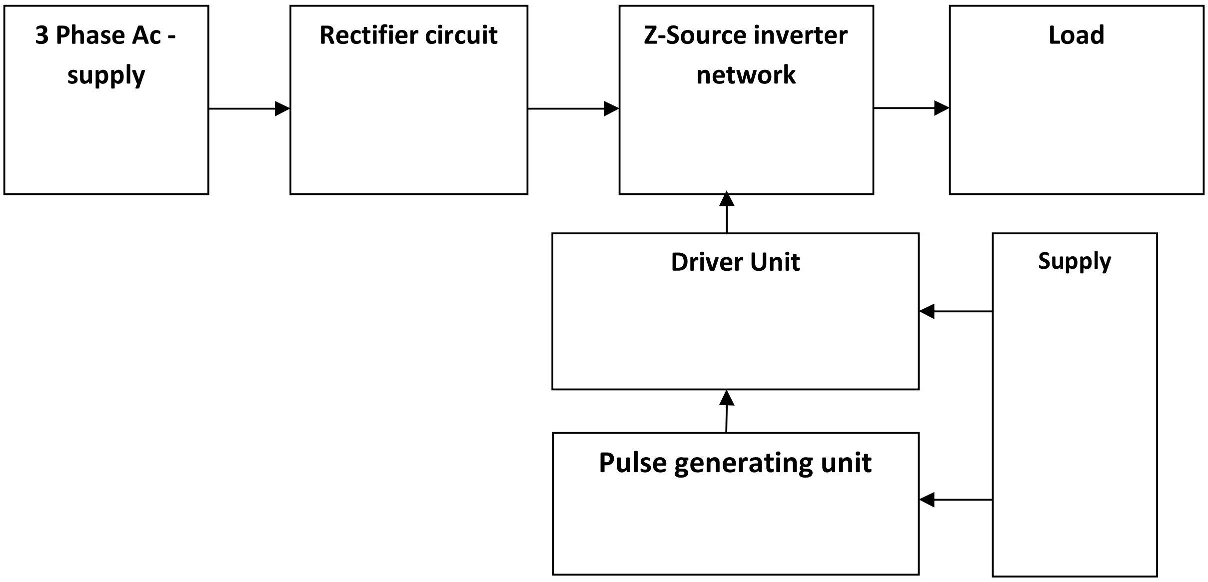


Fig 2.1

2.2 POWER SUPPLY UNIT

As we all know any invention of latest technology cannot be activated without the source of power. So itNthis fast moving world we deliberately need a proper power source which will be apt for a particular requirement. All the electronic components starting from diode to Intel IC's only work with a DC supply ranging from -+5v to 0-+12v. We are utilizing , the cheapest and commonly available energy source of 230v-50Hz and stepping down, rectifying, filtering and regulating the voltage. This will be dealt briefly in the forth-coming sections.

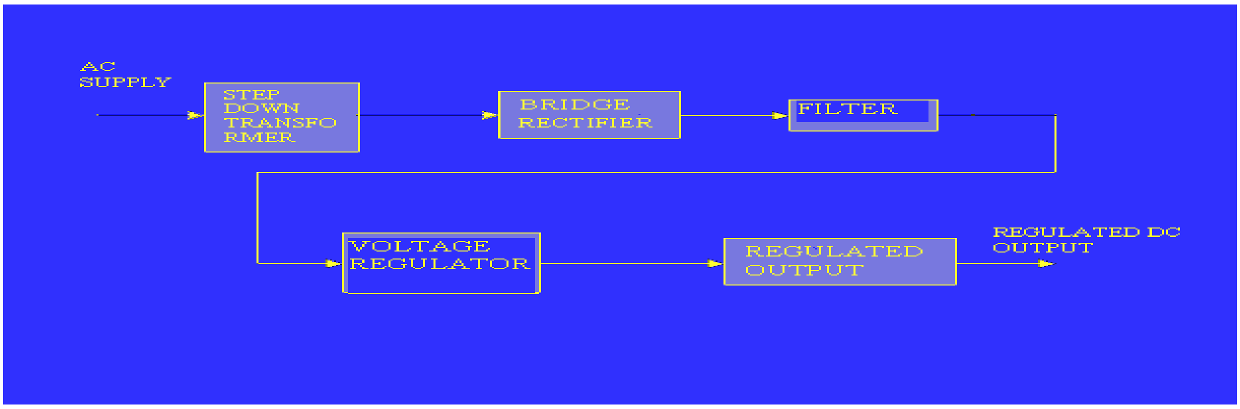


Fig 2.2

2.3 STEP DOWN TRANSFORMER

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230v/0-12v is used to perform the step down operation where a 230V AC appears as 12V AC across the secondary winding. One alteration of input causes the top of the transformer to be positive and the bottom negative. The next alteration will temporarily cause the reverse. The current rating of the transformer used in our project is 1A. Apart from stepping down AC voltages, it gives isolation between the power source and power supply circuitries.

2.4 DIODE BRIDGE RECTIFIERS

The stepped down AC voltage is converted into dc voltage using a diode bridge rectifier.The diode bridge rectifier consists of four diodes arranged in two legs. The diodes are connected to the stepped down AC voltage. For positive half cycle of the ac voltage, the diodes D1 and D4 are forward biased (ref fig). For negative half cycles diodes D2 and D3 are forward biased. Thus dc voltage is produced to provide input supply to the inverter.

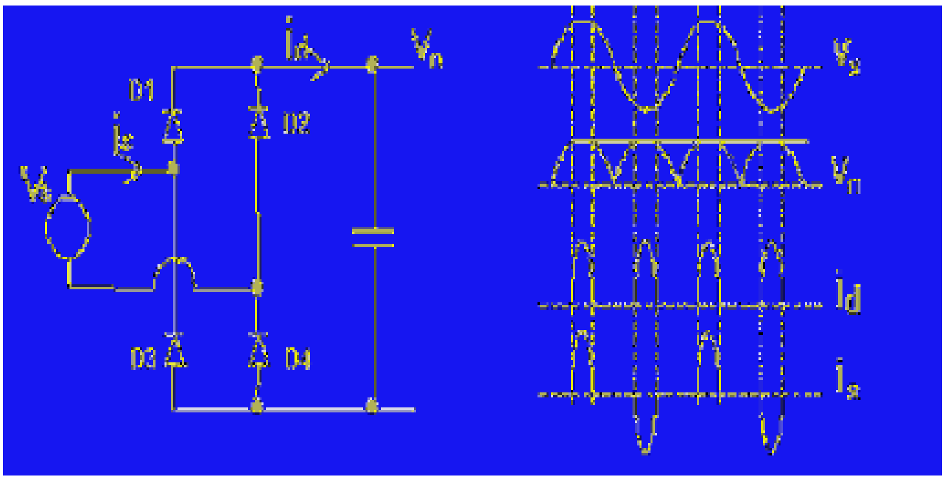


Fig 2.3

When the positive half cycle is applied to the diode bridge rectifier, the diodes D1 and D4 are forward biased. The diodes start conducting and the load current flows through the positive of the supply, diodeD1, the load, the diode D4 and the negative of the supply. The diode D2 and D3 are reverse biased and do not conduct.

During the negative half cycle, the diodes D1 and D4 are reverse biased and they stop conducting. The diodes D2 & D3 are forward biased and they start conducting. The load current flows in the same direction for both the half cycles. Thus the ac supply given to diode bridge rectifier is converted into pulsating dc.

2.5 FILTERING UNIT

Filter circuits which are usually capacitors acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor, is used not only to 'short' the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output.

2.6 VOLTAGE REGULATORS

The voltage regulators play an important role in any power supply unit. The primary purpose of a regulator is to aid the rectifier and filter circuit in providing a constant DC voltage to the device. Power supplies without regulators have an inherent problem of changing DC voltage values due to variations in the load or due to fluctuations in the AC liner voltage. With a regulator connected to the DC output, the voltage can be maintained within a close tolerant region of the desired output..

CHAPTER 3

3.1 WHAT IS INVERTER

A device that converts dc power into ac power at desired output voltage and frequency is called an inverter. An inverter is a device that flips DC current to AC, or vice versa. It performs its function with the help of many small transformers that are located within it that continuously turn on and off, thus reshaping the DC current into AC. Inverters can be configured to a particular output requirement and are handy in extracting electricity from batteries for home use. Similarly, to charge batteries from AC power, a reverse inverter is required that converts AC power to DC power.

