ISSN: 2096-3246
Volume 54, Issue 02, April, 2022

Performance Analysis of Induction Motor Drive with Peak DC Link Voltage Control using Maximum Boost Controlled Z Source Inverter

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Keywords:
Performance analysis, DC link, Voltage control, Z source, Inverter

ABSTRACT

In order to properly evaluate a Z-source inverter while it is powering an induction motor, closed-loop operation is required. The induction motor and Z-source inverter are in a state of closed-loop control. To improve inverter performance and reduce harmonics, we have opted to use multilevel inverters rather than the more common single-layer kind. In order to get the most out of an induction motor, you need to use a variable-speed drive to control its speed. Z-source inverters precisely regulate the input voltage drop by using the peak dc link voltage, while also filtering out transient disturbances such the input voltage ripple and the load current. In order to adjust the inverter's boost and the induction motor's output frequency, the switching method employs pulse width modulation (PWM) control. In this article, we look at how an induction motor's speed is controlled by a PI controller and how it compares to that of a fuzzy logic controller. When applied to a 1.8 kW induction motor driven by a Z source multilevel inverter, the necessary speed control yields positive results from PSIM simulation, indicating proper performance analysis. In both dynamic and steady-state simulations, the proposed technology is proven to be superior to the conventional voltage source inverter fed induction motor.

1. INTRODUCTION

Since induction motors were first created, their prevalence in usage has skyrocketed. They are actuators in a variety of manufacturing processes, robots, and consumer items. Its rising popularity might be attributable to a variety of factors, including the high quality of the product, the ease of its usage, and the reasonableness of its pricing. One of the limitations of the application that limits motor selection is the need for variable speed operation. Popularity of the Volts/Hertz control approach may be attributed to its ability to accurately adjust speed across a wide range while yet offering excellent operational and transient performance. Scalar control mode is used to describe this method of command. The necessity for a converter that can simultaneously increase and invert voltage has been growing in recent years, prompting the development of several inverter topologies. Despite the fact that all of these novel topologies use a modified dc link stage and a standard VSI as the power converter, Z-Source Inverter emerges as the most competitive and promising.

Using a novel impedance network in combination with an inverter and rectifier, the impedance source inverter is able to circumvent the theoretical hurdles and practical constraints of conventional converters. Z-source inverters are designed to increase dc voltage and produce an output through shoot-through-zero circumstances.

Superior energy to that provided by the ac power supply. The elimination of potentially damaging shoot-through states, which may be caused by electromagnetic interference, is another way in which the Z-source structure improves the inverter's dependability (EMI). ZSI feedback control systems are becoming more important, as seen by the expanding quantity of research on the subject. Capacitor voltage, indirect dc-link voltage control, direct dc-link voltage control, and unified control are the four ways to adjust the ZSI's dc-link voltage. Since this is the case, peak dc link voltage control is the simplest approach to implement. This study analyzes the low-speed-to-rated-speed transition of an induction motor drive supplied by a z source converter using closed-loop speed management. By controlling the voltage of the peak dc link, the system's functioning is improved.

Figure 2 is a diagram depicting the most basic type of a V/f regulated induction motor. The hybrid inverter/induction machine's dynamic performance is enhanced by slip regulation's closed-loop control. A proportional integral (PI) controller and limiter uses the speed loop error to create slip commands. The frequency command is calculated by summing the slip and the speed feed-back (or observer signal). A volts/hertz generator with low-frequency stator-drop correction may be used to convert the frequency instruction into a voltage one. Since the produced torque is proportional to the slip at constant flux, this system may be thought of as open loop with a speed control loop.

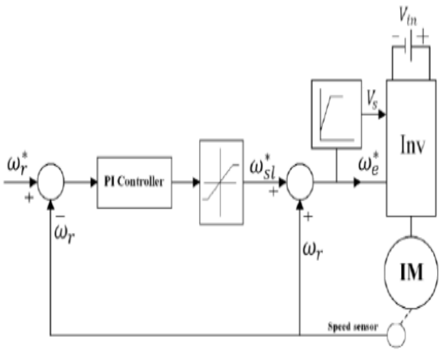

Fig. 1. Closed loop scalar controlled induction motor drive

The topologies of a voltage-type, three-phase Source inverter are shown in Figure 2; in this case, the network terminals are linked to a dc voltage source and a standard VSI with three-phase legs. The on and off switching patterns of VSI might be imitated using z-source voltage inverters. When both switches on a phase leg are turned ON at the same time, a shoot-through condition is created and may severely harm inverters that are not of the Z-source kind.

Nowadays, ZSI control must focus more than ever on minimizing voltage stress while yet achieving the appropriate voltage gain. If a bullet were built using MBC, it could be possible for it to transition into a zero state. For your perusal, we provide the MBC in the form of a handy dandy block diagram. Through the use of

MBC, all 0 states are converted into shot-through 0s, but the 6a-d states are left unaltered. This allows for the optimization of both T0 and B for a given modulation index without introducing any distortion into the waveform of the signal. The circuit enters shoot-through condition, as shown in, if the triangle wave is excessively high or low in relation to the reference curves (Va, Vb, and Vc). There is no set pace at which bullets may breach the shield.

