

Field Programmable Gate Array (FPGA) Controller Application for Four Switch Three Phase Inverter (FSTPI) Drive

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ABSTRACT: In Process industries lots of pumps, fans, and compressor are used for various application uses Induction motor. Most of the times these pumps were throttle which causes pressure spikes in pipe line. Variable speed Drive instead of constant speed can save up to 40% energy consumption in paper & pulp industries. In direct online starts, the driven equipment is subject to a high stress. AC drives gradually ramp the motor up to the operating speed, decreasing the mechanical stress using single-speed starting methods results in abrupt motor starts and in a high level of current from the supplying network to the motor. Using AC drives, the current from the supply will be much lower, and the high starting torque is still available when needed. This project is based on FPGAs (field programmable gate array) which provides switching PWM pulses for Four Switch Three Phase Inverter. Conventional VSI inverter uses six switch thus with use of FSTPI inverter component count of the device is reduced. Unlike traditional solutions based on microprocessors and digital signal processing (DSP) devices, the FPGAs introduce hardware parallelism by breaking the paradigm of sequential execution. A field programmable gate array is a set of digital logic gates and configurable logic blocks which can be reprogrammed to meet the desired motor control features for industrial process applications.

KEYWORDS: FPGAs, Industrial Control Systems, VHDL, Design Methodologies, Programmable Architectures, SoC

I. INTRODUCTION

In Paint shop, Paper, Pulp, Chemical enterprises lot of pumps, fans, and compressor are utilized for different application utilizes Induction engine. The vast majority of the circumstances these pumps were throttle which causes weight spikes in pipe line. Acceptance engine running with variable speed rather than steady speed can set aside to 40% vitality utilization. In direct online begins, the determined gear is liable to a high anxiety.

1.1 Introduction

Air conditioning drives continuously incline the engine up to the working velocity, diminishing the mechanical anxiety utilizing single-speed beginning strategies brings about sudden engine begins and in an abnormal state of current from the providing system to the engine. Utilizing AC drives, the current from the supply will be much lower, and the high beginning torque is as yet accessible when required. Speed execution of new segments and adaptability natural of every programmable arrangement give today numerous open doors in the field of advanced usage for mechanical control frameworks. This is particularly valid with programming arrangements, for example, chip or DSPs (Digital Signal Processors). Be that as it may, particular equipment innovations, for example, Field Programmable Gate Arrays (FPGAs) can likewise be considered as a proper arrangement so as to lift the execution of controllers. A few articles provide details regarding FPGA Architecture [9] and their application to AC engine speed control [4-6] to be sure; these nonexclusive segments join minimal effort advancement, utilization of helpful programming apparatuses and more huge coordination thickness. FPGA innovation is currently considered by an expanding number of originators in different fields of use, for example, wired and remote media communications, picture and flag preparing, where the constantly all the more requesting information through puts exploit the regularly expanding thickness of the chips. Still,

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more as of late, other application fields are in developing interest, for example, medicinal hardware, mechanical technology, car and space and airplane implanted control frameworks. For these inserted applications, decrease of the power utilization, warm administration and bundling, unwavering quality and insurance against sun based radiations are of prime significance. At long last, mechanical electrical control frameworks are additionally of extraordinary intrigue due to the regularly expanding level of expected execution, while in the meantime decreasing the cost of the control frameworks. Without a doubt, FPGAs have as of now been utilized with achievement in a wide range of electric framework applications, for example, converter control (PWM inverters, control calculate remedy, multilevel converters, grid converters[2], delicate exchanging, and STATCOM and electrical machines control enlistment machine drives, SRM drives movement control, multi-machines frameworks, Neural Network control of acceptance engines, Fuzzy Logic control of energy generators, speed estimation) . This is on the grounds that a FPGA-based usage of controllers can productively answer present and future difficulties of this field. A field programmable door cluster is an arrangement of computerized rationale entryways and configurable rationale pieces which can be reconstructed to meet the coveted engine control highlights. While the get together and abnormal state dialects like C are utilized by microcontrollers and DSPs, the innovation free equipment depiction dialects including VHDL and Verilog are utilized to program FPGAs.