3.2 CLASSICIFICATION OF INVERTER

Inverter is power electronic circuit that converts a direct current into an alternative current power of desired magnitude and frequency. The inverters find their application in modern ac motor and uninterruptible power supplies.

Based on the source used

- Voltage source inverter
- Current source inverter

3.3 VOLTAGE SOURCE INVERTER

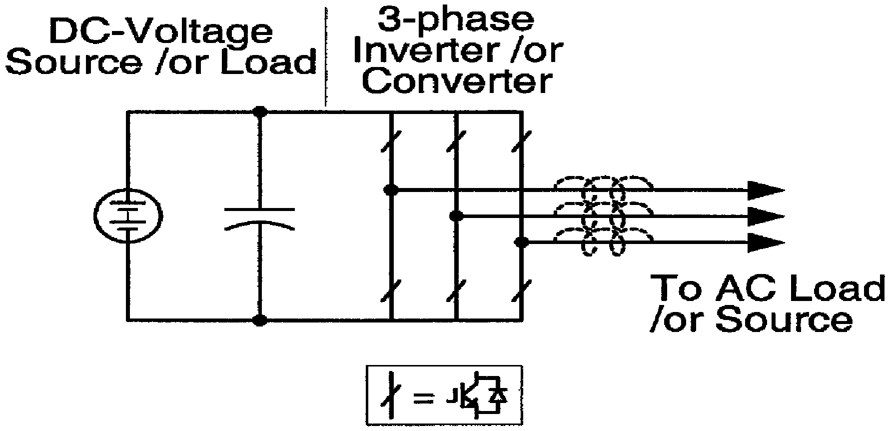


Fig 3.1

Fig 3.1 shows the traditional three-phase voltage-source converter (abbreviated as V-source converter) structure. A dc voltage source supported by a relatively large capacitor feeds the main converter circuit, a three-phase bridge. The dc voltage source can be a battery, fuel-cell stack, diode rectifier, and/or capacitor.

Six switches are used in the main circuit; each is traditionally composed of a power transistor and an anti parallel (or freewheeling) diode to provide bidirectional current flow and unidirectional voltage blocking capability. The V-source converter is widely used. It, however, has the following conceptual and theoretical barriers and limitations

The ac output voltage is limited below and cannot exceed the dc-rail voltage or the dc-rail voltage has to be greater than the ac input voltage. Therefore, the V-source inverter is a buck (step-down) inverter for dc-to-ac power conversion and the V-source converter is a boost (step-up) rectifier (or boost converter) for ac-to-dc power conversion. For applications where over drive is desirable and the available dc voltage is limited, an additional dc-dc boost converter is needed to obtain a desired ac output. The additional power converter stage increases system cost and lowers efficiency.

- The upper and lower devices of each phase leg cannot be gated on simultaneously either by purpose or by EMI noise. Otherwise, a shoot-through would occur and destroy the devices. The shoot-through problem by electromagnetic interference (EMI) noise's miss gating-on is a major killer to the converter's reliability. Dead time to block both upper and lower devices has to be provided in the V-source converter, which causes waveform distortion, etc.

- An output *LC* filter is needed for providing a sinusoidal voltage compared with the current-source inverter, which causes additional power loss and control complexity.

3.4 CURRENT SOURCE INVERTER

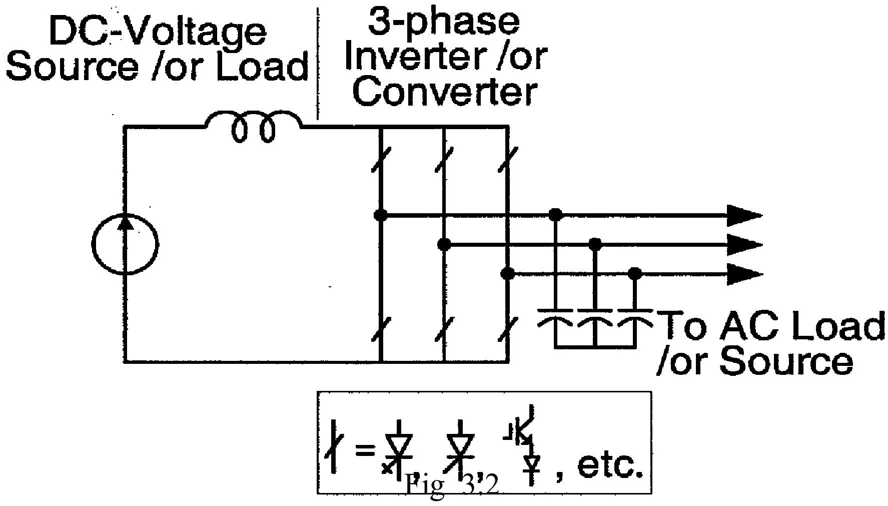


Fig 3.2

Fig. 3.2 shows the traditional three-phase current-source converter (abbreviated as I-source converter) structure. A dc current source feeds the main converter circuit, a three-phase bridge. The dc current source can be a relatively large dc inductor fed by a voltage source such as a battery, fuel-cell stack, diode rectifier, or thyristor converter.

Six switches are used in the main circuit, each is traditionally composed of a semiconductor switching device with reverse block capability such as a gate-turn-off thyristor (GTO) and SCR or a power transistor with a series diode to provide unidirectional current flow and bidirectional voltage blocking.

However, the I-source converter has the following conceptual and theoretical barriers and limitations

. • The ac output voltage has to be greater than the original dc voltage that feeds the dc inductor or the dc voltage produced is always smaller than the ac input voltage. Therefore, the I-source inverter is a boost inverter for dc-to-ac power conversion and the I-source converter is a buck rectifier (or buck converter) for ac-to-dc power conversion. For applications where a wide voltage range is desirable, an additional dc–dc buck (or boost) converter is needed. The additional power conversion stage increases system cost and lowers efficiency.

• At least one of the upper devices and one of the lower devices have to be gated on and maintained on at any time. Otherwise, an open circuit of the dc inductor would occur and destroy the devices. The open-circuit problem by EMI noise's miss gating-off is a major concern of the converter's reliability. Overlap time for safe current commutation is needed in the I-source converter, which also causes waveform distortion, etc.

• The main switches of the I-source converter have to block reverse voltage that requires a series diode to be used in combination with high-speed and high-performance transistors such as insulated gate bipolar transistors (IGBTs).

This prevents the direct use of low-cost and high-performance IGBT modules and intelligent power modules (IPMs). In addition, both the V-source converter and the I-source converter have the following common problems.

• They are either a boost or a buck converter and cannot be a buck–boost converter. That is, their obtainable output voltage range is limited to either greater or smaller than the input voltage.

• Their main circuits cannot be interchangeable. In other words, neither the V-source converter main circuit can be used for the I-source converter, nor vice versa.

• They are vulnerable to EMI noise in terms of reliability.

3.5 Z SOURCE INVERTER

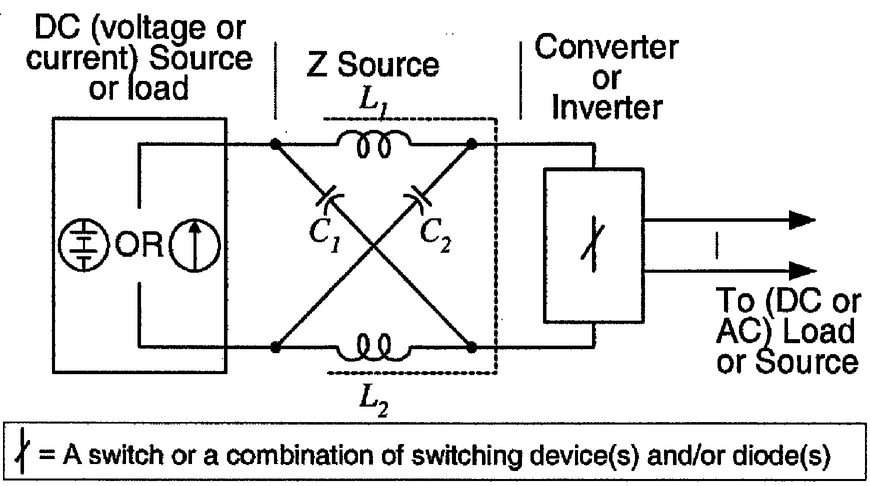


Fig 3.3

To overcome the above problems of the traditional V-source and I-source converters, here we present an impedance-source (or impedance-fed) power converter (abbreviated as Z-source converter) and its control method for implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion.