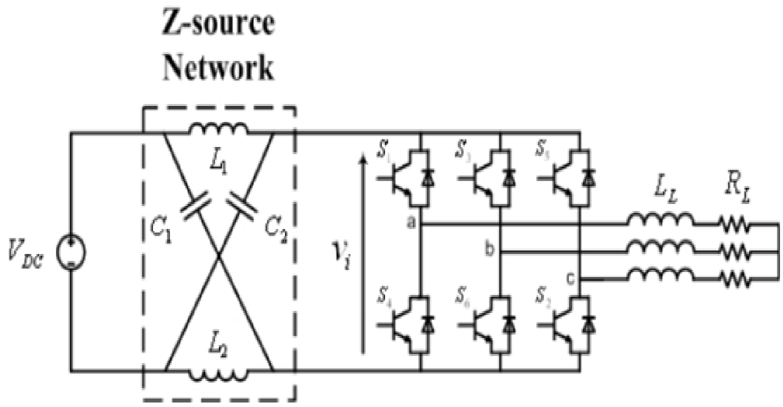

Fig 2. Z source converter

2. INDUCTION MOTOR

Torque is produced by an asynchronous induction motor when the magnetic field of the stator winding induces a current into the rotor. Therefore, unlike a universal, DC, or synchronous motor, an induction motor may function without having wires attached to the rotor. The rotor of an asynchronous motor may be coiled or it may be a squirrel cage.

Three-phase squirrel-cage asynchronous motors are widely used in industry drives because they are inexpensive, have long lifespans, and are very durable. Single-phase induction motors are more common in fans and other low-power appliances because they are more energy-efficient. Induction motors coupled with variable-frequency drives are increasingly being used for applications requiring speed regulation (VFDs). Energy savings opportunities for variable-torque centrifugal loads, such as fans, pumps, and compressors, are substantial when using present and future induction motors with variable frequency drives (VFDs). Common uses for squirrel cage induction motors include constant-speed and variable-frequency drive (VFD) setups. In variable-speed applications, not only do motors but also voltage and frequency drivers vary speeds.

The rotor's effective rotating speed must be smaller than the RMF's rotational speed for the rotor to produce current in its conductors. Torque increases as a result of increased current in the rotor's windings when the rotor speed drops below synchronous speed. To calculate slip, divide the number of revolutions of the rotor's magnetic field by the number of stator field revolutions. Since the load slows the wheel down, the slip rises, and the torque is increased, the load may be spun. The term "asynchronous motor" is also used to describe induction motors. [25] An induction motor may be used to generate electricity, or it can be unrolled to create a linear induction motor that can generate linear motion directly.

Table 1: 1.8 Kw Induction Motor Parameters

Parameter	*Value*
Output power	1.8kv
RMS linevoltage	400V
Input frequency	50Hz
No.ofpoles	4
Statorresistance, R_s	2.56Ω
Rotorresistance,R_r	1.97Ω
Stato rinductance,L_{ls}	0.01472Ω
Rotorinductance,L_{lr}	0.01124Ω
Mutualinductance,L_m	0.2815Ω
Moment ofinertia,J	0.012024kgm^2
Rate ddc input voltage	500Vdc
Capacitors	750µF
Inductors	450µH

3. PROPOSED MLI

To convert direct current (DC) to alternating current (AC), an inverter must be used (AC). In the case of a blackout, the inverter will kick in and supply emergency power. Multiple aircraft systems use inverters, which convert direct current (DC) into alternating current (AC). Many typical household electrical gadgets utilize alternating current (AC) energy, including lights, radar, radio, motors, and more.

Multilevel Inverter

There has been a rise in the need for very high power across a wide variety of industrial uses in recent years. But many popular manufacturing devices may function on a medium or even low voltage source. Connecting many loads to a single high-voltage power supply may improve the efficiency of high-powered industrial motors, but it might have catastrophic effects for the other loads. Medium voltage is required for certain motor drives and utility equipment. Originally developed in 1975, multi-level inverters have subsequently found widespread usage in both high-power and medium-voltage settings. In high-power and medium-voltage industrial settings, the multilayer inverter may replace the traditional inverter.

Advantages of Multilevel Inverter

The multilayer converter has several advantages.

Multilayer inverters reduce strain on the motor and keep it from burning out by producing a common-mode voltage.

Also, the electricity that is used to power it:

Multilevel inverters lessen distortion in the input current.

Change Velocity:

The basic switching frequency of the multilayer inverter may be adjusted to suit either high or low operation. It's worth noting that efficiency is enhanced and switching loss is minimized when the switching frequency is lowered.

Reduction in Harmonic Distortion

When selective harmonic elimination is used in conjunction with a multi-level design, total harmonic distortion in the output waveform may be decreased without resorting to a filter circuit.

Multiple multilayer inverter configurations are shown in the following diagram.

