15EE401L - ELECTRIC DRIVES LABORATORY

YEAR: IV

SEMESTER: VII

ACADEMIC YEAR: 2018-2019 (ODD)

NAME :

REG.NO:



DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Name:

Reg.No:

INDEX

Exp. No	Date of Exp.	Name of the Experiment	Date of Sub.	Marks (40)	Staff Sign with date
1		Speed control switched reluctance motor using DSP controller			
2		Speed control of permanent magnet synchronous motor using FPGA spartan 6 controller			
3		V/F control of three phase induction motor using dsPIC micro controller			
4		Speed and position control of servo motor by DSP controller			
5		FPGA based dc motor control using dc-dc chopper			
6		Simulation of three phase voltage source inverter using SPWM			
7		Simulation of Chopper fed dc motor			
8		Simulation of Z source Inverter			
TOTAL					

Average Marks:

Signature of Faculty:

DEPT. OF ELECTRICAL & ELECTRONICS ENGINEERING

SRM UNIVERSITY, Kattankulathur – 603203

Title of Experiment :
Name of the student : Register Number : Date of Experiment : Date of Submission :

S.No	Marks Split up	Maximum Marks	Marks Obtained
1	Pre viva questions	5	
2	Execution of experiment	15	
3	Calculation/evaluation of result	15	
4	Post viva questions	5	
	Total	40	

Signature of the Faculty

PRELAB QUESTIONS:

1. **Define Electric Drives.**

2. **What is meant by Switched Reluctance Motor?**

3. **Why rotor position sensor is essential for the operation of Switched Reluctance Motor?**

4. **What are disadvantages of Switched Reluctance Motor?**

5. **What is difference between SRM and PMSM?**

1. SPEED CONTROL SWITCHED RELUCTANCE MOTOR USING DSP CONTROLLER

AIM:

To obtain speed control of Switched Reluctance Motor using DSP controller TMS320F2812.

APPARATUS REQUIRED:

Apparatus Name	Specifications / Range	Qty
Auto Transformer	230 V, 50 Hz, 1 phase	1
SRM Power Module	PEC16DSMO15 trainer kit	1
DSP controller - Micro-2812 trainer	TMS320F2812 – 32 bit fixed	1
Switched Reluctance Motor	300V dc, 2.5 Amp, 0.75 KW (1HP), 4000 RPM	1
PC -PC serial port cable		2
Power Patch Chords	1 phase 3 pin chord	4
26 Pin FRC cable		1
34 Pin FRC cable		1
Personal Computer		1
Connecting wires		Required

THEORY:

Theoretical Details of Switched Reluctance Motor

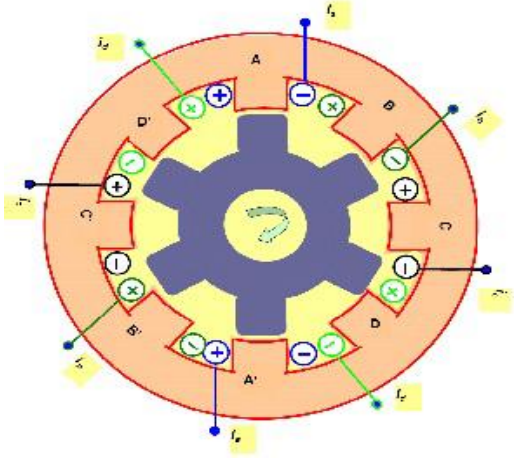
A Switched Reluctance or Variable Reluctance Motor does not contain any permanent magnets. The stator is similar to a brushless dc motor. However, the rotor consists only of iron laminates. The iron rotor is attracted to the energized stator pole. The polarity of the stator pole does not matter. Torque is produced as a result of the attraction between the electromagnet and the iron rotor.

The rotor forms a magnetic circuit with the energized stator pole. The reluctance of a magnetic circuit is the magnetic equivalents to the resistance of an electric circuit. The reluctance of the magnetic circuit decreases as the rotor aligns with the stator pole. When the rotor is in-line with the stator the gap between the rotor and stator is very small. At this point the reluctance is at a minimum. This is where the name “Switched Reluctance” comes from.

Basic construction of an SRM

- The SRM is a doubly salient, singly excited machine with independent windings of the stator.
- Its stator structure is same as PM motor, but the rotor is simpler having no permanent magnet on it.

- Stator windings on diametrically opposite poles are connected in series or parallel to form one phase of the motor.
- Several combinations of stator and rotor poles are possible, such as 6/4 (6 stator poles and 4 rotor poles), 8/6, 10/6, 12/6 etc.
- The configurations with higher number of stator/rotor pole combinations have less torque ripple.
- The design objectives are to minimize the core losses, to have a good starting capability and to eliminate mutual coupling.
- The switched Reluctance motor used is of 8/6-Pole type motor. It consists of four phases A, B, C & D. The figure shows the 8/6 SR motor

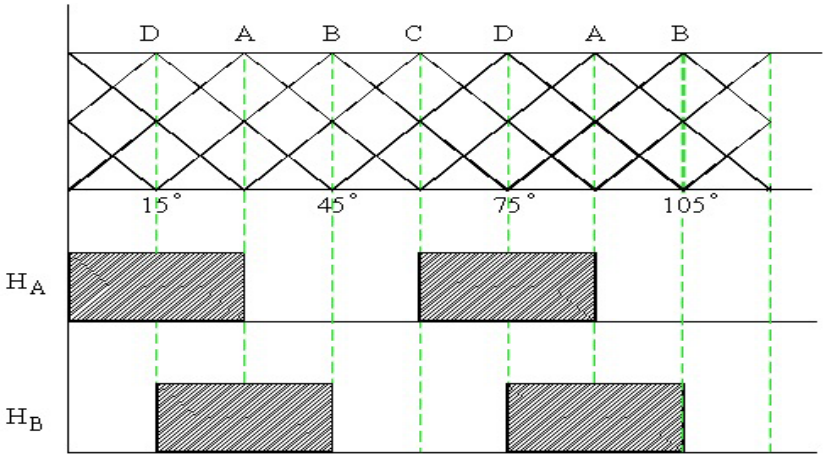


Structure of 8/6 SR Motor

Working of SR Motor

When stator phase pair is excited the rotor tends to align with a stator phase. When the rotor aligns with a phase, the next pair is excited so as to maintain a continuous rotation of the motor. As the motor rotates, each stator phase undergoes a cyclic variation of inductance. In the fully aligned position (when a rotor pole axis is directly aligned with the stator pole axis) the reluctance of the magnetic circuit through the stator and rotor poles will be at a minimum, and thus the inductance of the stator winding will be at a maximum. The opposite will occur in the

fully unaligned position (when the rotor interpole axis is aligned with the stator pole). Thus the inductance becomes a function of position. Hence, for the excitation of SR motor phase, the feedback position is compared with the inductance profile of the SR motor. From the comparison the respective phase pairs are excited. The following figure shows the inductance profile and rotor position signal of SR motor.



From the above figure, the PWM signal sequence is obtained. The comparison shows the aligned stator pole axis. For clockwise rotation, the next phase pairs are excited and for counter clockwise rotation, the previous phase pairs are excited. For eg. for a given rotor position, phase A is aligned with the rotor then for a clockwise rotation phases B and C are to be excited and for a counter clockwise rotation phases C and D are to be excited. The switching sequence for clockwise (CW) and counter clockwise rotation (CCW) rotation is given in the table below.