Fig.3.3 shows the general Z-source converter structure proposed. It employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, load, or another converter, for providing unique features that cannot be observed in the traditional V- and I-source converters where a capacitor and inductor are used, respectively. The Z-source converter overcomes the above-mentioned conceptual and theoretical barriers and limitations of the traditional V-source converter and I-source converter and provides a novel power conversion concept.

In Fig. 3.3, a two-port network that consists of a split-inductor L1and L2 and capacitors C1 and C2 connected in X shape is employed to provide an impedance source (Z-source) coupling the converter (or inverter) to the dc source, load, or another converter. The dc source/or load can be either a voltage or a current source/or load.

Therefore, the dc source can be a battery, diode rectifier, thyristor converter, fuel cell, an inductor, a capacitor, or a combination of those. Switches used in the converter can be a combination of switching devices and diodes such as the antiparallel combination , the series combination, etc. As two three-phase Z-source inverter configurations. The inductance L1and L2 and can be provided through a split inductor or two separate inductors. The Z-source concept can be applied to all dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. To describe the operating principle and control, this paper focuses on an application

3.6 USE OF Z SOURCE INVERTER

It can produce any desired output even greater than line voltage It provides ride through during voltage sags without additional circuit Improve the power factor and reduces harmonics Minimizes the motor rating to delivered a recquired power Z source inverter employs a unique impedance network coupled with the inverter main circuit to the power source.

Ac voltage is rectified to dc voltage by the rectifier consist of six diode this rectified output dc voltage_fed to impedance network which consist of two equal inductors L1and L2 and two equal capacitor C1 and C2. When C1 and C2 approach to zero then L1and L2 becomes in series then it will act as a CSI and when L1and L2 approach to zero then C1and C2 becomes in parallel it will act as a VSI Impedance netwok used for buck or boost the input voltage depends upon boosting factor Impedance network provide second order filter and require less inductor and capacitor and of small size

3.7 DIFFERENCE BETWEEN VSI CSI AND ZSI

Current source inverter	**Voltage source inverter**	**Z-source inverter**
Inductance used in DC link source impedance increases acts as a constant current source.	Capacitor used in DC link acts as a low impedance voltage source.	As capacitor and inductor is used in DC link it acts as a constant high impedance source.
A current source inverter is capable of withstanding short circuit across any two of its output terminals. Hence short circuit on load and misgatting of switches are acceptable.	A VSI is more dangerous situation as the parallel capacitor feeds more powering to the fault.	In ZSI miss gating of the switches are accepted.
Main circuit cannot be interchangeable.	Main circuit cannot be interchangeable.	Main circuit can be interchangeable.
Affected by EMI and noise.	Affected by EMI and noise.	Less affected by EMI and noise.
Power loss is high.	Power loss is high.	Power loss is low.
Low efficiency due to power loss.	Low efficiency due to power loss.	high efficiency due to power loss.

CHAPTER 4

4.1 SEMICONDUCTOR DEVICES

The electronic semiconductor device act as a switching device in the power electronic converters. In general, the characteristics of the device are utilized in such a way that it acts as a short circuit when closed. In addition to, an ideal switch also consumes less power to switch from one state to other.

Semiconductor is defined as the material whose conductivity depends on the energy (light, heat, etc.,) falling on it. They don't conduct at absolute zero temperature. But, as the temperature increases, the current conducted by the semi conductor increases as it gets energy in the form of heat. The increase in current is propotional to the temperature rise. Semiconductor switches are diodes, SCR, MOSFET, IGBT, BJT, TRIAC etc.

4.2 THE INSULATED-GATE BIPOLAR TRANSISTOR OR IGBT

The insulated-gate bipolar transistor or IGBT is a three-terminal power semiconductor device, noted for high efficiency and fast switching. It switches electric power in many modern appliances: electric cars, variable speed refrigerators, air-conditioners, and even stereo systems with digital amplifiers. Since it is designed to rapidly turn on and off, amplifiers that use it often synthesize complex waveforms with pulse width modulation and low-pass filters.

The IGBT combines the simple gate-drive characteristics of the MOSFETs with the high-current and low–saturation-voltage capability of bipolar transistors by combining an isolated-gate FET for the control input, and a bipolar power transistor as a switch, in a single device. The IGBT is used in medium- to high-power applications such as switched-mode power supply, traction motor control and induction heating. Large IGBT modules typically consist of many devices in parallel and can have very high current handling capabilities in the order of hundreds of amps with blocking voltages of 6,000 V.

Their high pulse ratings, and low prices on the surplus market, also make them attractive to the high-voltage hobbyist for generating large amounts of high-frequency power to drive experiments like Tesla coils. Availability of affordable, reliable IGBTs is a key enabler for electric vehicles and hybrid cars. Toyota's second generation hybrid Prius has a 50 kW IGBT inverter controlling two AC motor/generators connected to the DC battery pack.