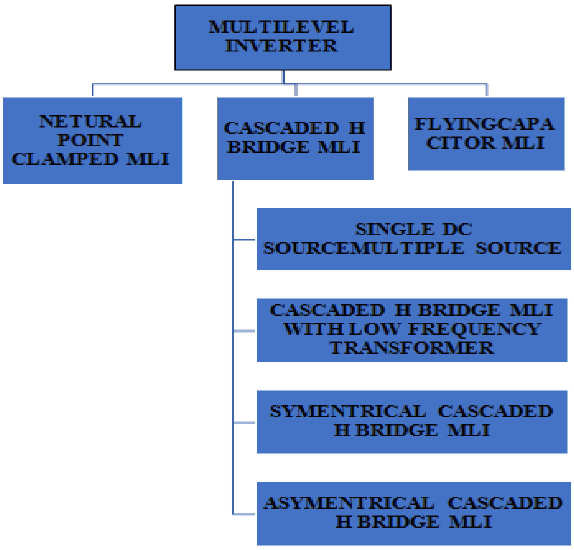

Fig. 4 Different types of multilevel inverter

4. NETURAL POINT CLAMPED MLI

To ensure that voltage is delivered evenly throughout the many power switches, Neutral Point Clamped (NPC) inverters utilize clamping diodes to set them apart from other types of multilevel power converters. Following is a diagram depicting the topology used in the simulation of a three-phase neutral point clamped (NPC) inverter.

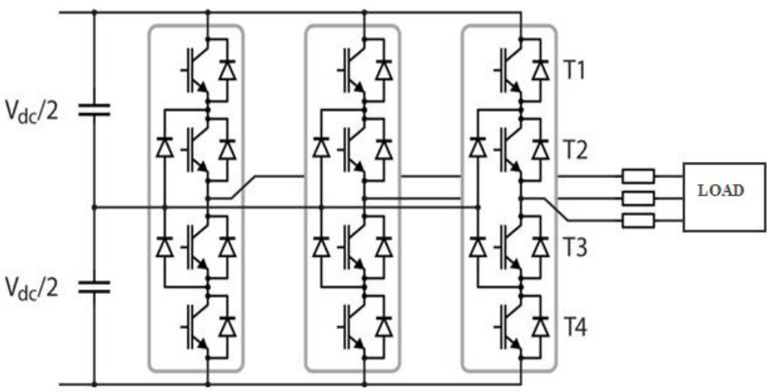

Fig .5 Topology of three-phase neutral point clamped (NPC) inverter

Neutral Point Clamped inverters reduce the need for filtering since the quality of the waveform they produce is superior than that of two-level inverters. When used in medium-voltage contexts, their strong blocking voltage capabilities becomes invaluable. However, owing to the complexity of the mechanical arrangement of the power components beyond three levels, NPC-type inverters are seldom employed in industry.
Any number of modulation methods may be used to Neutral-Point-Clapped inverters. Several factors, such as: arriving at a voltage ground

In order of effectiveness, the best methods of preventing theft are:
Losses in power switches: a case study
On the AC side, we have enhanced harmonic performance.

5. EXISTING CONTROLLER

In industrial control, a PI controller is often used to regulate parameters including temperature, flow rate, pressure, and velocity. The proportional integral (PI) controller, which has a control loop as its feedback mechanism, is one of the most accurate and dependable controllers.
Evidence indicates that PI control is effective in guiding a system to a desired state. Heavy reliance on it may be seen in the chemical and scientific fields, as well as in automated and non-automated businesses. Utilizing closed-loop control feedback, PI control maintains a process's real output as close to the intended or target output as is technically feasible.

6. PROPOSED CONTROLLER

The range of possible applications of fuzzy logic and the number of fields where it is applied have both expanded. These algorithms might be useful for a wide variety of applications, including but not limited to industrial process control, medical equipment, decision-support systems, and portfolio selection. This includes consumer gadgets such as cameras, camcorders, washing machines, and microwave ovens.

The article's use of the term "fuzzy logic" might be interpreted in two ways. Fuzzy logic is a logical framework that develops from multivalve logic. However, in a more general sense, FL is similar to the idea of fuzzy sets, which looks at groups whose membership is conditional on degree rather than absolute exclusion or inclusion. A subset of fl might represent common conceptions of fuzzy logic. In many fundamental ways, fuzzy logic is distinct from traditional multi-gate logical systems.

Fuzzy Logic Controller

Simple Fuzzy Logic Controllers

In the case of first-generation fuzzy logic controllers, a block diagram may often convey the essential information.

As a result of its extensive training, this module can differentiate between any pair of fuzzy input and output values. The term set and associated membership functions will be used to create input variables for the fuzzy rule-base system and output variables (control actions for the controlled plant). Exemplification of fuzzy logic using a basic regulator.