For Clockwise rotation,

Hall Sensor Outputs		Switching Sequence			
H_A	H_B	1	2	3	4
0	0	0	0	1	1
0	1	0	0	1	1
1	1	1	0	0	1
1	0	1	1	0	0

Advantages

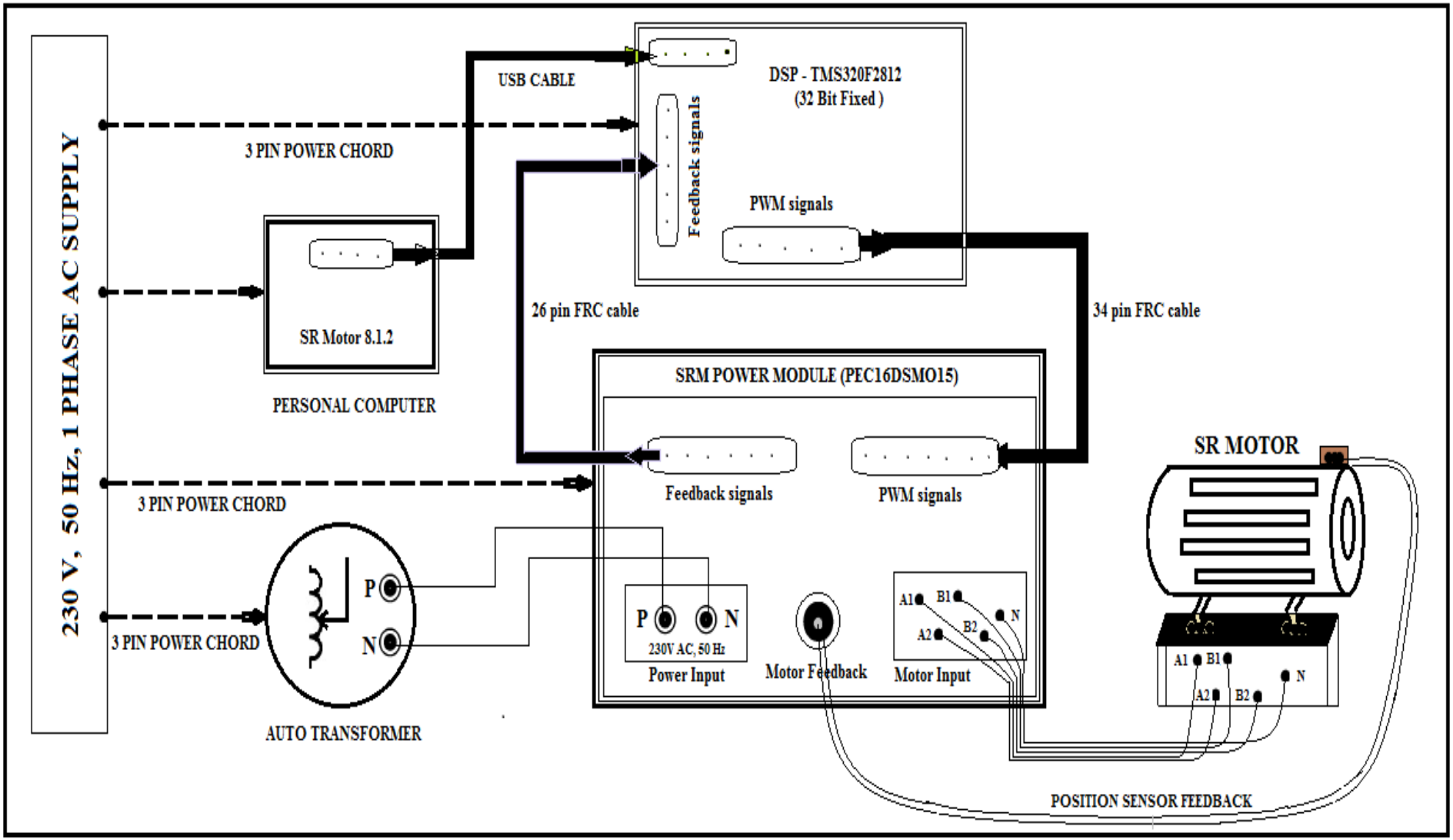
- ✓ The rotor does not have any windings, commutators, brushes or cages.
- ✓ The torque-inertia ratio is high.
- ✓ It provides high reliability, wide-speed range at constant power; low manufacturing cost, fast dynamic response, ruggedness and fault-tolerance.
- ✓ No shoot-through and crossovers in the converter.

- ✓ The maximum permissible rotor temperature is higher since there is no permanent magnet.
- ✓ Open-circuit voltage and short-circuit current at faults are zero or very small.

Disadvantages

- ✓ Doubly salient structure causes vibration and acoustic noise.
- ✓ High torque-ripple.

CONNECTION DIAGRAM



TABULATION:

OPEN LOOP

Input Voltage (V)	Duty Cycle (D)	Current (in Ampere)	Actual Speed (rpm)

CLOSED LOOP

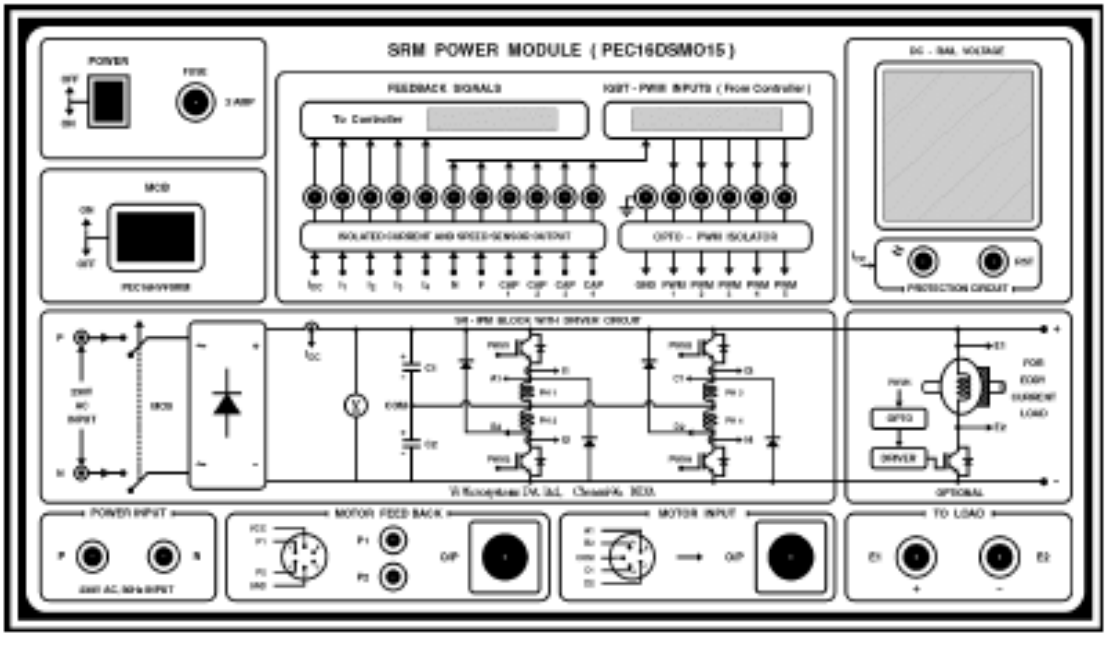
Input Voltage (V)	Current (in Ampere)	Set Speed (rpm)	Actual Speed (rpm)	Error speed (rpm)

SRM POWER MODULE:

Features of PEC16DSMO15

- ✓ Various test points to check waveforms at different stages of operation.
- ✓ Flexibility to work with different controller modules developed by us.
- ✓ Necessary protections are provided through fuses and MCBs. A separate protection circuit for input over current faults.
- ✓ Power supply to the Eddy Current load coil is also provided from the module.
- ✓ Required connectors are provided for motor input supply connection and feedback signal connection.