In this project a general method to generate pulse width modulated (PWM) signals for control of four-switch, three phase voltage source inverters[3][7], even when there are voltage oscillations across the two dc-link capacitors. The method is based on the so called space vector modulation [10],[11] and includes the scalar version. The proposed method provides a simple way to select either three, or four vectors to synthesize the desired output voltage during the switching period. In the proposed approach, the selection between three or four vectors is parameterized by a single variable. This permits to implement all alternatives, thus allowing for a fair comparison of the different modulation techniques. The influence of different switching patterns on output voltage symmetry, current waveform, switching frequency and common mode voltage is examined.

1.2 Motivation

The FPGAs (field programmable gate array) provide programmable system-on-chip designing environments by incorporating the programmability of programmable logic devices and the architecture of gate arrays which makes it an appreciate solution for drive applications. Unlike traditional solutions based on microprocessors and digital signal processing (DSP) devices, the FPGAs introduce hardware parallelism which replaces sequential execution.

Space vector Modulation technique has become the most popular and important PWM technique for Three Phase Voltage Source Inverters for the control of AC Induction, Brushless DC, Switched Reluctance and Permanent Magnet Synchronous Motors. SVPWM gives 15% enhanced fundamental output with better quality. Space vector is better technique in comparison with PWM & SPWM because of its lesser THD wider linear modulation range easier digital realization .As compare with six switch three phase inverter (SSTPI) Four switch three phase inverter (FSTPI) has lesser number of switches hence cost & losses are minimized.

Space Vector PWM (SVPWM) method is an advanced; computation intensive PWM method and possibly the best techniques for variable frequency drive application.

1.3 Objectives of this project

1. The main objective of this project work are to implement and evaluate performance of Four Switch Three Phase Inverter for the application three phase induction motor with the help of Field Programmable Gate Array.
2. FPGA has higher computation speed; more reliability hence can be able to replace DSP and microcontroller.
3. With the use of only four switches for three phases inverter reduces the component requirement of the power & control circuit.

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1.4 Background

Over the year's induction motor (IM) has been utilized as a workhorse in the industry due to its easy build, high robustness, and generally satisfactory efficiency. By tradition, 6-switch 3-phase inverters have been widely used for variable speed IM drives. The last work on FSTPI for IM drives investigated the performance of a 4-switch, 3-phase inverter fed cost effective induction motor in real time, which has been implemented by vector control. A standard three-phase voltage source inverter utilizes three legs [six-switch three-phase voltage source inverter], with a pair of complementary power switches per phase. The FSTPI structure generates four active vectors in the plane, instead of six, as generated by the SSTPI topology. A reduced switch count voltage source inverter four switch three-phase voltage source inverter uses only two legs, with four switches. [3] Several articles report on FSTPI structure regarding inverter performance and switch control. This thesis presents a general method to generate pulse width modulated (PWM) signals for control of four-switch, three phase voltage source inverters, even when there are voltage oscillations across the two dc-link capacitors. The method is based on the so called space vector modulation, and includes the scalar version. [5] This permits to implement all alternatives, thus allowing for a fair comparison of the different modulation techniques. The proposed method provides a simple way to select either three, or four vectors to synthesize the desired output voltage during the switching period. In the proposed approach, the selection between three or four vectors is parameterized by a single variable. The influence of different switching patterns on output voltage symmetry, current waveform, switching frequency and common mode voltage is examined. [8]

II. LITERATURE SURVEY

2.1 Application of Drive for Induction motor control

Most of the industrial machines in Paint shop, Paper and Pulp industries use induction motor for various applications for driving pump, blower and compressors. To reduce the flow rate, the throttling valve is partially closed. This causes loss of energy across throttling valve. This energy loss can be avoided by eliminating the throttling valve and driving the pump at the speed that results in desired speed. This decrease in power requirement can be calculated by recognizing that in a centrifugal pump

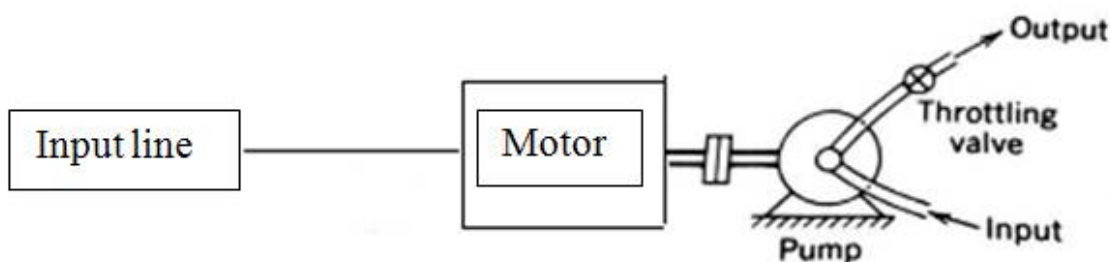
$$\text{Torque} \approx k_1 (\text{speed})^2$$