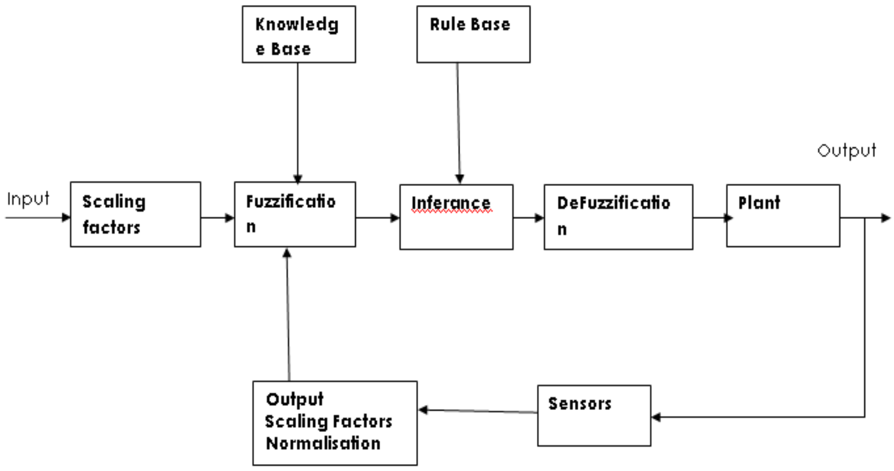

Fig 6 .Simple Fuzzy Logic Control System

7. PROPOSED SIMULATION RESULTS

Dynamical systems may be modeled, simulated, and analyzed with the help of Simulink. It may be used to nonlinear and linear systems modeled in continuous time and sample time, respectively. Simulink has a GUI for making block diagram models, which speeds up the modeling process (GUI). Models may be constructed in either an upward or downward direction because of their tree-like structure. After we gain a high-level overview of the complete arrangement, we can next focus in on the finer details of certain components. The usage of scopes and other sorts of display blocks might allow us to see the simulation's results unfold in real time. In addition, we may experiment with different configurations and watch how they impact the system in real time.

There are two separate steps involved in using Simulink to model a dynamic system. Using Simulink's model editor, a graphical representation of the system to be studied must first be developed. It's a visual depiction of the time-varying mathematical connections between a system's inputs, states, and outputs. The following step involves running a time-based simulation of the system in Simulink. The simulation will be executed by Simulink using the information you provide.

8. BLOCK DIAGRAM

Visualize a functional system with the help of Simulink's block diagram editor. The system is made up of blocks of symbols that are linked together by lines. Each unit is a timed or nonstop (dynamic) mechanism that yields some kind of result (a discrete block). The beginnings of the lines indicate the inputs to the blocks, while the ends of the lines reveal the blocks' outputs. In a block diagram, each block stands in for a single occurrence of a certain category. The outputs of a block depend on its type, as well as its inputs, states, and the passage of time. It is acceptable practice to include as many of each kind of block in a block diagram as is necessary to adequately represent the system being modeled. As the smallest dynamic system type, blocks are Simulink's bread and butter. The following items, or any combination thereof, may make up a block:

The three components of a setup are
1) Inputs,
2) States, and
3) Outputs.

A compiled set of results.
Time, inputs, and the condition of the block all have a role in the final product (if any). A block's output is related to its inputs, states, and time by a specific function; this function is instance-specific.

9. SIMULINK BLOCK LIBRARIES

Simulink's modular building components are organized in function-based libraries.
You may find the fundamental building elements for creating signals in the Sources manual.
The output of several blocks may be seen or recorded using a sink.
Finally, discrete-time components may be expressed using Discrete library blocks.
Linear functions may be seen in a block-like layout inside the Continuous library.
Fifthly, there are blocks in the library's "Math" section that teach common mathematical procedures.
You may find comprehensive descriptions of useful functions (7) and table lookups (9) in the blocks (6) of the Functions & Tables library (8).
Seven) Nonlinear functions are available as building blocks in the Nonlinear library.
In order to do tasks like as multiplexing and demultiplexing, implementing external input/output, communicating data to other areas of the model, etc., the Signal & Systems library provides blocks that may be used to accomplish these tasks.
The library's components can be used as building blocks to create a wide variety of subsystems.
The Extras block library is a part of the larger library known as the Block sets and Toolboxes library.

10. SUB SYSTEMS

With Simulink, you can quickly and easily create graphical block diagrams to represent complicated systems as a collection of linked components. The Subsystem block and model editor in Simulink allow us to create a fully-functional subsystem. When creating hierarchical models, components may be embedded into one another at any level of granularity. A switch in the value of a triggering or enabling input may initiate a conditionally executed subsystem.

11. SOLVERS

Using the information in the model, Simulink may simulate a dynamic system by computing the system's state using a series of time step solvers over a certain time interval. Solving a model entails deducing the future states of a system from the model itself. No one strategy works equally well for all types of model solving.

12. DETERMINING BLOCK UPDATE ORDER

Simulink updates the states and outputs of the blocks making up a model at every time step of a simulation. As a result, the outcomes will change based on the sequence in which the blocks are exchanged. A block must be updated after the blocks that drive its inputs if its outputs are a function of their inputs at the current time step. In such case, the findings of the block would be worthless. While running a simulation, it is not necessary to update blocks in the order in which they appear in the model file. During the model's startup in Simulink, the blocks are placed in their proper positions.

13. PROPOSED CLOSED LOOP SPEED CONTROL OF AN INDUCTION MOTOR FED BY Z-SOURCE MULTILEVEL INVERTER

The graphic depicts a peak dc link voltage control system for closed loop speed regulation of a z-source multilevel inverter fed induction motor drive.