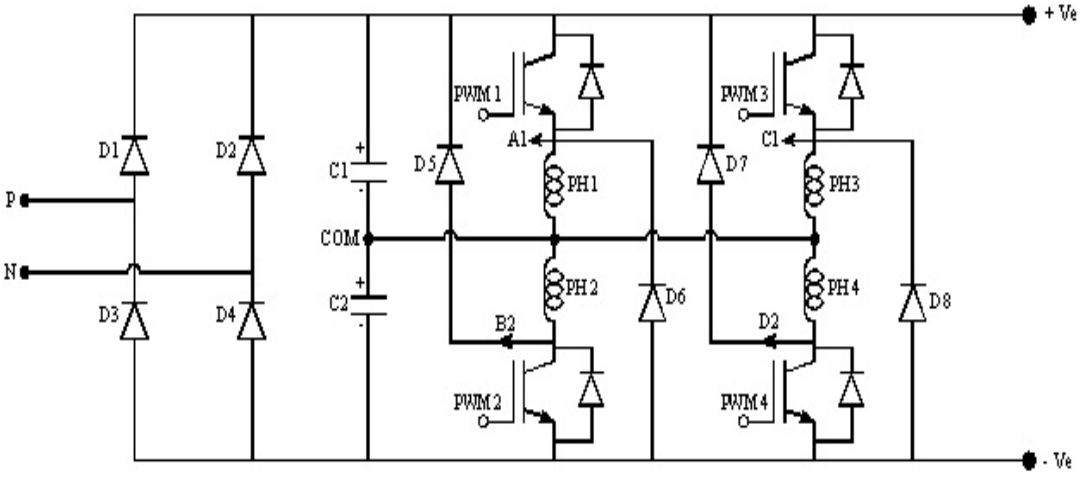
Front Panel View



Description

- P and N - Applied to 1N AC input supply.
- A1, B2, C1, D2 - Four phase output terminals.
- +Ve & -Ve - Rectifier with filter DC output voltage (DC link voltage).
- Voltmeter - To Read the DC rail voltage.
- RST - Reset the Flip-flop, then 'SD' LED will off.
- SD - Shut down LED will glow, when over voltage/current occurs in power circuit.
- I_1, I_2, I_3 and I_4 - 4 phase A, B, C and D current transducer output currents.
- I_{DC} - DC link current (current transducer output).
- N - Speed sensor output.
- CAP1, CAP2, CAP3, and CAP4 - Testing point for SRM Hall sensor output.

- F - Fault output signal comes from IGBT Module, when over voltage/current occurs
- MCB - Power ON/OFF the 1N AC supply.
- Power - Power ON/OFF the control circuits.
- PWM1.... PWM5 - Testing point for PWM signal from DSP.
- Motor Input - To connect motor input terminals to the power module Connector
- Motor feedback Connector - To connect SRM hall sensor output signal.
- P1, P2 - LED indication for SRM hall sensor output signal.



Power Converter for SRM

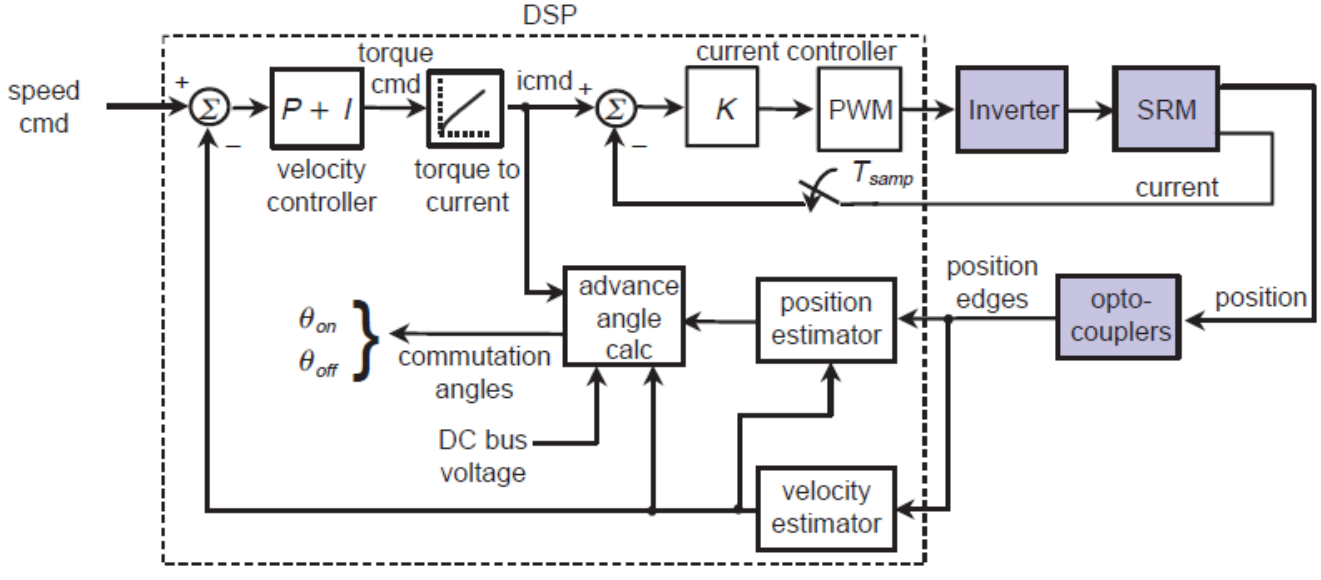
Theoretical Details of DSP controller TMS320F2812

Features:

- Processor: TMS320F2812
- Operating Speed: 150 MHz
- 128KB on chip flash memory
- 256KB RAM for program / data memory
- JTAG connector for external JTAG emulator
- Opto-isolated RS232 serial port at 9pin 'D'
- 16*2 LCD interface
- 2 limits switches are provided for general purpose usage in the software. (factory configured as increment, decrement switches)
- 34 pin motor control I/F connector
    - ✓ 12 motor control PWM
    - ✓ 4 Individual PWM
    - ✓ 6 capture I/P signals

✓ 2 quadrature encoder interface

- 26 pin ADC I/F connector
- 16 channel 12bit ADC
- 12.5 MSPS sampling rate / 80 ns conversion rate



Block diagram representation of DSP controller

Connection Procedure

- Connect the 3-pin power chord of the Micro-2812 trainer to the supply.
- Connect the power module to the 1N power supply.
- Connect the 34 pin FRC cable one end to 34 pin FRC connector in Micro-2812 trainer and the other end to "IGBT- PWM INPUTS" of the PEC16DSMO15.
- Connect the 26 pin FRC cable one end to P6 connector in Micro-2812 trainer and the other end to "FEEDBACK SIGNALS" of the PEC16DSMO15.
- Connect the motor feedback to the motor feedback connector provided in the SRM power module.
- Connect the motor power output terminal of PEC16DSMO15 to the power input terminal of Switched Reluctance Motor.
- Connect the PC with DSP controller.

Experiment Procedure

- Verify the connections as per the connection procedure and connection diagram.
- Switch ON the Micro-2812 trainer.
- Switch ON the power ON/OFF switch in the SRM Power Module (PEC16DSMO15).