Therefore, the power required by the pump from the motor is

$$\text{Power} \approx k_2 (\text{speed})^3$$

Where k_1 , and k_2 are the constant of proportionality

If the motor and the pump energy efficiencies can be assumed to be constant as their speed and loadings change, then the input power required by the induction motor would also vary as the speed cubed. Therefore in comparison with a throttling valve to control the flow rate, the variable speed driven pump can result in significant energy conservation, where reduced flow rate are required for long period of the time [8].



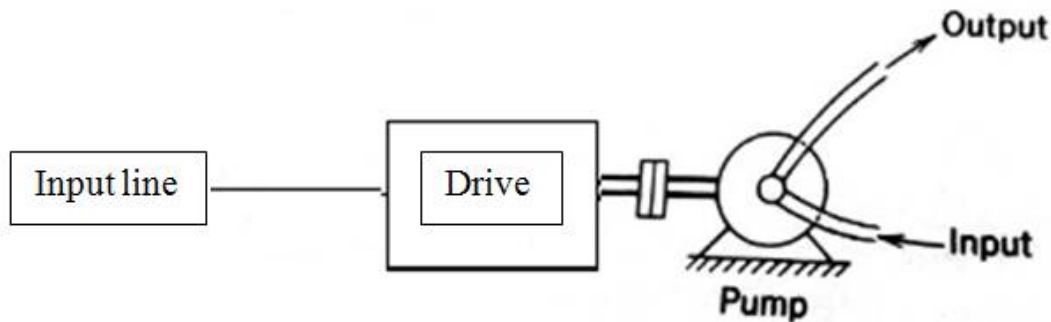
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(b)

Figure 2.1: Centrifugal Pump (a) Constant speed drive (b) Variable speed drive

2.2 Modulation techniques used for control of Inverter

2.2.1 Pulse Width Modulation

In recent decades there has been a large number of variable speed induction motor drives which serves many industrial applications such as fans, pumps, machine tool cutting, steel rolling mills, etc.,

III. METHODOLOGY

3.1 Block diagram of proposed FSTPI scheme

Block diagram of proposed scheme is as shown in given below figure.