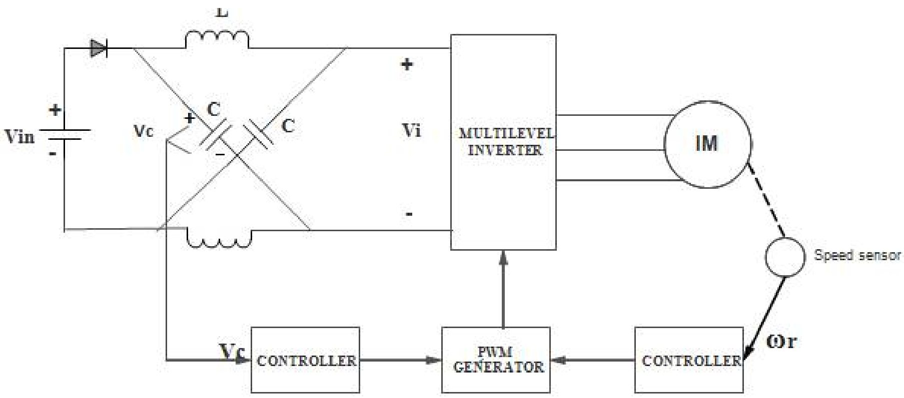

Fig 7.Closed loop scalar controlled Z source multilevel inverter fed induction motor drive

14. SIMULATION RESULTS

In order to determine whether or not the Z-source inverter can effectively control an induction motor, we construct a PSIM simulation diagram. Table I displays the most critical simulation settings.
By simulating a power supply circuit for an induction motor drive, we compare the performance of a voltage source inverter (VSI) with that of a Z-source inverter. The drive communicates with the PWM signal generator to convey the motor's rotational speed. Whenever the load on the motor changes, we check the stator current and the speed at which the motor is spinning.
Extensive testing is performed on the drive system's closed-loop operation across a wide range of speeds and loads. We model the operation of a Z-source multilevel inverter driving an induction motor.

When the rotating rates of the induction motor and the IME are different, pulse width modulation signals are produced. Below is an excerpt from a simulation demonstrating the usage of a Pi and Fuzzy controller to set a maximum allowable voltage in a dc circuit.

When determining the rotational speed of an induction motor, the Z sourceconverter Pi controller takes sensor data into account. The device is powered by a 1,500 RPM rotating, four-pole synchronous induction motor.

PI controller at Z source MLI fed induction motor drive with PWM control technique

ZSI has produced a design (Fig. 6.2) to simulate an induction motor. A PI controller is used in both the inverter and the induction motor in this closed-loop system to maintain a constant 400V dc input voltage. In Figure 6.3, we can see the system response of an inverter-fed VSI motor drive operating at its rated input voltage, output voltage, and output current.

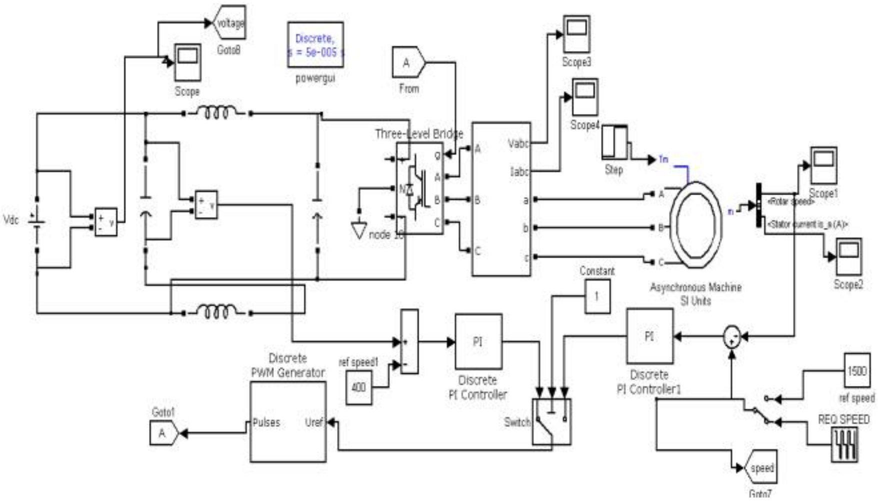

Fig:8. The simulation diagram of ZSI fed induction motor drive using pi controller

The motor's maximum speed is 1492 RPM, which cannot be reached while using only a Raspberry Pi. Z-source inverters use a Multilevelinverter(MLI) with a 3-level bridge and 12-switch pulse to invert the DC input voltage to the AC output voltage while filtering out harmonics.

The motor can be revved up to full speed in less than 0.2 seconds, and its torque remains constant throughout its entire operating range.

In Figure 6.4 below, we can see how the stator current in an induction motor relates to the rotational speed of the motor.