- Check whether shut down LED "SD" glows or not. If 'SD' LED glows press the Reset switch, the LED gets OFF.
- Switch on the MCB and gradually increase the voltage upto 300 V(DC link voltage) using 1 ph variac.
- Switch ON the PC and then press Reset switch of the Micro-2812 trainer.
- Download and execute the program by following the “Download Procedure” given in the following section

RESULT:

Thus the speed control of Switched Reluctance Motor using DSP controller for open and closed loop was verified and corresponding readings were tabulated.

POST-LAB QUESTIONS:

1. **What are applications of Switched Reluctance Motor?**

2. **What are the types of rotor position sensors in SRM?**

3. **What are the various parts of electrical drives?**

4. **Define Duty cycle.**

5. **What is operating frequency of TMS320F2812 dsp controller?**

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Name of the student : Register Number : Date of Experiment : Date of Submission :

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1	Pre viva questions	5	
2	Execution of experiment	15	
3	Calculation/evaluation of result	15	
4	Post viva questions	5	
	Total	40	

Signature of the Faculty

PRELAB QUESTIONS:

1. **What is meant by self control?**

2. **What is difference between PMSM and BLDC motor?**

3. **Write EMF equation of PMSM?**

4. **What are advantages of PMSM?**

5. **Define FPGA.**

2. SPEED CONTROL OF PERMANENT MAGNET SYNCHRONOUS MOTOR USING SPARTAN 6 FPGA CONTROLLER

AIM:

To obtain speed control of Permanent magnet synchronous Motor using SPARTAN 6 FPGA controller.

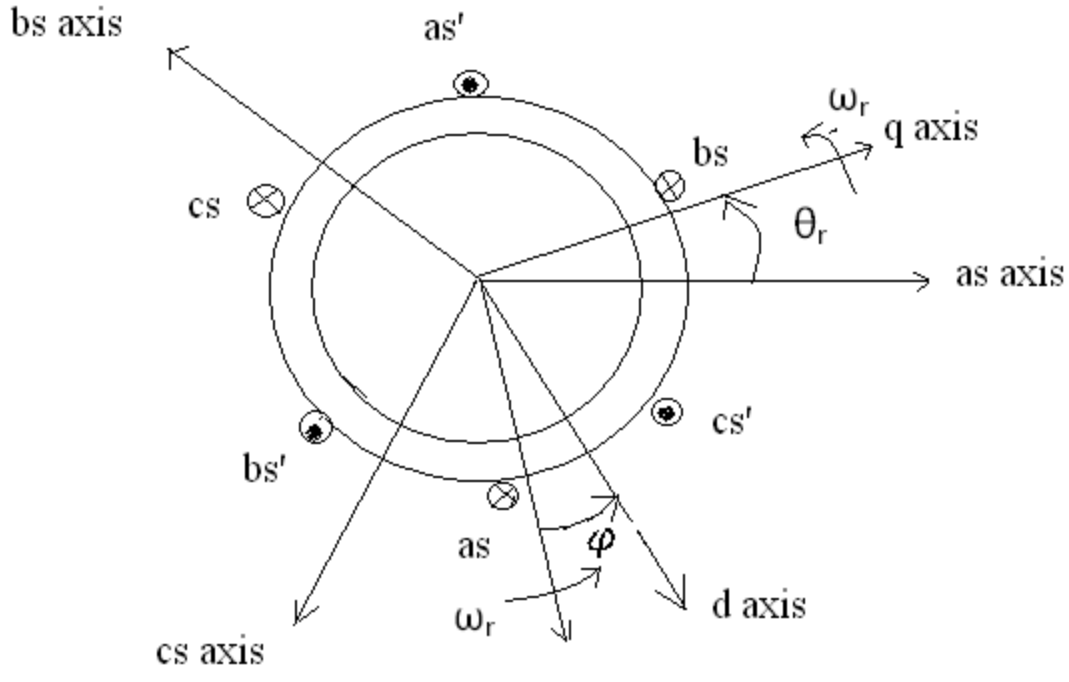
APPARATUS REQUIRED:

Apparatus Name	Specifications / Range	Qty
Auto Transformer	440 V, 15A,50 Hz, 3 phase	1
SRM Power Module	PEC16DSMO15 trainer kit	1
FPGA CONTROLLER	SPARTAN 6	1
Permanent Magnet Synchronous Motor	230V ac, 2.5 Amp, 5000 RPM	1
PC -PC serial port cable		2
Power Patch Chords	1 phase 3 pin chord	4
26 Pin FRC cable		1
34 Pin FRC cable		1
Personal Computer		1
Connecting wires		Required

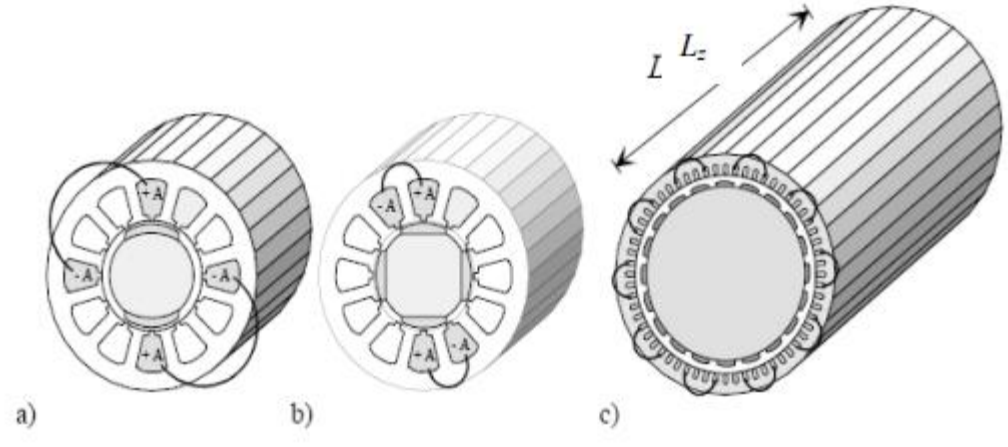
THEORY:

Theoretical Details of PMSM

The competitor to the induction motor is the permanent magnet (PM) motor. The permanent magnet motors have magnets on the rotor, while the stator construction is same as that of induction motor. The PM motors can be surface mounted type or the magnets can be inset within the rotor. The PM motors can also be classified as sinusoidal type or trapezoidal type depending on the flux density distribution in the air gap. Permanent magnet motors with sinusoidal air gap flux distribution are called Permanent Magnet synchronous Motors (PMSM) and the with trapezoidal air gap flux distribution are called Brushless DC (BLDC) motors.The permanent magnet synchronous motor (PMSM) is a PM motor with a sinusoidal back - EMF. Compared to the BLDC motor, it has less torque ripple because the torque pulsations associated with the current commutation do not exist. A carefully designed machine in combination with a good technique can yield a very low level of torque ripple (< 2 % rated), which is attractive for the high performance motor control applications such as machines tool and servo applications.