CHAPTER 5

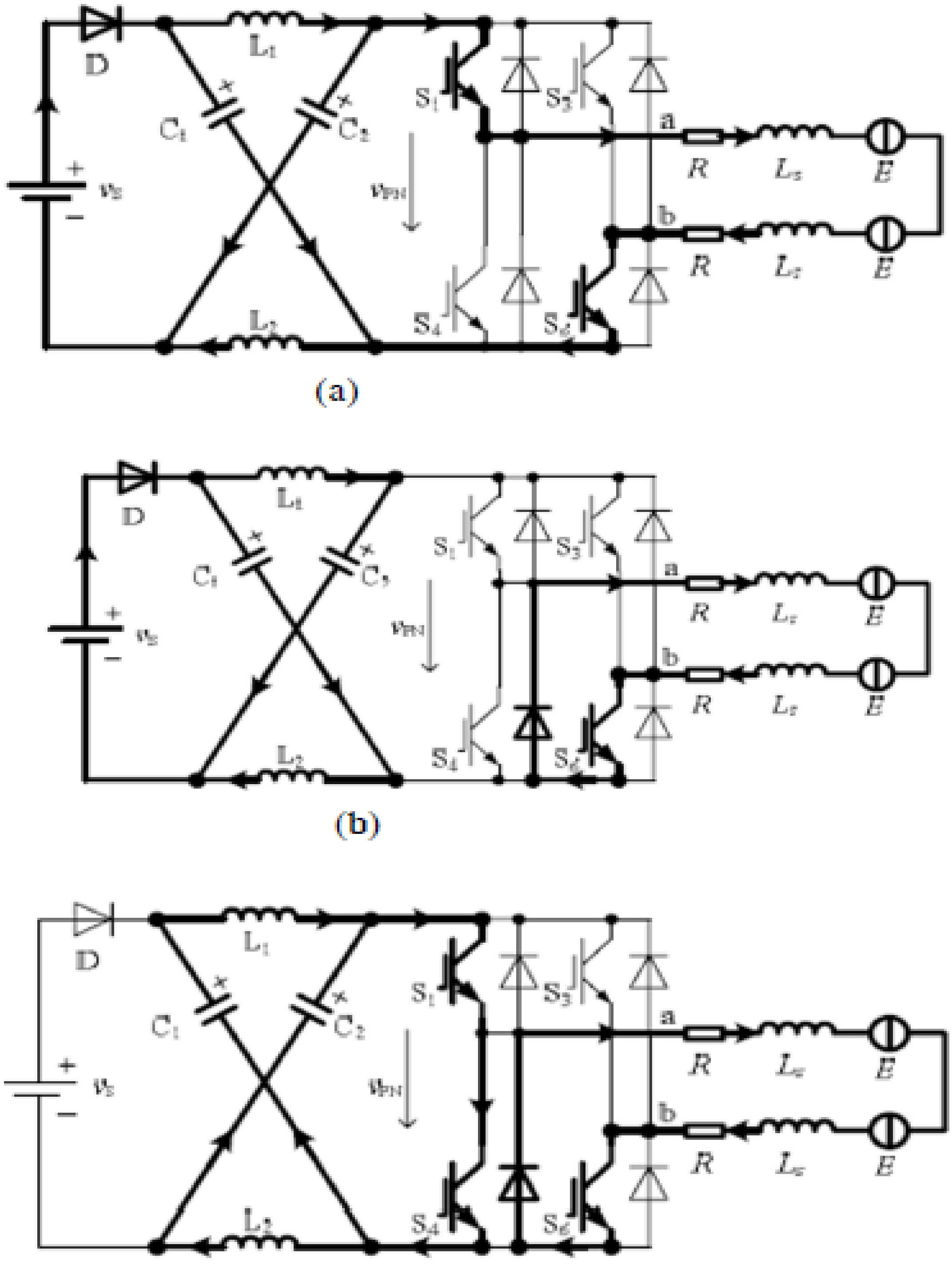
5.1 Z – SOURCE INVERTER BASED INDUCTION MOTOR DRIVE SYSTEM

Fig. 1 shows the main circuit of the proposed Z-source inverter based induction drive system. A voltage-type Z source inverter is utilized, instead of the traditional voltage source inverter (VSI) or current source inverter (CSI), to feed electric energy from the dc source to the motor. To gain the buck/boost ability, the pulse width modulation (PWM) method should be used to control the Z-source inverter to generate shoot-through states.

Unlike the Z-source inverter based ASD system with induction machines, the output currents of the Z-source inverter in the proposed induction drive system are composed of square waveforms of 120° electrical degree. Consequently, the operation principle, the modeling method and the control are all different from the Z-source inverter based ASD system with induction machines.

Fig.2 shows some equivalent circuits when the phase a and b windings are conducted, with the current flows from phase-a winding to phase-b winding. The shoot-through states can be generated via shorting either any one arm or both arms in the bridge For ease of illustration, assume that the upper switches of the bridge operate in chopping modes, while the lower are used to short the bridge arms.

The broad-brush lines and arrows indicate the path and direction of the currents, respectively. From Fig.2 (a) and (b), it can be seen that only two semiconductor devices (IGBT or the anti-parallel diode) in different arms of the bridge are conducted in the non-shoot-through modes. While in the shoot-through modes, four devices are conducted when the shoot-through occurs in one phase arm, as shown in Fig.2(c).And six devices may be conducted if the shoot-through occurs in two phase arm.

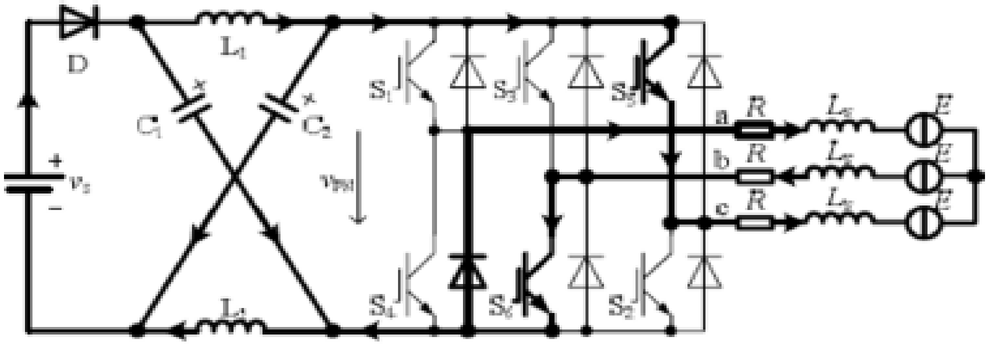


(c)

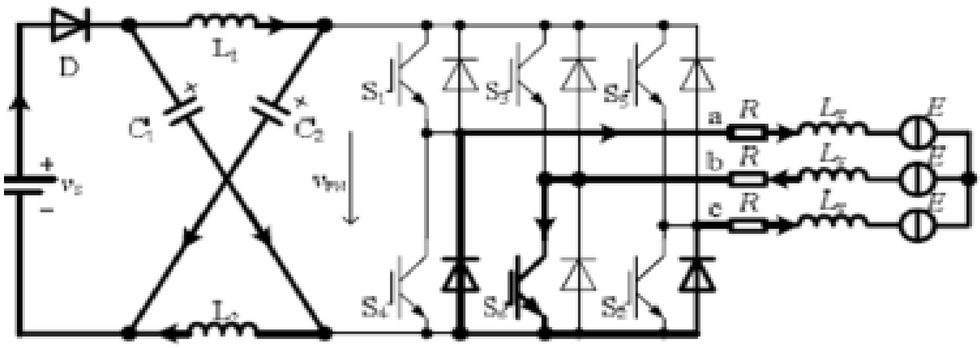
Fig. 2 Equivalent circuits during non – commutation stage
(a) open state (b) active state (c) shoot – through

In the phase commutation stage, the switch S1 is shut off, and the switch S5 is turned on at the same time. There are three devices conducted in the non-shoot-through modes, as shown in Fig.3 (a) and (b). While in the shoot-through modes, five devices may be conducted when the shoot-through occurs in one phase arm, as shown in Fig.3(c).

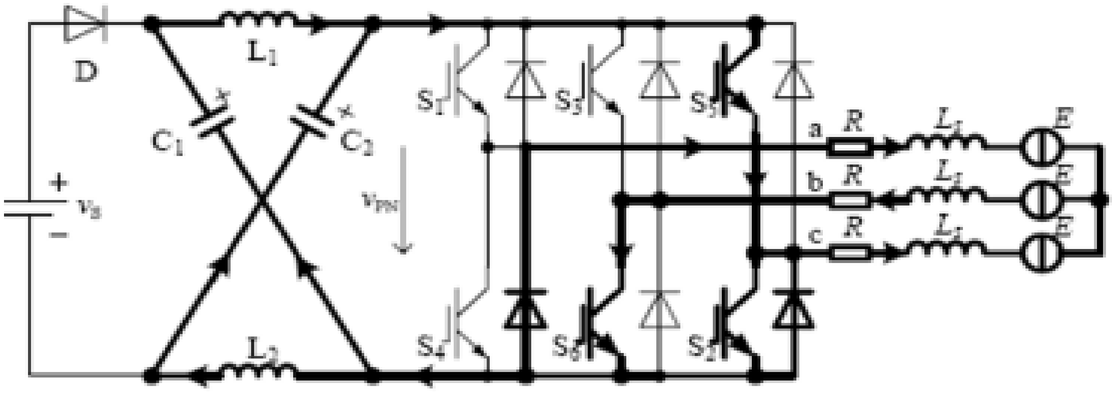
And seven devices may be conducted if the shoot-through occurs in two phase arms. It is worth noting that, the shoot-through states should be generated by gating on the lower switch only when the inverter output is in 'active' state. For example, in Fig.2(c), the switches S1 and S6 are triggered to feed the phase a and b windings, the switch S4 is used to shorted the arm, and the sketch of gating signals to the switches S1, S6and S4 can be seen in Fig.4.



(a)



(b)



(c)

Fig. 3 Equivalent circuit during phase commutation stage (a)open state (b) active state (c) shoot – through state

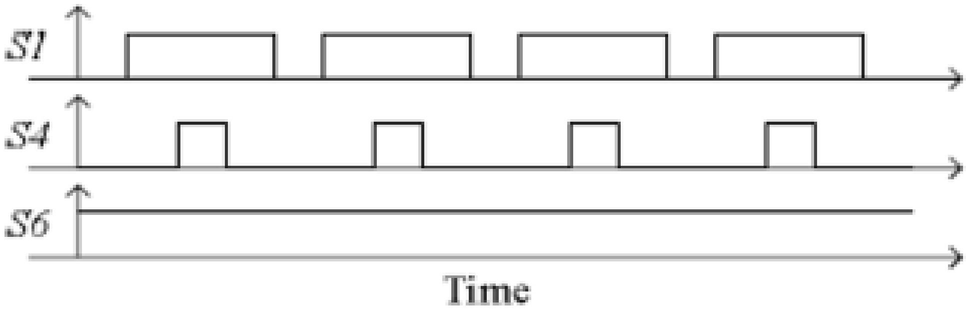


Fig. 4 waveform of the gate signals

Taking the duty ratio of S1 is D1 and the duty ratio of S4 is D4, the average output voltage of the inverter is

$$V_0 = \frac{D_1 - D_4}{1 - 2D_4} V_s \text{ , where } 0 < D_1, 0 < D_4 < 0.5, D_4 < D_1$$

and $0 < \frac{D_1 - D_4}{1 - 2D_4} < \infty$.