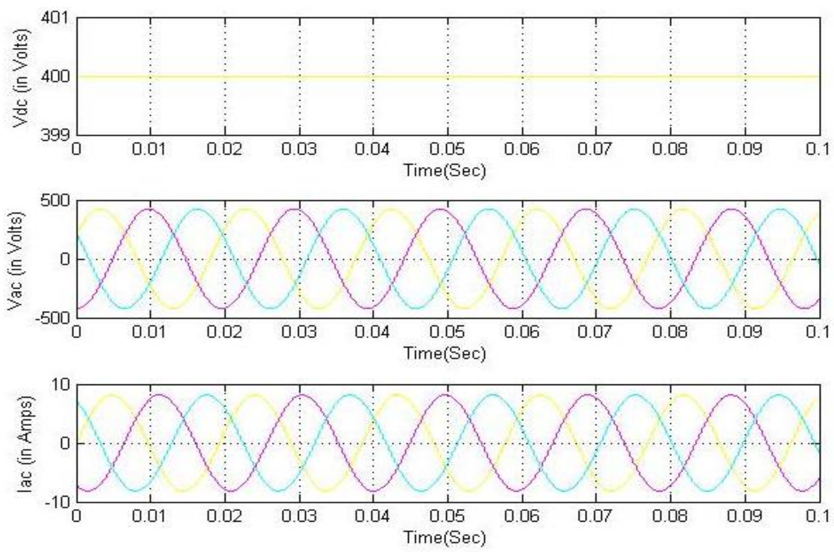

Fig:9 .The system response of VSI fed induction motor drive with rated input voltage and inverter output voltage and current.

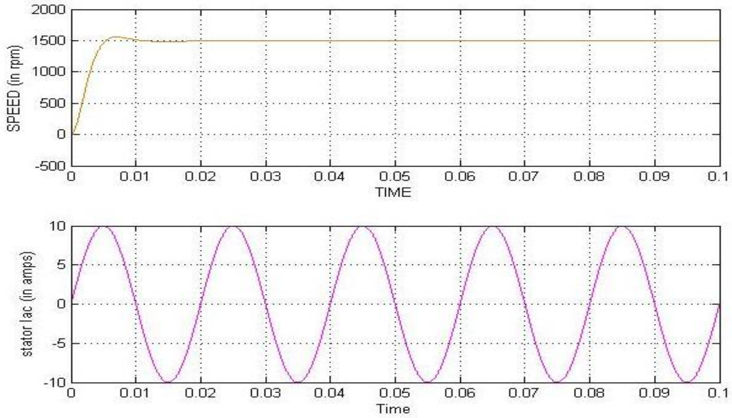

Fig:10 .The system response of VSI fed induction motor drive with rated speed and stator current

The accompanying figure shows the substantial difference in speed and current waveforms between the rated input voltage and a lower input voltage for an induction motor drive powered by a controlled voltage inverter. Z source inverter fed induction motor drives provide a novel approach to energy saving by sidestepping the theoretical and conceptual difficulties experienced by voltage source inverter fed induction motor drives when the input voltage is reduced by 20%. Keeping the rated output voltage at 1492rpm for both the inverter and the motor requires the remaining 3/4 of the power, which is provided by the Z source (ML)inverter with peak dc link voltage. Unfortunately, the motor can't attain synchronous speed. Figure 6.5 displays the system response of a VSI-fed induction motor at input and rated output voltages below their nominal values.

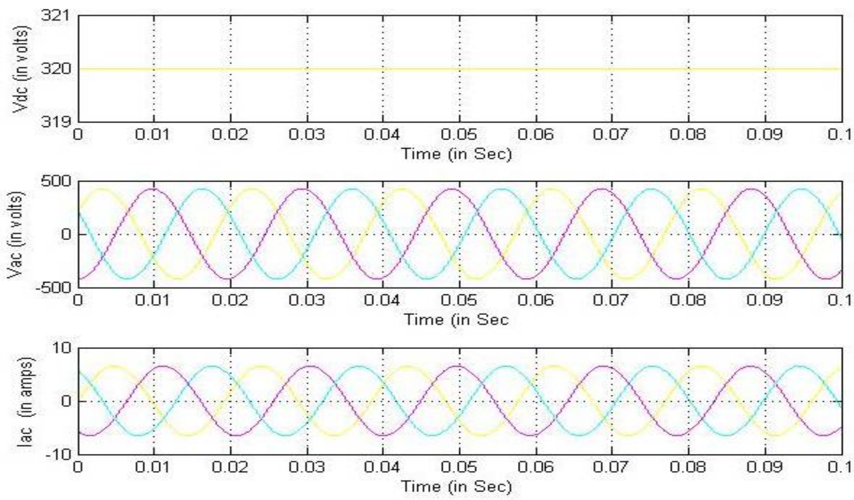

Fig:11. The system response of VSI fed induction motor with reduced input voltage and rated output voltage

FUZZY LOGIC controller at Z source MLI fed induction motor drive with PWM controltechnique

Even if synchronous operation is impossible, the output voltage of the aforementioned circuit may be kept at its nominal value by using a proportional-integral (PI) controller. Fuzzy logic may be used in pulse width modulation (PWM) generators that power induction motors. Fuzzy logic may be used to analyze data about induction motors, such as the gap between the rated and actual speeds. The simulation results for ZSI's induction motor fuzzy logic controller are shown in Fig. 6.6. The induction machine's Fuzzy logic controller and the PI of the multilayer inverter work together to allow for a dc input voltage of up to 400V.