Cross sectional view of the simplified three-phase surface mounted PMSM



a) Conventional winding, where p=2 and q=2 b) Concentrated fractional slot winding, where p=4,q=0.5 c) a winding where q=1 and the pole number is high

Working of PMSM

To produce torque, in general, a rotor flux and a stator mmf has to be present that are stationary with respect to each other but having a nonzero phase shift between them. In PM machines, the necessary rotor flux is present due to rotor PMs. Currents in the stator windings generate the stator mmf. The zero relative speed between the stator mmf and the rotor flux is achieved if the stator mmf is revolving at the same speed as the rotor flux , that is, rotor speed and also in the same direction. The revolving stator mmf is the result of injecting a set of

polyphase currents phase shifted from each other by the same amount of phase shift between the polyphase windings. For example, a three phase machine with three windings shifted in space by electrical 120° between them produces a rotating magnetic field constant in magnitude and travelling at an angular frequency of the currents (just as in case of Induction machines). The rotor has permanent magnets on it, hence the flux produced by the rotor magnets start to chase the stator mmf and as a result torque is produced. Since the relative speed between the stator mmf and rotor flux has to be zero, the rotor moves at the same speed as the speed of the stator mmf. Hence, the PM machines are inherently synchronous machines.
As the coils in the stator experience a change of flux linkages caused by the moving magnets, there is an induced emf in the windings. The shape of the induced emf is very dependent on the shape of the flux linkage. If the rotational electrical speed of the machine ω_r and the air gap flux is sinusoidal then it can be expressed as,

$$\phi = \phi_m \sin(\omega_r t)$$

$$\omega_r = \frac{N_p}{2}\omega_{mech}$$

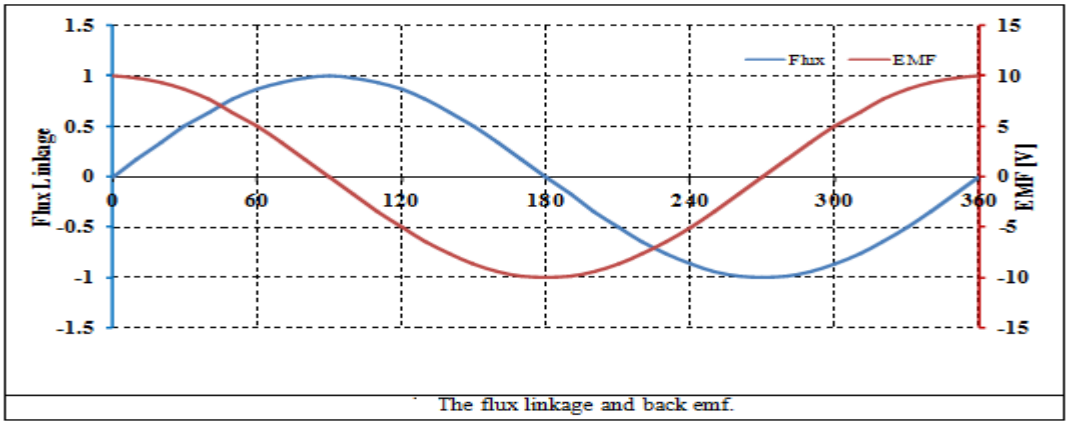
where

Φ_m is the peak flux produced

ω_r electrical speed of rotation of the rotor

ω_{mech} is the mechanical speed of the rotor

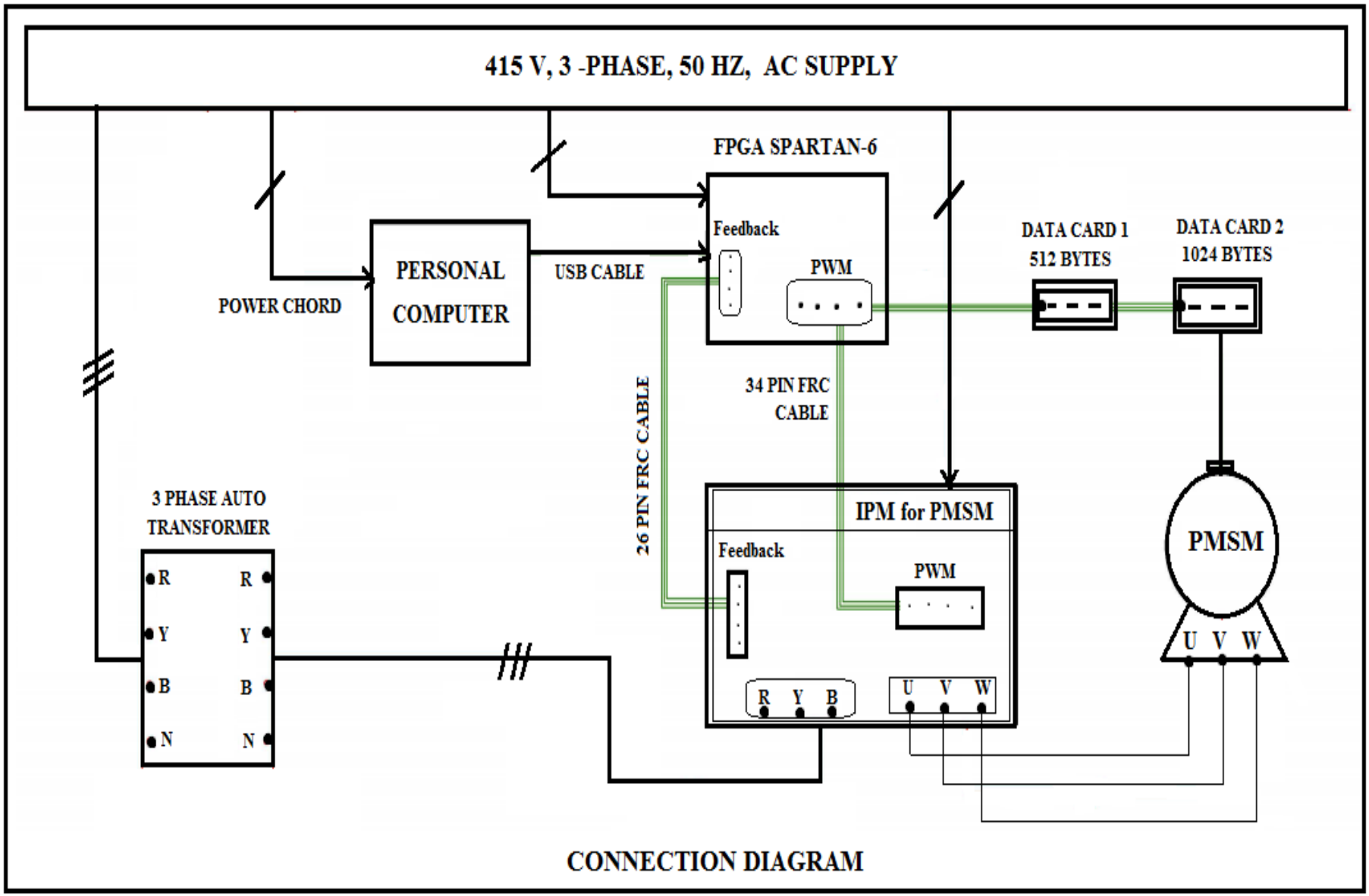
N_p is the number of poles of the motor



The flux linkage and back emf.