It can be seen that the output voltage can be bucked and boosted within a wide range. A straight line is used to control the shoot-through states. When the triangular waveform is lower than the straight line, the circuit turns into shoot through modes.

5.2 THREE PHASE INDUCTION MOTOR

Three phase induction motors are the most widely used in various industrial applications because the following properties - self starting property; elimination of a starting device; robust construction; higher power factor and good speed regulation. But the induction motor is a constant speed machine which makes its applications pretty much limited.

To increase the areas of application of the induction motor, its speed has to be controlled by varying the supply frequency. The advantage of speed control of the induction machine is that it can save the energy spent by the machine. For example, a speed reduction of about 20% can improve the energy savings upto 50% in a centrifugal pump.

This means that an energy inefficient motor can be replaced by a variable speed machine given an efficient control system. The base speed of an induction motor is directly proportional to the supply frequency and the number of poles. Now since the number of poles is fixed in the motor design, the best way to control the speed of the motor is to vary the supply frequency.

The torque developed by the motor is directly proportional to the ratio of the applied voltage and the supply frequency. The torque is kept constant by varying the applied voltage and the supply frequency and by keeping their ratio to a constant value. The torque speed characteristics also denote that :

The starting current requirement is lower.2. The stable operating point of the motor is increased. The motor can be run at 5% of the synchronous speed upto base speed instead of running the motor from the base speed itself. 3. The acceleration and deceleration of the motor can be controlled by controlling the change of the supply frequency of the motor with respect to time. The open loop Volts/Hz control of an induction motor is far the most popular method of speed control because of its simplicity and these types of motors are widely used in industry. Traditionally, induction motors have been used with open loop 60Hz power supplies for constant speed applications.

For adjustable speed applications, frequency control is natural. However, voltage is required to be proportional to frequency so that the stator flux remains constant if the stator resistance is neglected.

In an outer loop controlled induction motor drive, the actual rotor speed is compared with its commanded value, and the error is processed through a controller usually a PI controller and a limiter are used to obtain the slip-speed command.

The limiter ensures that the slip-speed command is within the maximum allowable slip-speed of the induction motor. The slip-speed command is added to electrical rotor speed to obtain the stator frequency command. Thereafter the stator frequency command is processed as in an open loop drive. In the closed loop induction motor drive the limits on the slip speed, boost voltage and reference speed are externally adjustable variables. The external adjustment allows the tuning and matching of the induction motor to the converter and inverter and the tailoring of its characteristics to match the load requirements.

CHAPTER 6

6.1 PULSE WIDTH MODULATION TECHNIQUE:

The advent of the transformer less multilevel inverter topology has brought forth various pulse width modulation (PWM) schemes as a means to control the switching of the active devices in each of the multiple voltage levels in the inverter.

The most efficient method of controlling the output voltage is to incorporate pulse width modulation control (PWM control) within the inverters. In this method, a fixed d.c. input voltage is supplied to the inverter and a controlled a.c. output voltage is obtained by adjusting the on and–off periods of the inverter devices. Voltage-type PWM inverters have been applied widely to such fields as power supplies and motor drivers. This is because: (1) such inverters are well adapted to high-speed self turn-off switching devices that, as solid-state power converters, are provided with recently developed advanced circuits; and (2) they are operated stably and can be controlled well.

The PWM control has the following advantages:

(i)The output voltage control can be obtained without any additional components.
(ii)With this type of control, lower order harmonics can be eliminated or minimized along with its output voltage control. The filtering requirements are minimized as higher order harmonics can be filtered easily.

The commonly used PWM control techniques are:

(a)Sinusoidal pulse width modulation (sin PWM)
(b)Single pulse width modulation
(c)multiple pulse width modulation

The performance of each of these control methods is usually judged based on the following parameters: a) Total harmonic distortion (THD) of the voltage and current at the output of the inverter, b) Switching losses within the inverter, c) Peak-to-peak ripple in the load current, and d) Maximum inverter output voltage for a given DC rail voltage.

From the above all mentioned PWM control methods, the Sinusoidal pulse width modulation (sinPWM) is applied in the proposed inverter since it has various advantages over other techniques. Sinusoidal PWM inverters provide an easy way to control amplitude, frequency and harmonics contents of the output voltage.

6.2 SINUSOIDAL PULSE WIDTH MODULATION

In the Sinusoidal pulse width modulation scheme, as the switch is turned on and off several times during each half-cycle, the width of the pulses is varied to change the output voltage. Lower order harmonics can be eliminated or reduced by selecting the type of modulation for the pulse widths and the number of pulses per half-cycle.

Higher order harmonics may increase, but these are of concern because they can be eliminated easily by filters. The SPWM aims at generating a sinusoidal inverter output voltage without low-order harmonics. This is possible if the sampling frequency is high compared to the fundamental output frequency of the inverter.

Sinusoidal pulse width modulation is one of the primitive techniques, which are used to suppress harmonics presented in the quasi-square wave.

$$Vo = a0 + \sum(ancoswnt + bnsinwnt)$$

Where n=1,3,5…….∞

The figure below gives the sinusoidal pulse width modulation.