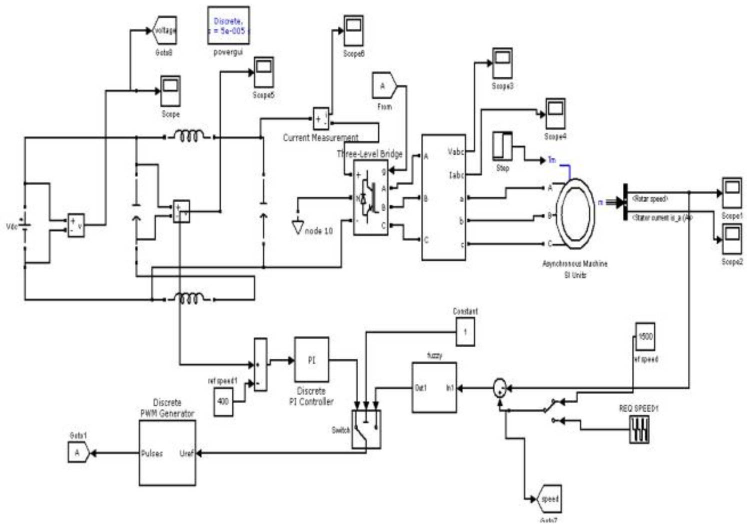

Fig:12. Simulation diagram of ZSI fed induction motor drive with Fuzzy logic controller

An induction motor coupled with a motor drive allows for a rotational frequency of 1500 rpm. Fuzzy logic has allowed for improvements that reduce the time it takes for a motor to accelerate from a stop to around 0.01 seconds. Figure (6.2) shows that the output voltage and current of the VSI and the pi controller are both within their respective parameters. As can be seen in Figure 6.7, as the rotational speed of a motor increases, so does the current drawn from the stator.

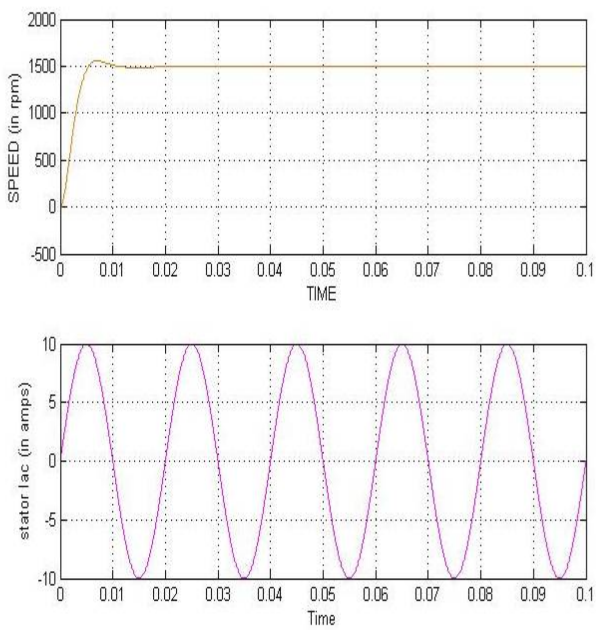

Fig: 13. The system response of VSI fed induction motor drive with rated speed and stator current.

Savings of up to 20% on energy costs may be possible with a 320Vdc input voltage. A single loop controller is used to maintain synchronization between the rated output voltage of the inverter and the driving speed of the induction motor when the ZSI is operating at its maximum dc link voltage. When the input voltage, the speed, and the stator current all fall, as shown in Figure 6.8, the system response of a VSI fed induction motor drive is shown. The system's reaction to changing the inverter's voltage and current supply to the induction motor is shown in Figure 6.9. Motors driven using fuzzy logic, unlike those controlled by the proportional integral, may reach synchronous speed. The use of fuzzy logic in IM enhances the control system performance and decreases the time to stable state in comparison to PI.

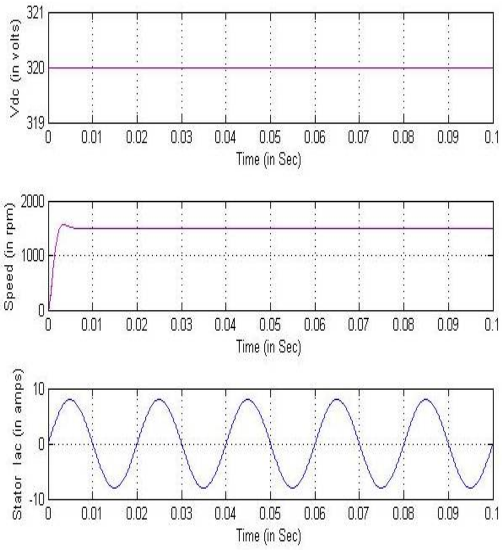

Fig: 14. The system response of VSI fed induction motor drive with reduced input voltage, speed, and stator current.