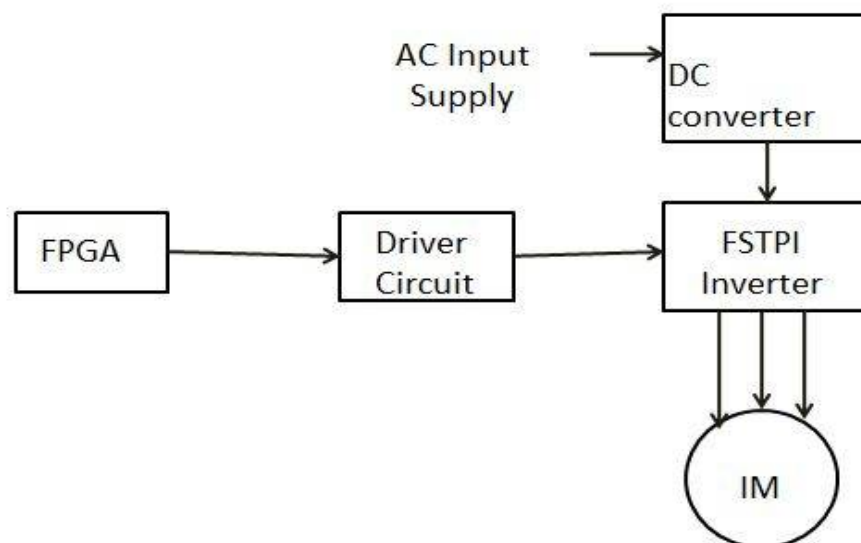


Figure 3.1: Block diagram of proposed FSTPI drive

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Explanation-

In above diagram novel direct torques control (DTC) strategy for induction motor (IM) drives fed by a four-switch three-phase inverter (FSTPI). The introduced strategy is based on the emulation of the operation of the conventional six-switch three-phase inverter (SSTPI). This has been achieved thanks to a suitable combination of the four unbalanced voltage vectors intrinsically generated by the FSTPI, leading to the synthesis of the six balanced voltage vectors of the SSTPI. This approach has been adopted in the design of the vector selection table of the proposed DTC strategy which considers a subdivision of the Clarke plane into six sectors. Simulation results have revealed that, thanks to the proposed DTC strategy, FSTPI-fed IM drives exhibit interesting performance. These have been experimentally validated and compared to the ones yielded by the Takahashi and the basic DTC strategies dedicated to the SSTPI and to the FSTPI, respectively.

3.2 Function of different element

The block diagram of proposed topology based on FSTPI fed IM drive is shown in Figure 3.1. The diode bridge rectifier converts three phase AC supply to DC supply. The FSTPI is used to convert input from DC converter circuit into controlled three phases AC supply, which is used to drive the induction motor. The FPGA is used to generate PWM pulse to control the FSTPI. The FPGA processor output pulses are fed to the inverter through driver circuit to drive the Induction Motor through FSTPI.

3.3 FPGA architecture

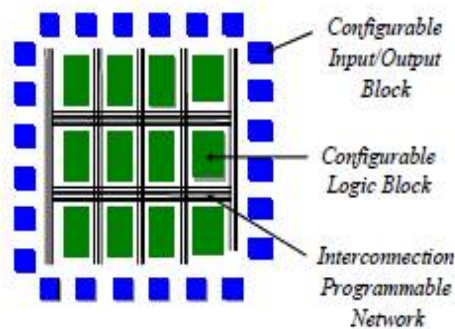


Figure 3.2: FPGA architecture

FPGA is as a matrix of configurable logic blocks. It is linked by an interconnection network which is reprogrammable. The memory cells control the logic blocks and the connections. Bordered ring of matrix core has configurable Input/output blocks. Any block can be use as input or output as per developer requirement. FPGA has parallel structure which provides fast computation speed.

3.4 Space Vector Pulse Width modulation

3.4.1 Introduction

Three phase sinusoidal voltages fed to three phase windings of the induction motor. This applied sinusoidal voltage produces revolving mmf in the air gap around the periphery of the rotor .The revolving mmf is an example of a space vector.

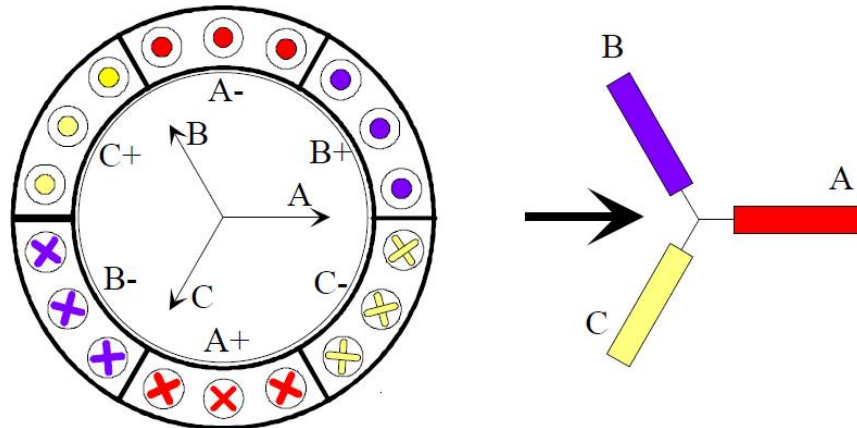


Figure 3.3: Magnetic axes of the stator phase windings

When we adopt the space-vector theory approach to the electrical machines, the phase windings of the stator divided into slots are usually illustrated by windings now concentrated on the magnetic axes, as shown by Figure 3.3. It is seen from the figure 3.3 that magnetic axis of the three phase windings A, B & C is at 120 degree from each other. In space-vector theory, the following assumptions are usually made to simplify the analysis:

1. The flux density distribution is assumed sinusoidal in the air gap,
2. The saturation of the magnetizing circuit is assumed constant,
3. There are no iron losses, and
4. The resistances and inductances are independent of the temperature and frequency

IV. SIMULATION AND HARDWARE DEVELOPMENT

4.1 Schematic diagram of Isolation circuit

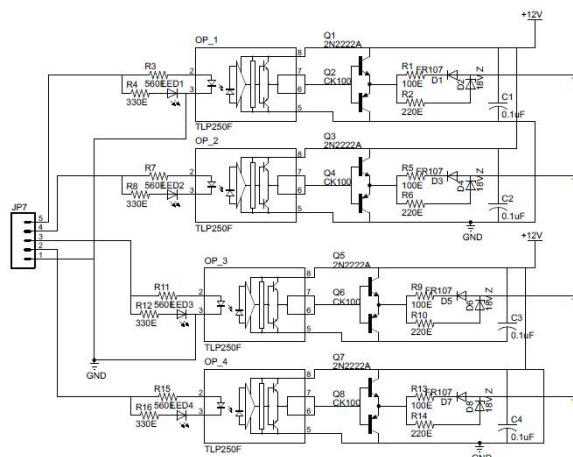


Figure 4.1: TLP250F Isolation circuit

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FPGA control output is applied from Connector JP 7 to TLP250F drive board. In proposed drive circuit TLP250F driver board is used as MOSFET gate drive circuit. Driver board performs two functions one is optical isolation between FPGA controller and power circuit. Other is switching of MOSFET switches of Inverter circuit.

4.2 Inverter Power circuit

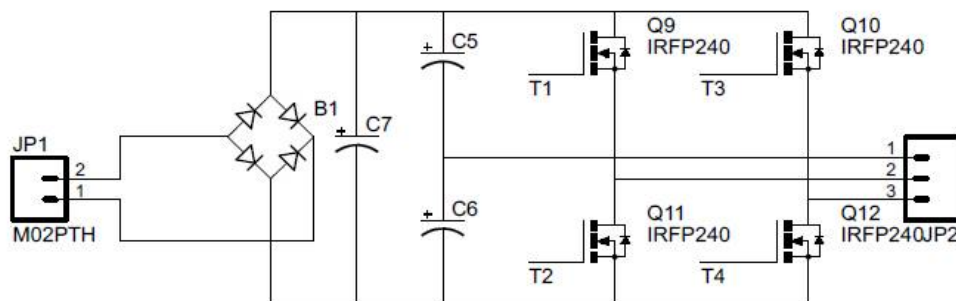


Figure 4.2: Inverter power circuit

Four MOSFET switches T1, T2, T3 and T4 (IRFP240) are connected across DC link voltage. This output taken from uncontrolled bridge rectifier B1 as shown in figure 4.2. Across two legs of the MOSFET Bridge two output phases are taken out. The third phase is taken from middle of the capacitors C5 and C6. MOSFET switching sequence is controlled by FPGA controller.

4.3 Selection of FPGA Hardware

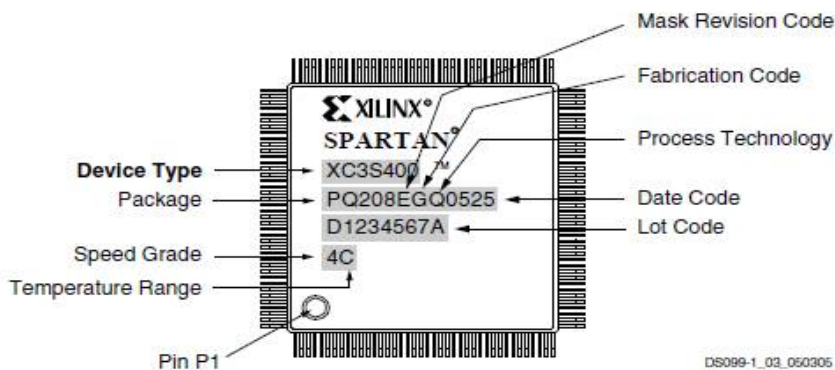


Figure 4.4: FPGA controller

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V. SIMULATION AND HARDWARE RESULTS