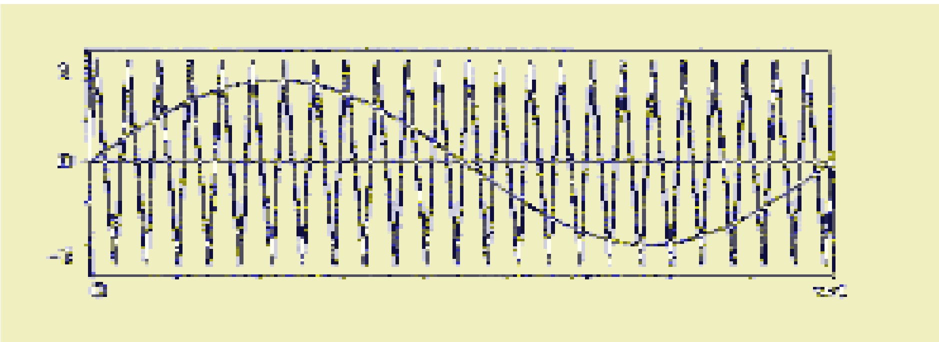


Fig6.1

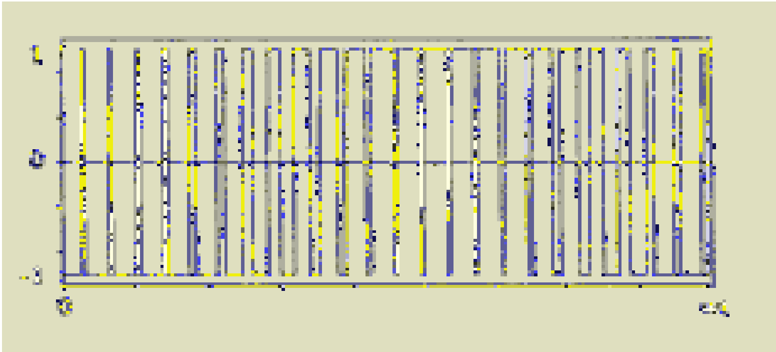


Fig 6.2

Fig 6.3

CHAPTER 7

7.1 INDUCTION MOTOR FED BY Z SOURCE INVERTER AND ITS WORKING

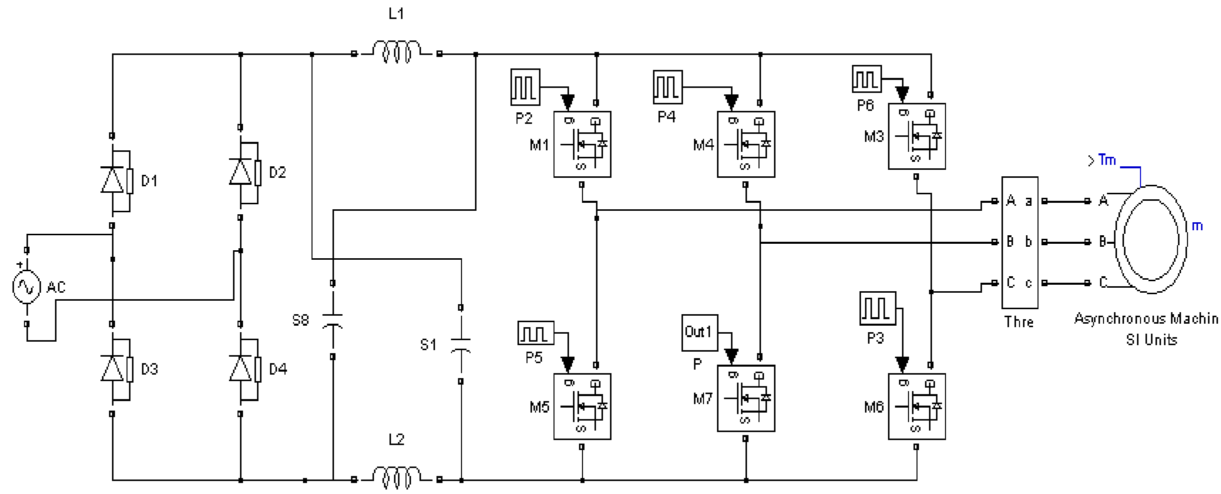


Fig 7.1

The three phase induction motor is connected to the three inverter bridge whose 6 switches are controlled in order three phase ac output from the dc bus. PWM signals generated from a pwm generator are used to control the 6 switches. The DC bus voltage in this case is increased or decreased to the required value by the improved version of the z source inverter.

The higher value of the dc voltage is obtained when the value of the inductance in the circuit is increased. Likewise, the dc voltage is decreased by increasing the value of the capacitance in the circuit, thereby providing buck/boost functionality to the circuit. And also the Z source inverter allows both the switches in the same phase leg to be gated at the same time without producing any damage to the switches.

This negates the presence of any dead time in the circuit, and actually helps in the buck/boost performance of the improved ZSI by controlling the duty cycle of the shoot through state. The amplitude of the phase voltage is dependent on the duty cycle of the PWM signals given to the inverter switches. At any instant of time, 3 switches (2 upper and1 lower or 1 upper and 2 lower) are gated and the remaining 3 are turned OFF.

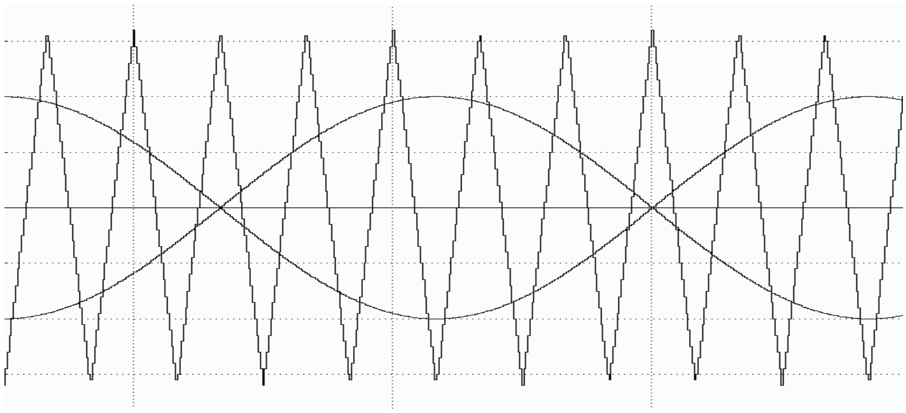
The switching produces a rectangular shaped output waveform that is rich in harmonics. The supplied current with harmonics is made to produce 3-phase sine wave with negligible harmonics by the inductive nature of the motor’s stator windings. The inductive nature of the windings oppose any sudden change in the reverse direction of flow of current until all of the energy stored in the windings are dissipated, when the switches are turned off. This is accomplished using fast recovery diodes, known as freewheeling diodes across every Insulated-Gate Bipolar Transistor (IGBT) switch. Figure 5(a) show the simulation of the open loop operation of the induction motor using MATLAB program.

The simulation results prove that the motor has a high starting torque and does not require any separate starting circuit unlike a few other motors. The motor block used in the simulation is the squirrel cage induction motor block which is a commonly used induction motor type. The rotor bars are permanently shorted in this motor, thus negating the addition of any external resistance to the motor circuit.

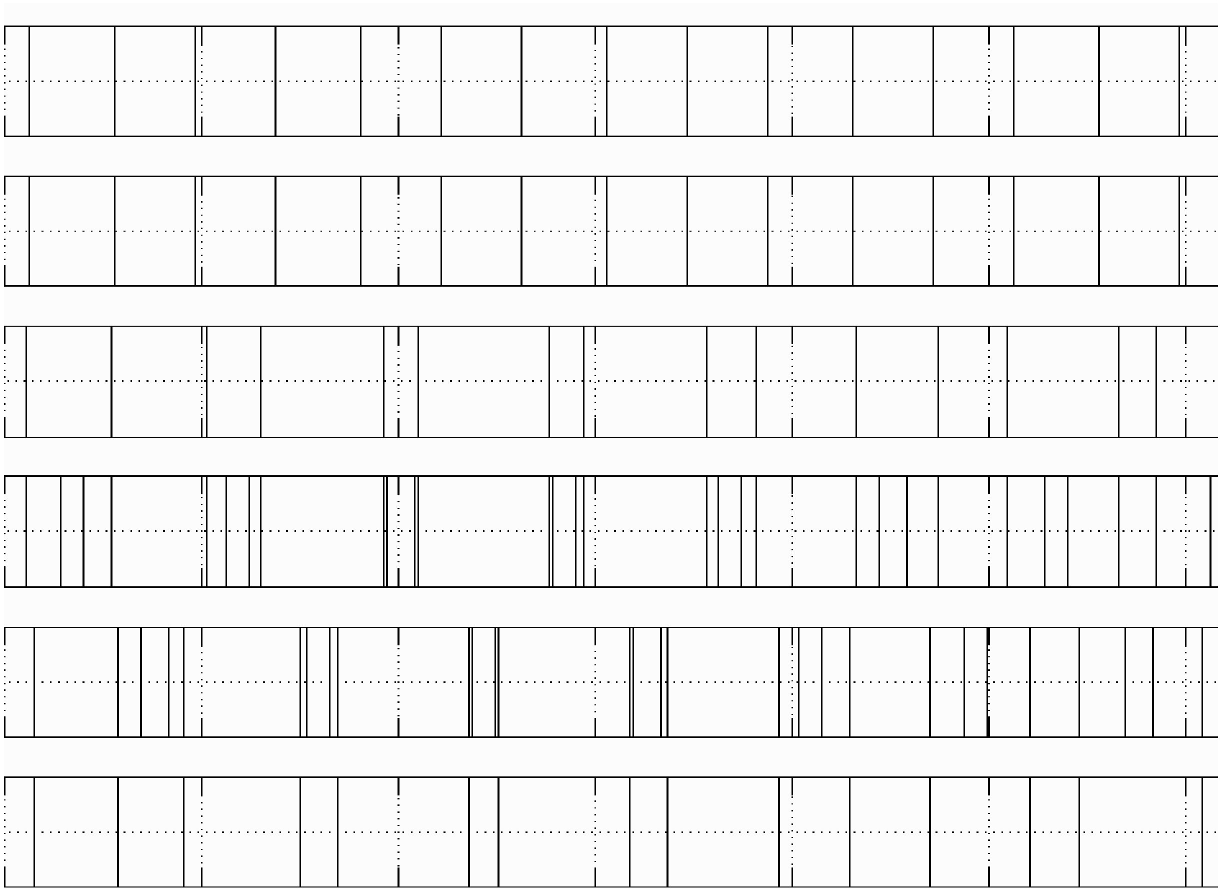
Thus the rotor copper losses are reduced, thus providing higher efficiency. Figure 5(b) shows the simulation of the closed loop operation of the induction motor in which the motor's actual running speed is compared with a base speed, in this case 1200 rpm.

The error between the actual running speed of the motor and the reference value is calculated and the control mechanism is executed by using a PI controller in this case. The control signal is then given to a PWM generator which then produces the required gating signals that are to be given the 6 IGBT switches.