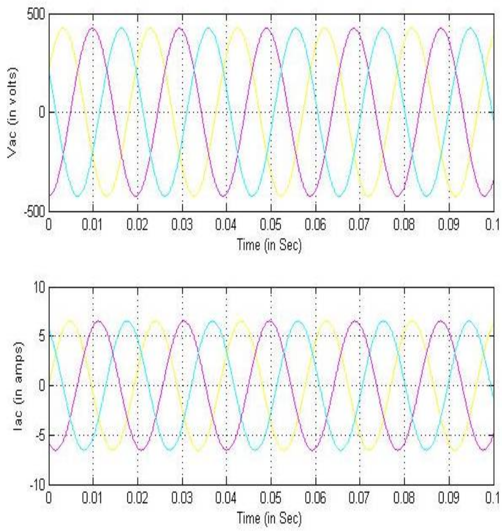

Fig: 15. The system response ZSI fed induction motor drive rated output voltage and current.

If the induction motor's parameters are adjusted correctly, the speed and torque may be maintained at a constant level. It is possible to estimate the lifespan of a pulse width modulation (PWM) induction motor, maybe powered by a Z-source inverter, by using a proportional-integral (PI) or proportional-integral (FL) controller. There are a wide range of power options available for motor output. The diagram in Fig. 6.10 illustrates one approach of controlling the drive of a VSD induction motor.

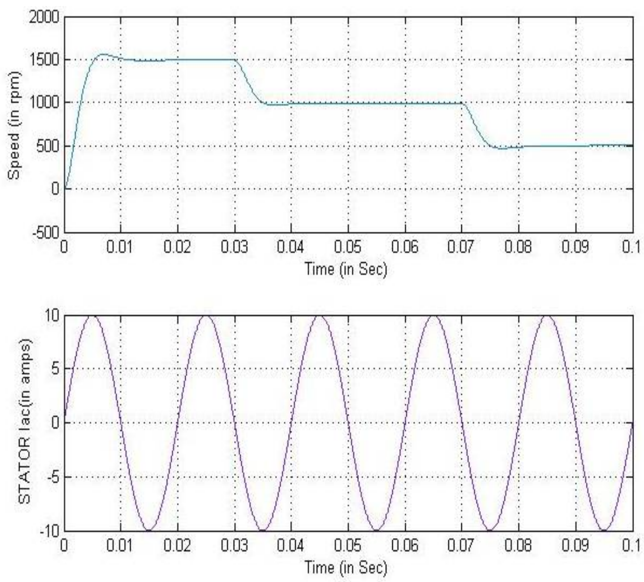

Fig: 16. Induction motor drive at required speed at different time intervals.

The inverter's output may be maintained at a set voltage and current with the use of a proportional integral (PI) controller or a Fuzzy logic controller. To illustrate, here is an image of a multilayer inverter being fed by a Z source converter with a PI controller (6.6 & 6.2). FFT analysis may be used to find out how many harmonics are in a specific output voltage given a certain input value. In both cases, the inverter's output voltage has a total harmonic distortion (THD) of 2.93 percent. The output voltage of the inverter was analyzed using a Fourier transform, and the findings are shown in Figure 6.11..

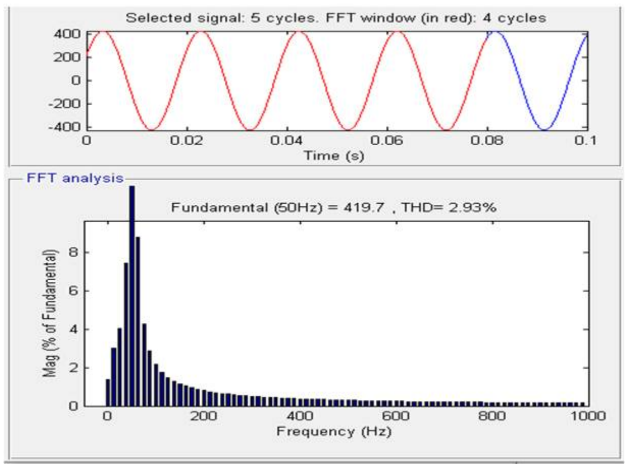

Fig: 17. THD at inverter output voltage

15. CONCLUSION

In this study, we provide a new method of closed-loop speed control for an induction motor controlled by a Z-source inverter, using voltage and frequency feedback. The dc connection's maximum voltage is kept constant by a single feedback loop. The simulations verified the efficiency of the proposed closed loop speed control schemes at startup and with input voltage. Increasing the voltage on a linear capacitor boosts ZSI efficiency. The proposed method provides transient responses that are insensitive to a 20% drop in dc input voltage, as well as insensitivity to changes in the voltage of the reference capacitor and the reference output voltage. Switch stress may be reduced and the output voltage can be precisely controlled by experimenting with various shoot-through intervals T0,zero states for a particular modulation index.

A multilevel system's voltage and power output rise in direct correlation with the number of levels at which it is used.

A PWM multilayer inverter, unlike a standard inverter, pulses the current across the stator.

Productivity and efficiency may both rise as a result of this basic practice.

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