Advantages

- ✓ Elimination of field copper loss
- ✓ Higher power density
- ✓ Lower rotor inertia



CONNECTION DIAGRAM

- ✓ More robust construction of motor
- ✓ Higher efficiency

Disadvantages

- ✓ Loss of flexibility of field flux control
- ✓ Higher cost

TABULATION:

CLOSED LOOP

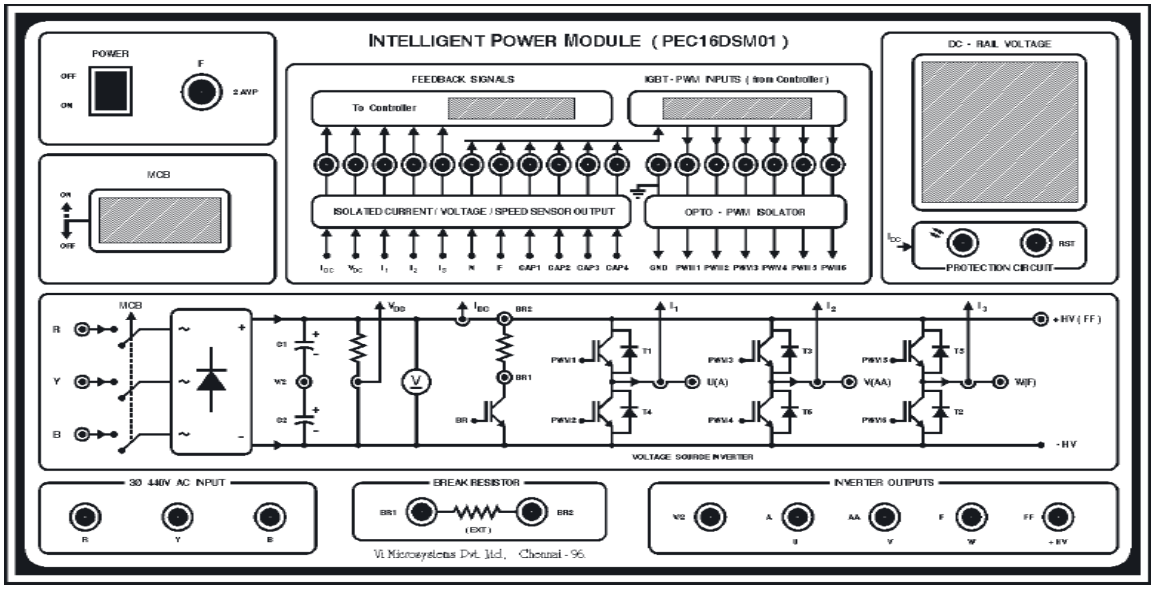
Input Voltage (V)	Current (A)	Set Speed (rpm)	Actual Speed (rpm)	Error speed (rpm)

INTELLIGENT POWER MODULE:

Features of PEC16DSMO1

- ✓ Various test points to check waveforms at different stages of operation.
- ✓ Flexibility to work with different controller modules developed by us.
- ✓ Necessary protections are provided through fuses and MCBs. A separate protection circuit for input over current faults.
- ✓ Power supply to the Eddy Current load coil is also provided from the module.
- ✓ Required connectors are provided for motor input supply connection and feedback signal connection.

Front Panel View



Description

- ✓ R,Y,B = Applied to 3 phase AC input supply.
- ✓ U,V,W = Three phase R, Y, B output terminals.
- ✓ BR1 & BR2 = Breaking Rheostat (470S - 2A).
- ✓ +HV = Rectifier with filter DC output voltage (DC link voltage).
- ✓ Voltmeter = Read the DC link voltage.
- ✓ V/2 = Voltage across V/2 is half of the DC link voltage.

Feed back signals (Isolated current/voltage/speed sensor output)

- ✓ I1, I2, I3 = 3 phase R,Y,B current transducer output currents are I1, I2,
- ✓ I3 respectively and measure this current across the
- ✓ terminals U, V and W.
- ✓ VDC = DC link voltage (voltage transducer output).
- ✓ IDC = DC link current (current transducer output).
- ✓ N(Speed) = Analog voltage (0 - 5V).
- ✓ F = Fault output signal comes from IPM, when over
- ✓ temperature/current occurs.
- ✓ MCB = Power ON/OFF the 3 phase AC supply.
- ✓ Power = Power ON/OFF the control circuits.

IGBT - PWM Inputs (from controller)

- ✓ PWM1,.... PWM6 = PWM pulses are coming from controller.
- ✓ PWM output

- ✓ High - 5V = IGBT ON.
- ✓ Low - 0V = IGBT OFF.
- ✓ CAP1,.....CAP6 = Capture input to processor.

Protection Circuit

- ✓ RST = Reset the protection circuit, then 'SD' LED will be off.
- ✓ SD = Shut down LED will glow, when over voltage/current occurs in power circuit.

Theoretical Details of SPARTAN 6 FPGA Features:

• Spartan-6 Family:
    • Spartan-6 LX FPGA: Logic optimized
    • Spartan-6 LXT FPGA: High-speed serial connectivity
• Designed for low cost
    • Multiple efficient integrated blocks
    • Optimized selection of I/O standards
    • Staggered pads
    • High-volume plastic wire-bonded packages
• Low static and dynamic power
    • 45 nm process optimized for cost and low power
    • Hibernate power-down mode for zero power
    • Suspend mode maintains state and configuration with multi-pin wake-up, control enhancement
    • Lower-power 1.0V core voltage (LX FPGAs, -1L only)
    • High performance 1.2V core voltage (LX and LXT FPGAs, -2, -3, and -3N speed grades)
• Multi-voltage, multi-standard SelectIO™ interface banks
    • Up to 1,080 Mb/s data transfer rate per differential I/O
    • Selectable output drive, up to 24 mA per pin
    • 3.3V to 1.2V I/O standards and protocols
    • Low-cost HSTL and SSTL memory interfaces
    • Hot swap compliance
    • Adjustable I/O slew rates to improve signal integrity
• High-speed GTP serial transceivers in the LXT FPGAs
    • Up to 3.2 Gb/s
    • High-speed interfaces including: Serial ATA, Aurora, 1G Ethernet, PCI Express, OBSAI, CPRI, EPON, GPON, DisplayPort, and XAUI
• Integrated Endpoint block for PCI Express designs (LXT)
• Low-cost PCI® technology support compatible with the 33 MHz, 32- and 64-bit specification.
• Efficient DSP48A1 slices
    • High-performance arithmetic and signal processing
    • Fast 18 x 18 multiplier and 48-bit accumulator

- Pipelining and cascading capability
- Pre-adder to assist filter applications

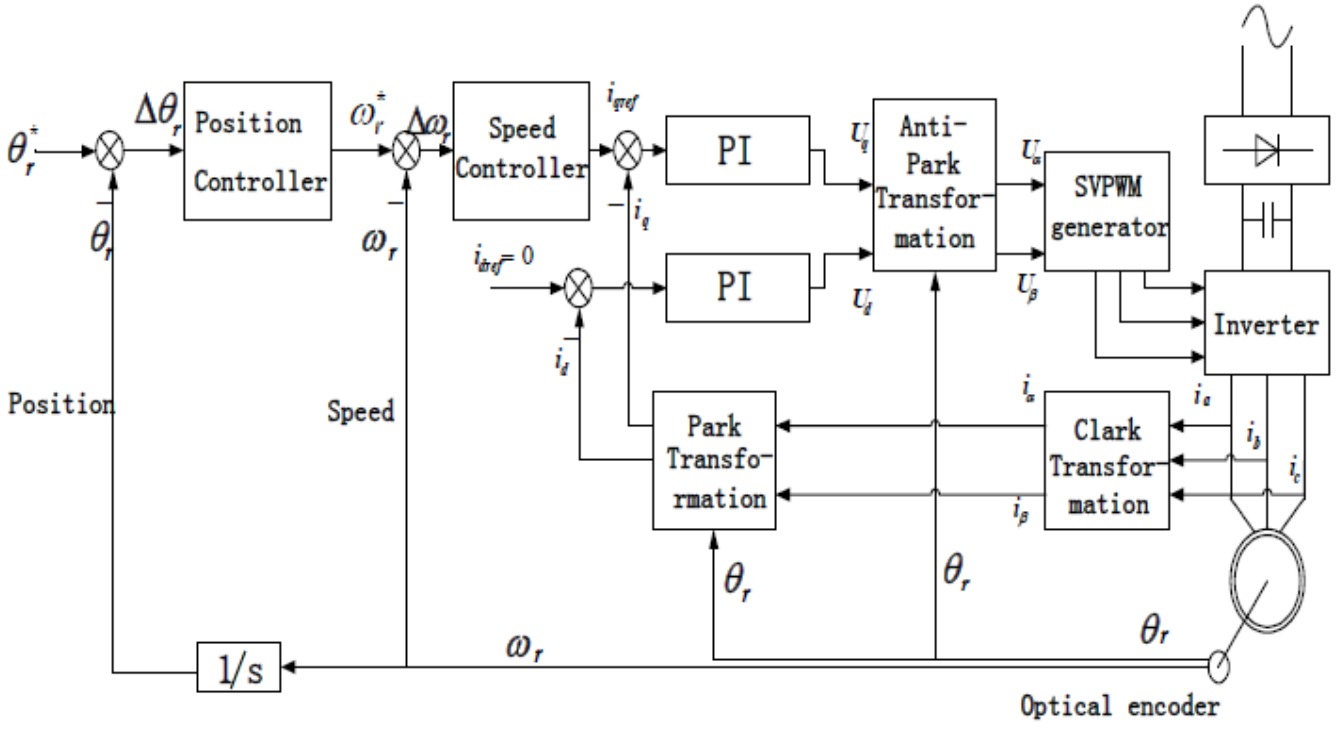
• Integrated Memory Controller blocks
- DDR, DDR2, DDR3, and LPDDR support
- Data rates up to 800 Mb/s (12.8 Gb/s peak bandwidth)
- Multi-port bus structure with independent FIFO to reduce design timing issues