The switches act according to the gate pulses given to them and the speed of the motor is controlled to the required value. The function of the proportional term of the PI controller is to consider the current size of the error value only at the time of controller calculation, and the integral term of the PI controller eliminates offset and sums up the complete controller error history up to the present time, starting from when the controller was first switched to automatic. Sinusoidal pulse width modulation as shown in Fig 6. is employed in the circuit to turn on the switches. The extent, to which the dc voltage is boosted via the Z source network i.e. the boost factor, is decided by the modulation index of the pulse width modulation used.



The switches 1,4 are simultaneously gated in the following figure (Fig 7) to provide the shoot through condition for the inverter. This enables the voltage to be increased to the required value without the additional need of switches like in the case of conventional buck/boost converters. The shoot through condition is also used to buck the voltage given to the load side via proper gating signals thus providing a dual buck/boost function using the same Z source inverter circuit.
Fig 7. Gate pulse to the IGBTs



The input dc voltage of 230V is boosted to a higher value of 393V in this circuit and then converted to an equal value of ac voltage via the inverter, which has been depicted in Fig 8 and Fig 9 respectively. Fig 8. 230V dc voltage is boosted to 393dc voltage.

CHAPTER 8

8.1 INTRODUCTION TO MATLAB CIRCUIT AND SIMULATION

SIMULATION RESULTS

Simulations have been performed to confirm the above analysis. The simulation parameters are as follows:

1. AC input voltage: 230 V

2. Rectifier output voltage: 300V

3. Z-source network: L1 = L2 = 1 mH,

C1 = C2 = 9000 μF

4. Switching frequency: 10 KHz

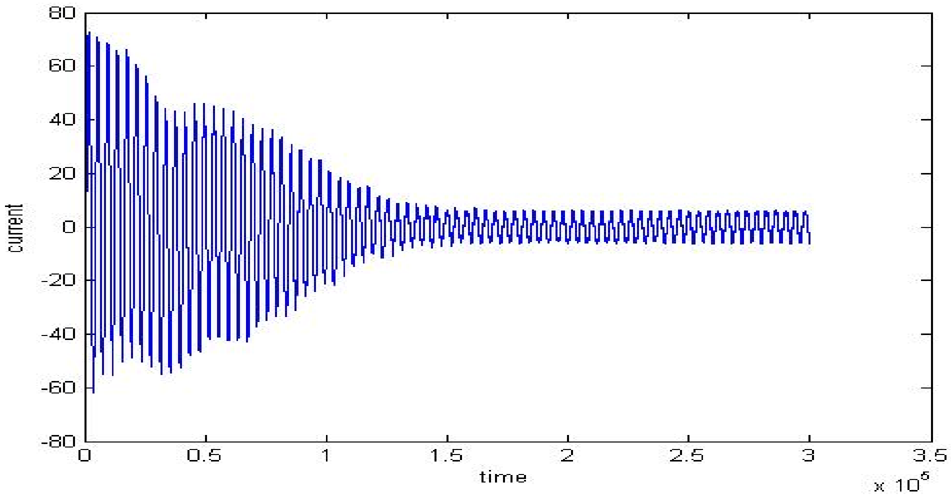


Fig 8.1

Output current of inverter(Ia)

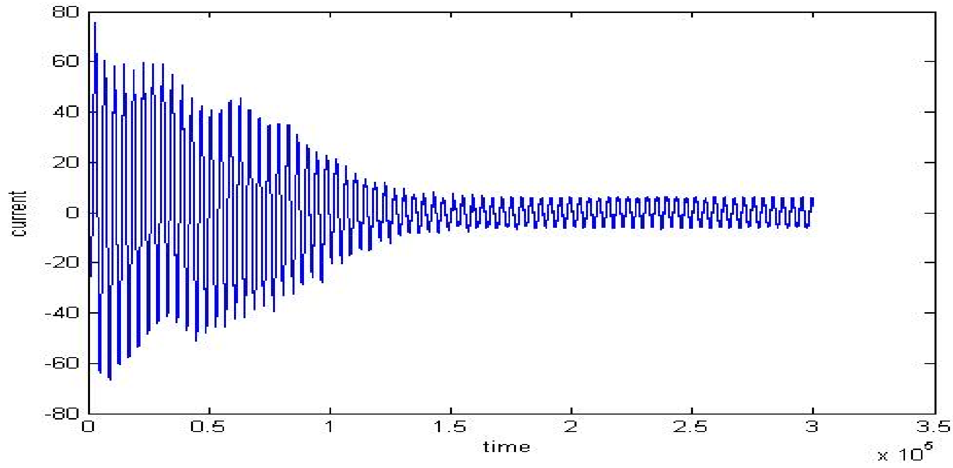


Fig 8.2

Output current of inverter(Ib)

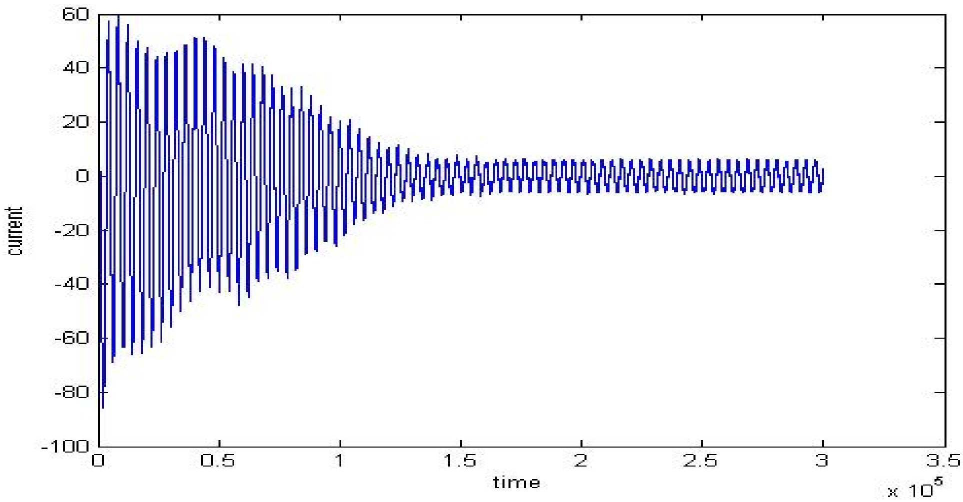


Fig 8.3

Output current of inverter(Ic)

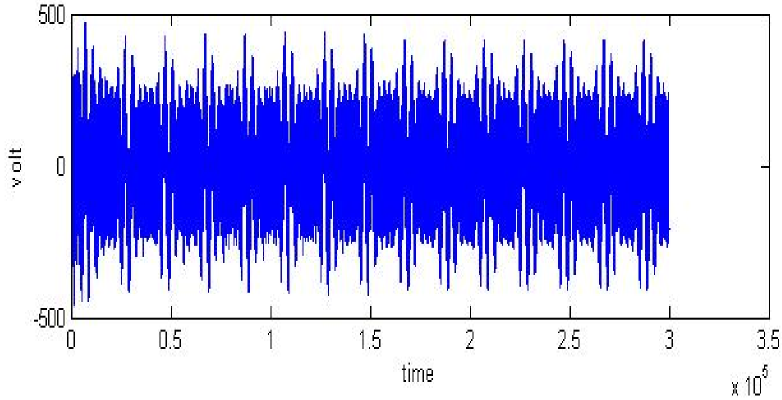


Fig 8.4

Output voltage of inverter(Va)

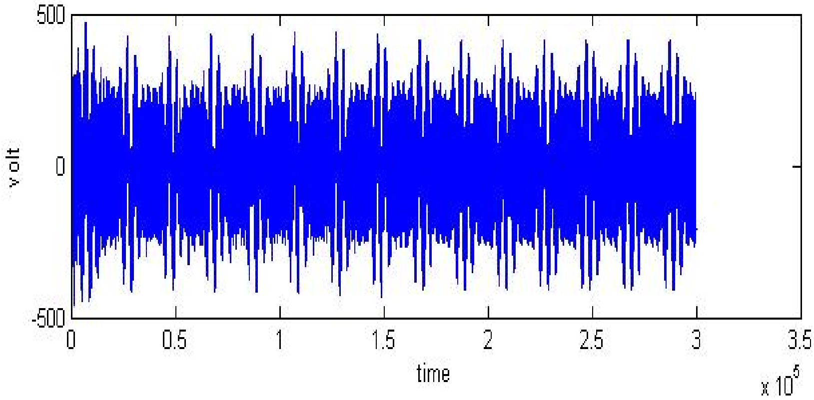


Fig 8.5

Output voltage of inverter(Vb)