5.1 Simulation results

5.1.1 DC link Current

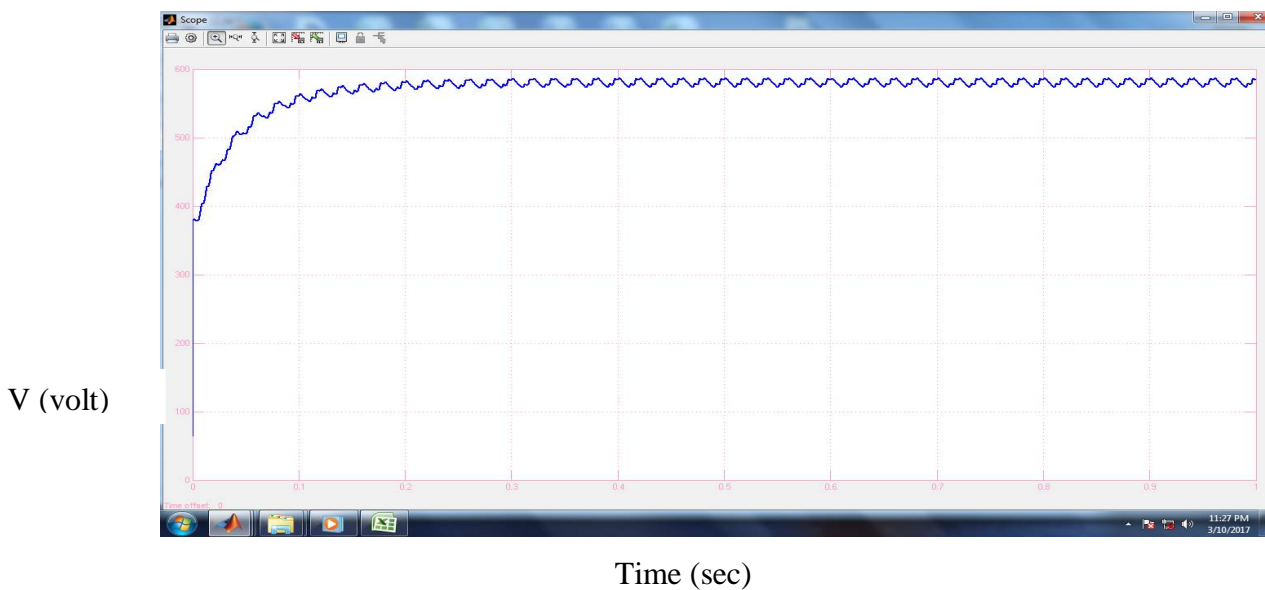


Figure 5.1: DC link current

5.1.2 Three phase Inverter output voltage

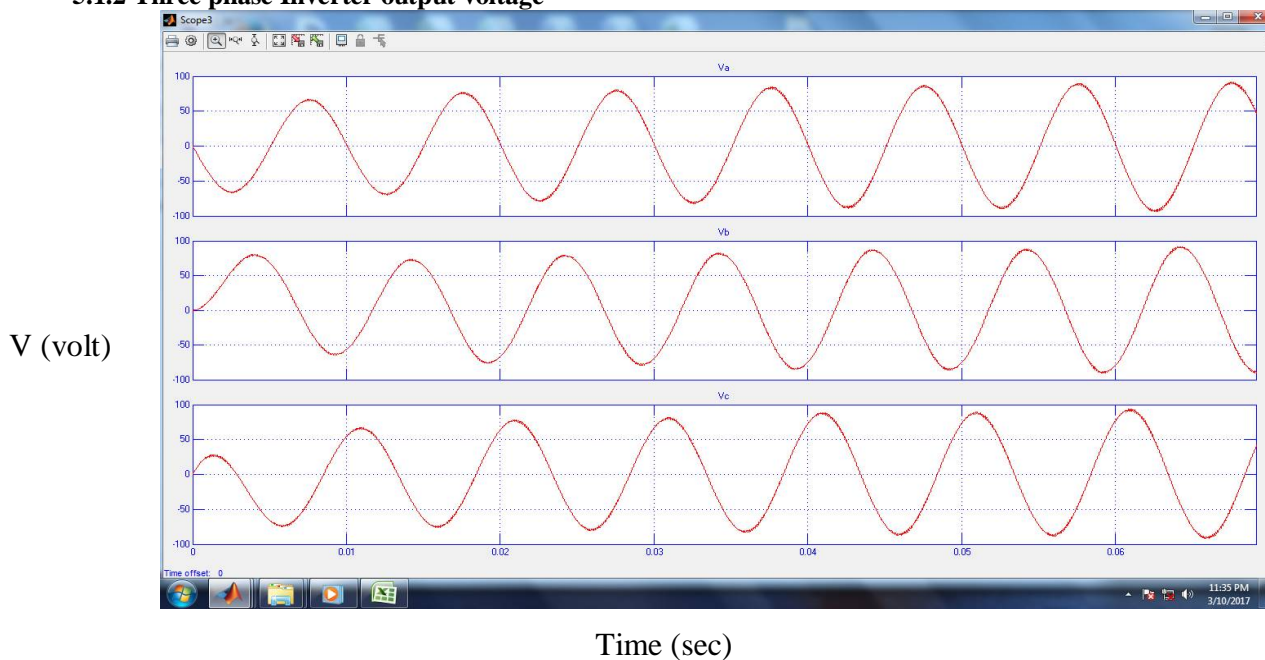


Figure 5.2: Three phase Inverter output voltages

5.1.3 Stator and Rotor current

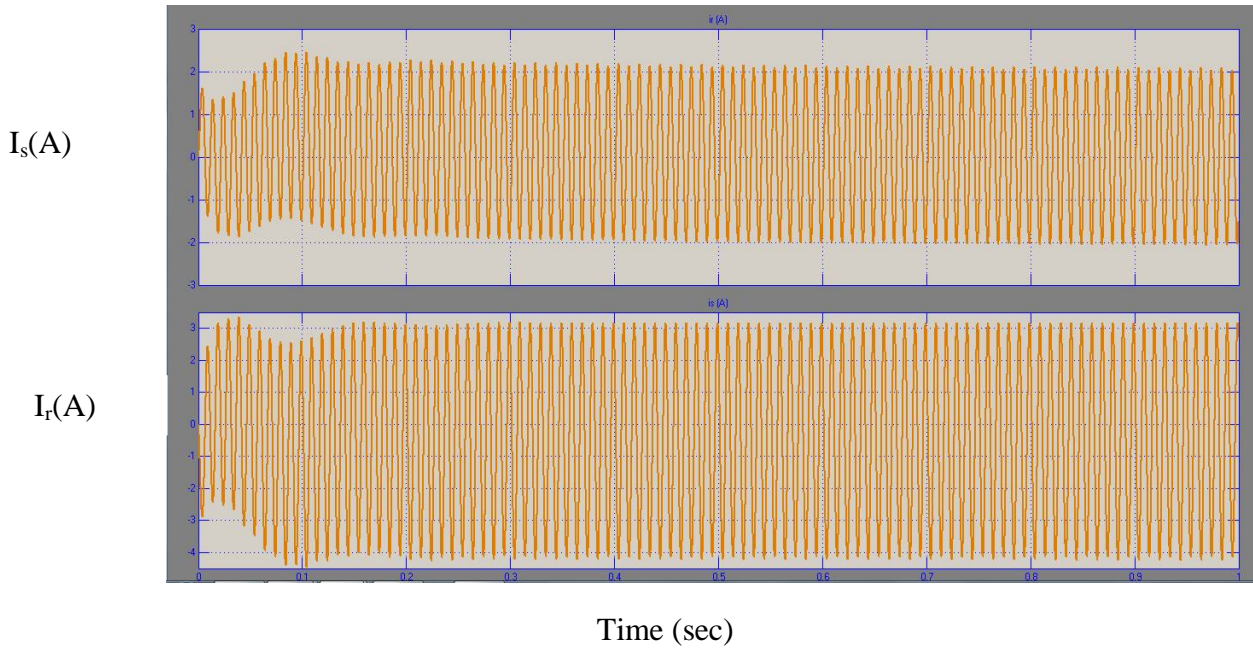


Figure 5.3: Output Stator and Rotor current

5.1.4 Output torque

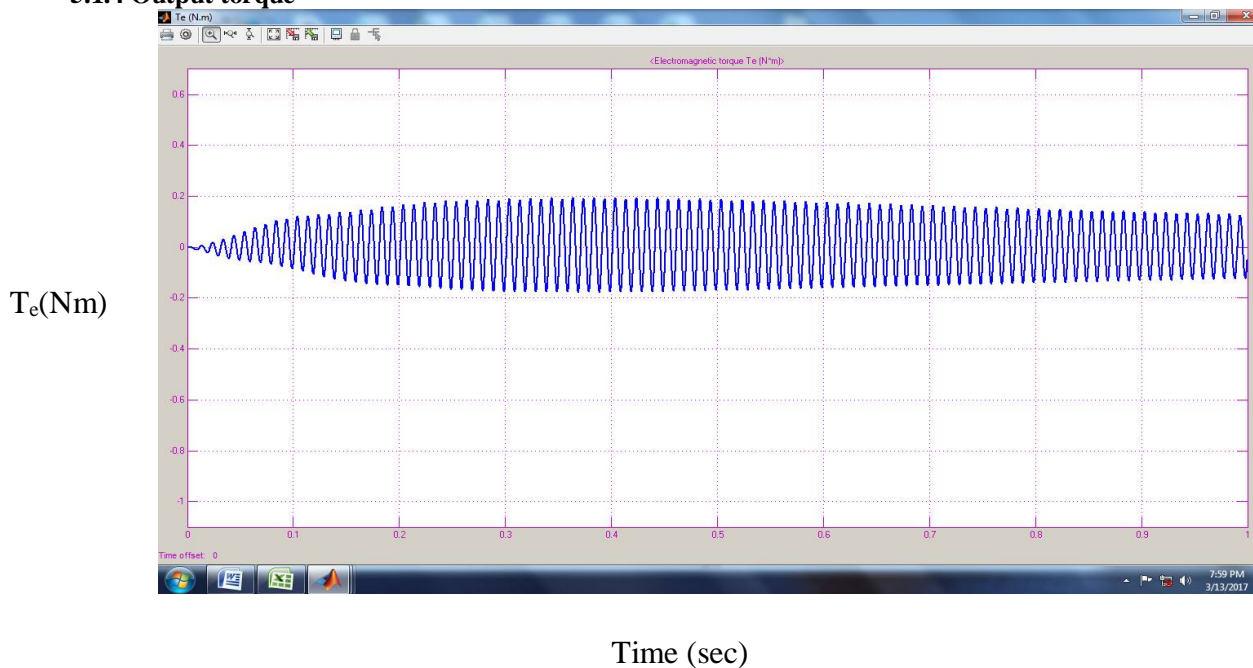


Figure 5.4: Output torque

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5.2 Testing of FSTPI hardware

1) For Sinusoidal PWM output Line Voltage of Inverter

$$V_{LL,max(rms)} = \frac{\sqrt{3}}{2\sqrt{2}} V_d = 0.612V_d$$

$$= 0.612 \times 50$$

$$= 30.6$$

1) For Space vector PWM output Line Voltage of Inverter