• Abundant logic resources with increased logic capacity
- Optional shift register or distributed RAM support
- Efficient 6-input LUTs improve performance and minimize power
- LUT with dual flip-flops for pipeline centric application

• Block RAM with a wide range of granularity
- Fast block RAM with byte write enable
- 18 Kb blocks that can be optionally programmed as two independent 9 Kb block RAMs

• Clock Management Tile (CMT) for enhanced performance
- Low noise, flexible clocking
- Digital Clock Managers (DCMs) eliminate clock skew and duty cycle distortion
- Phase-Locked Loops (PLLs) for low-jitter clocking
- Frequency synthesis with simultaneous multiplication, division, and phase shifting
- Sixteen low-skew global clock networks

• Simplified configuration, supports low-cost standards
- 2-pin auto-detect configuration
- Broad third-party SPI (up to x4) and NOR flash support
- Feature rich Xilinx Platform Flash with JTAG
- MultiBoot support for remote upgrade with multiple bitstreams, using watchdog



Block diagram representation of FPGA controller

Connection Procedure

- Connect the 3-pin power chord of the SPARTAN 6 FPGA trainer to the supply.
- Connect the power module to the 1N power supply.
- Connect the 34 pin FRC cable one end to 34 pin FRC connector in SPARTAN 6 FPGA trainer and the other end to “IGBT- PWM INPUTS” of the PEC16DSMO15.
- Connect the 26 pin FRC cable one end to P6 connector in SPARTAN 6 FPGA trainer and the other end to “FEEDBACK SIGNALS” of the PEC16DSMO15.
- Connect the motor feedback to the motor feedback connector provided in the SRM power module.
- Connect the motor power output terminal of PEC16DSMO15 to the power input terminal of PMSM.
- Connect the PC with SPARTAN 6 FPGA.

Experiment Procedure

- Verify the connections as per the connection procedure and connection diagram.
- Switch ON the SPARTAN 6 FPGA trainer.
- Switch ON the power ON/OFF switch in the SRM Power Module (PEC16DSMO15).
- Check whether shut down LED "SD" glows or not. If 'SD' LED glows press the Reset switch, the LED gets OFF.
- Switch on the MCB and gradually increase the voltage upto 300 V(DC link voltage) using 1 ph variac.
- Switch ON the PC and then press Reset switch of the SPARTAN 6 FPGA trainer.
- Download and execute the program by following the “Download Procedure” given in the following section

RESULT:

Thus the speed control of Permanent magnet synchronous Motor using DSP controller for closed loop was verified and corresponding readings were tabulated.

POST-LAB QUESTIONS:

1. **Write the applications of FPGA?**

2. **What are the advantages of closed loop operation of electrical drive?**

3. **What is meant by slip power?**

4. **Define VHDL.**

5. **Draw speed torque characteristics of PMSM.**

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Signature of the Faculty

PRELAB QUESTIONS:

1. **What is meant by v/f control?**

2. **Write the equation for relating flux, frequency and voltage.**

3. **What are the advantages of v/f control?**

4. **What are the various speed control methods of induction motor?**

5. **What is meant by dsPIC?**

3. V/F CONTROL OF THREE PHASE INDUCTION MOTOR USING DSPIC MICRO CONTROLLER

AIM:

To obtain speed control of three phase induction motor using dsPIC controller MICRO-4011.

APPARATUS REQUIRED:

Apparatus Name	Specifications / Range	Qty
Auto Transformer	440 V, 15A,50 Hz, 3 phase	1
Intelligent power module	PEC16DSMO1TRAINER KIT	1
dsPIC controller - trainer kit	MICRO 4011	1
Three phase induction Motor	415V Delta connected, 3.7 KW, 7A KW, 1440 RPM, power factor -0.8.	1
QEP sensor interface chord		1
PC -PC serial port cable		2
Power Patch Chords	1 phase 3 pin chord	4
26 Pin FRC cable		1
34 Pin FRC cable		1
Personal Computer		1
Connecting wires		Required

THEORY:

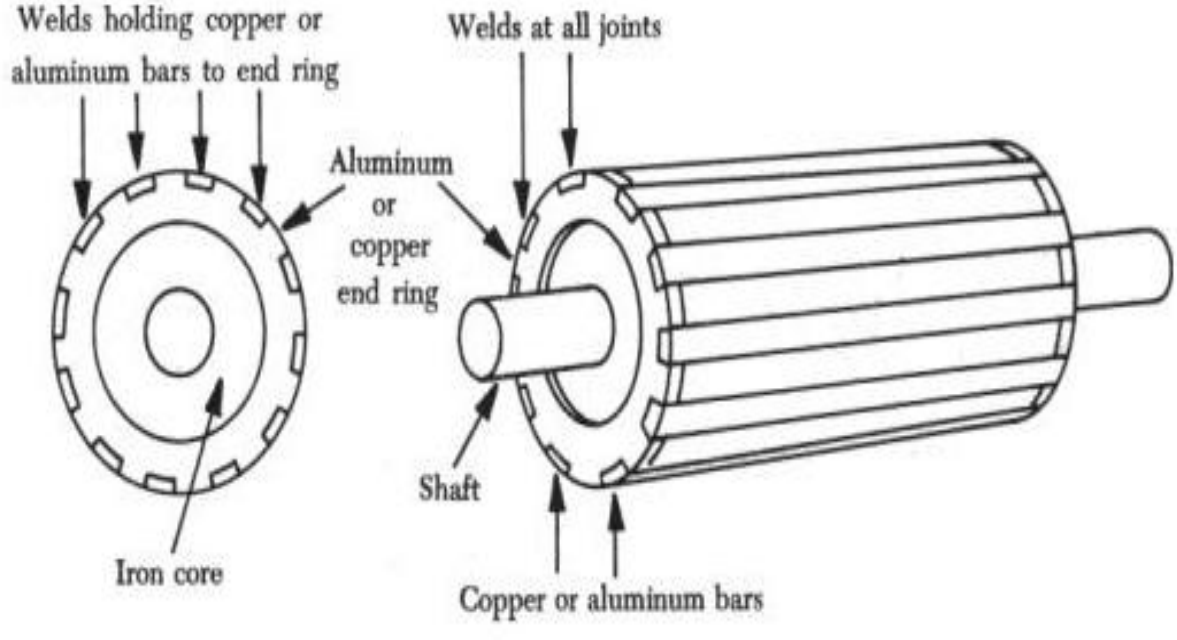
Theoretical Details of Induction Motor

The three phase induction motor is the most widely used electrical motor. Almost 80% of the mechanical power used by industries is provided by three phase induction motors because of its simple and rugged construction, low cost, good operating characteristics, absence of commutator and good speed regulation. In three phase induction motor the power is transferred from stator to rotor winding through induction. The Induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed.