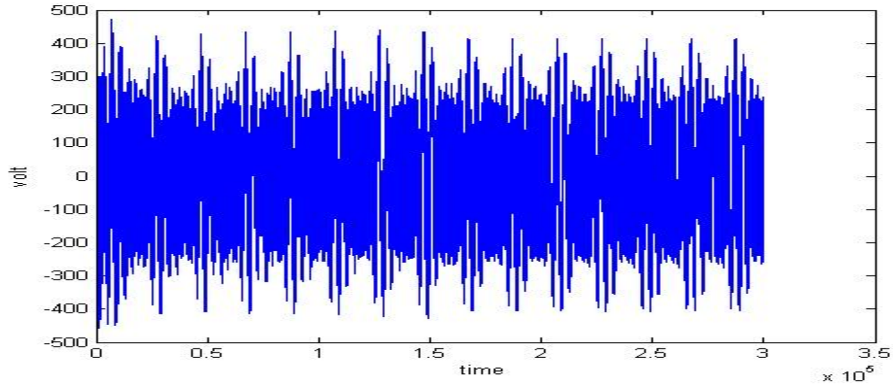


Fig 8.6

Output voltage of inverter(Vc)

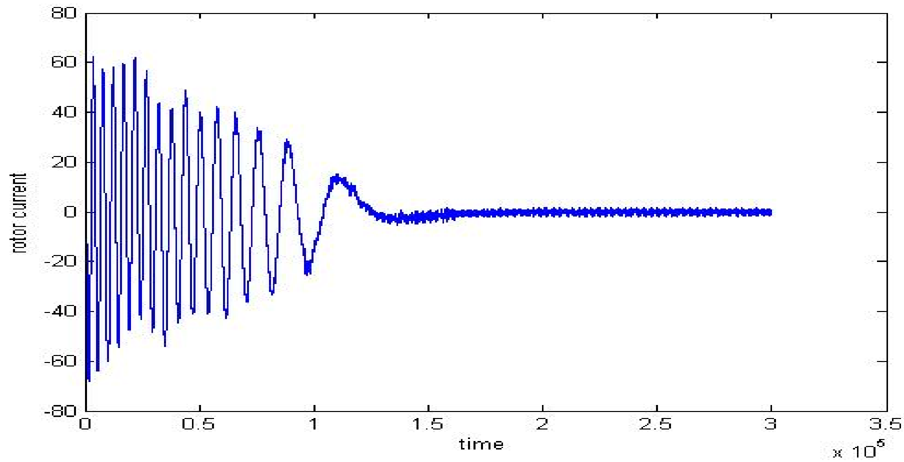


Fig 8.7

Rotor current of induction motor

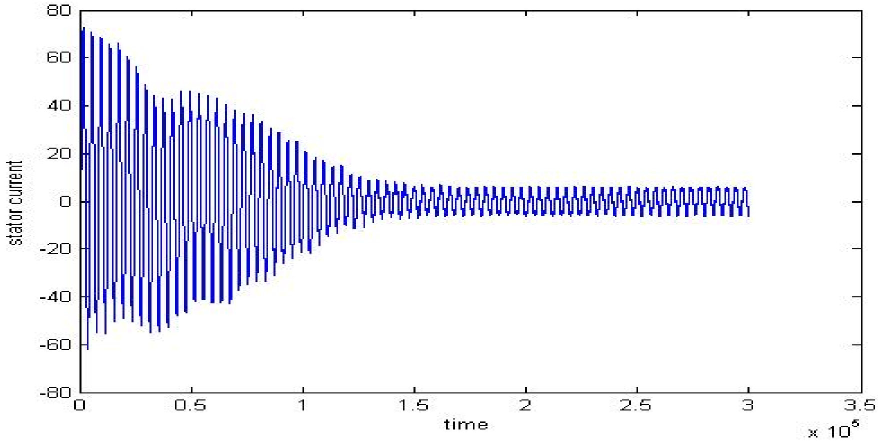


Fig 8.8

Stator current of induction motor

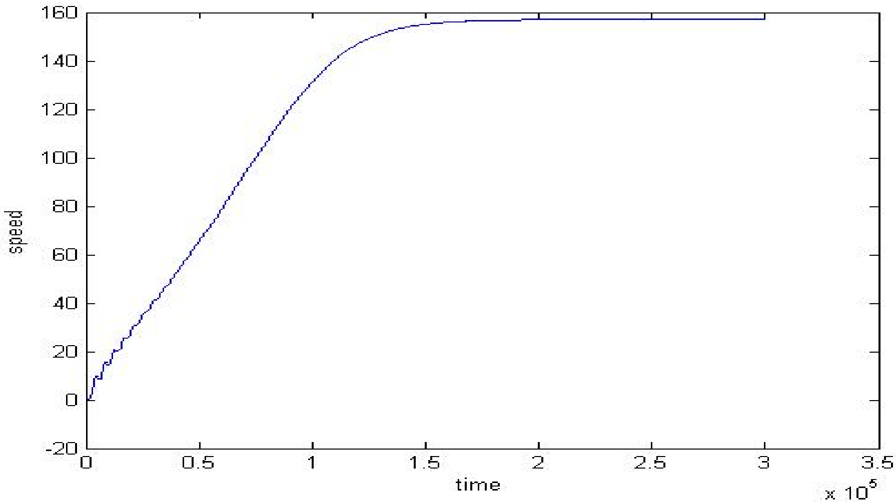


Fig 8.9

Speed of induction motor

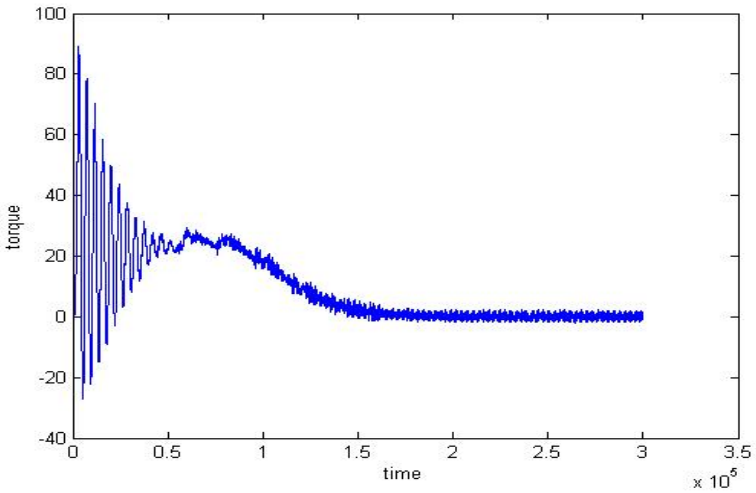


Fig 8.10

Torque of induction motor

CHAPTER 9

9.1 CONCLUSION

The simulation of ZSI fed IM drive has been carried out. Analysis, simulation, and experimental results verified that the output voltage can be boosted to any value irrespective of input voltage by using Z-Source inverter. This circuit also provides reduced line current harmonics. Therefore Impedance Source Inverter ASD system has several unique advantages that are very desirable for many ASD applications:

1. The Impedance Source Inverter concept can be applied to all AC-AC, DC-DC, AC-DC, DC-AC power conversion.
2. The output voltage range is not limited.
3. The Impedance Source Inverter is used as a buck-boost inverter.
4. The Impedance Source Inverter does not affect the Electromagnetic Interference noise.
5. The Impedance Source Inverter cost is low.
6. The Impedance Source Inverter has low current compared with the traditional source inverter.

FUTURE SCOPE

In this report, a Z-Source inverter fed induction motor for electric vehicle applications was presented. Only the power flow from DC source side to motor side was taken in to account. However a dc-dc converter is needed to accept a reverse power flow and to reduce the regenerative voltage to a battery voltage. Hence, the proposed inverter circuit can be modified to include a current fed Z-source dc-dc converter to make the Z-source circuit bi-directional in nature. Also, PID controller can be included for capacitor voltage control with an excellent transient performance which enhances the rejection of disturbance, including the input voltage ripple and load current variation, and have good ride-through for voltage-sags.

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