$$V_{LL,max(rms)} = \frac{\sqrt{3}}{\sqrt{2}} V_{phase\ max} = \frac{V_d}{\sqrt{2}} = 0.707V_d$$

$$= 0.707 \times 50$$

$$= 35.35$$

Sr no.	Parameter	Theoretical SPWM	Theoretical SVPWM	Practical SVPWM
1	DC link voltage	50 V	50 V	46 V
2	Line to Line Voltage	30.6 V	35.35 V	33 V

Table 5.1: Hardware results comparison

VI. CONCLUSIONS

The theory, design, and performance evaluation of the proposed scheme for the FSTPI is investigated. With the proposed approach, it is possible to implement SVPWM scheme using four vectors to synthesize the desired output voltage during the switching period. The scalar version of the proposed modulation technique can be implemented by software and may be easily included in drive software with a negligible increase in the computational effort. From hardware results we found that DC bus link voltage obtained in case of SVPWM is more than SPWM. With the use of only four switches for three proposed inverter reduces the component requirement of the power & control circuit which reduces the cost. Comparing micro controller and DSP controller FPGA controller performance is more promising.

FUTURE SCOPE

The four-switch inverters are known to have certain limitation for application which needs to eliminate to improve the performances compared to normal six-switch inverters. The voltage vectors of the inverter are under the fluctuation of the two dc-link capacitor voltages. Hence need to mitigate the effects of the capacitor center tap voltage fluctuation under heavy loads.

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