Basic construction of Squirrel cage three phase induction motor:

The rotor of the squirrel cage three phase inductions motor is cylindrical in shape and have slots on its periphery. The slots are not made parallel to each other but are bit skewed (skewing is not shown

in the figure of squirrel cadge rotor beside) as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of motor more smooth and quieter. The squirrel cage rotor consists of aluminum, brass or copper bars (copper bras rotor is shown in the figure beside). This aluminum, brass or copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor. The rotor conductors are permanently shorted by the copper or aluminum rings called the end rings. In order to provide mechanical strength these rotor conductor are braced to the end ring and hence form a complete closed circuit resembling like a cage and hence got its name as "squirrel cage induction motor". The squirrel cage rotor winding is made symmetrical. As the bars are permanently shorted by end rings, the rotor resistance is very small and it is not possible to add external resistance as the bars are permanently shorted. The absence of slip ring and brushes make the construction of Squirrel cage three phase induction motor very simple and robust and hence widely used three phase induction motor. These motors have the advantage of adapting any number of pole pairs. The below diagram shows squirrel cage induction rotor having aluminum bars short circuit by aluminum end rings.



Construction Squirrel cage induction motor

Working of Squirrel cage induction motor

The stator of the motor consists of overlapping winding offset by an electrical angle of 120°. When the primary winding or the stator is connected to a 3 phase AC source, it establishes a rotating magnetic field which rotates at the synchronous speed. According to Faraday's law an emf induced in any circuit is due to the rate of change of magnetic flux linkage through the

circuit. As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring, and cut the stator rotating magnetic field, an emf is induced in the rotor copper bar and due to this emf a current flows through the rotor conductor. Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation; hence as per Lenz's law the rotor will rotate in the same direction to reduce the cause i.e. the relative velocity.

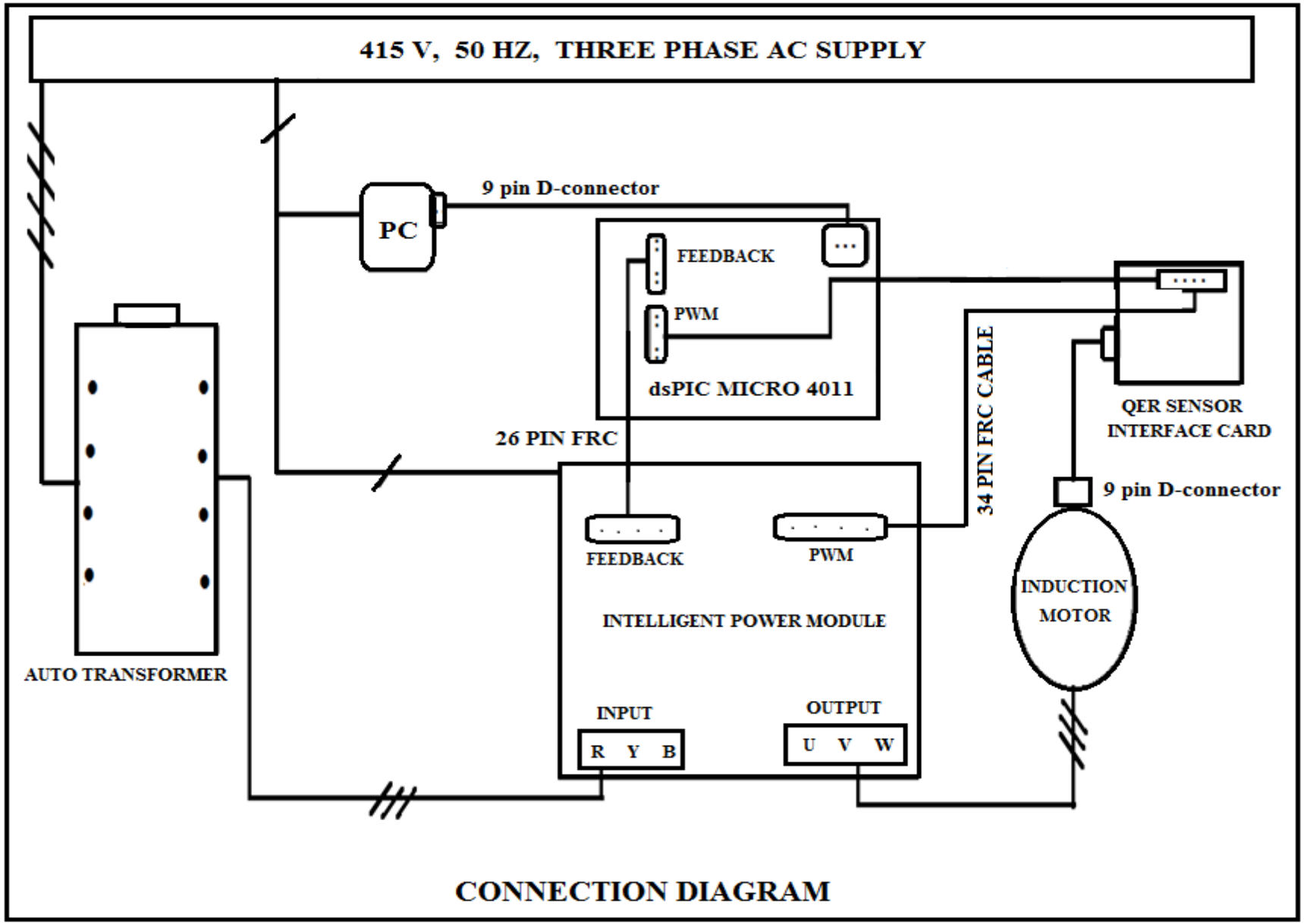
Thus from the working principle of three phase induction motor it may observed that the rotor speed should not reach the synchronous speed produced by the stator. If the speeds equals, there would be no such relative speed, so no emf induced in the rotor, & no current would be flowing, and therefore no torque would be generated. Consequently the rotor cannot reach the synchronous speed. The difference between the stator (synchronous speed) and rotor speeds is called the slip. The rotation of the magnetic field in an induction motor has the advantage that no electrical connections need to be made to the rotor.

Advantages of squirrel cage induction rotor-

- ✓ Its construction is very simple and rugged.
- ✓ As there are no brushes and slip ring, these motors requires less maintenance.

Disadvantages

- ✓ Doubly salient structure causes vibration and acoustic noise.
- ✓ High torque-ripple.



CONNECTION DIAGRAM

TABULATION:

OPEN LOOP

Input voltage	Frequency (HZ)	Actual Speed (rpm)	Current (A)

CLOSED LOOP

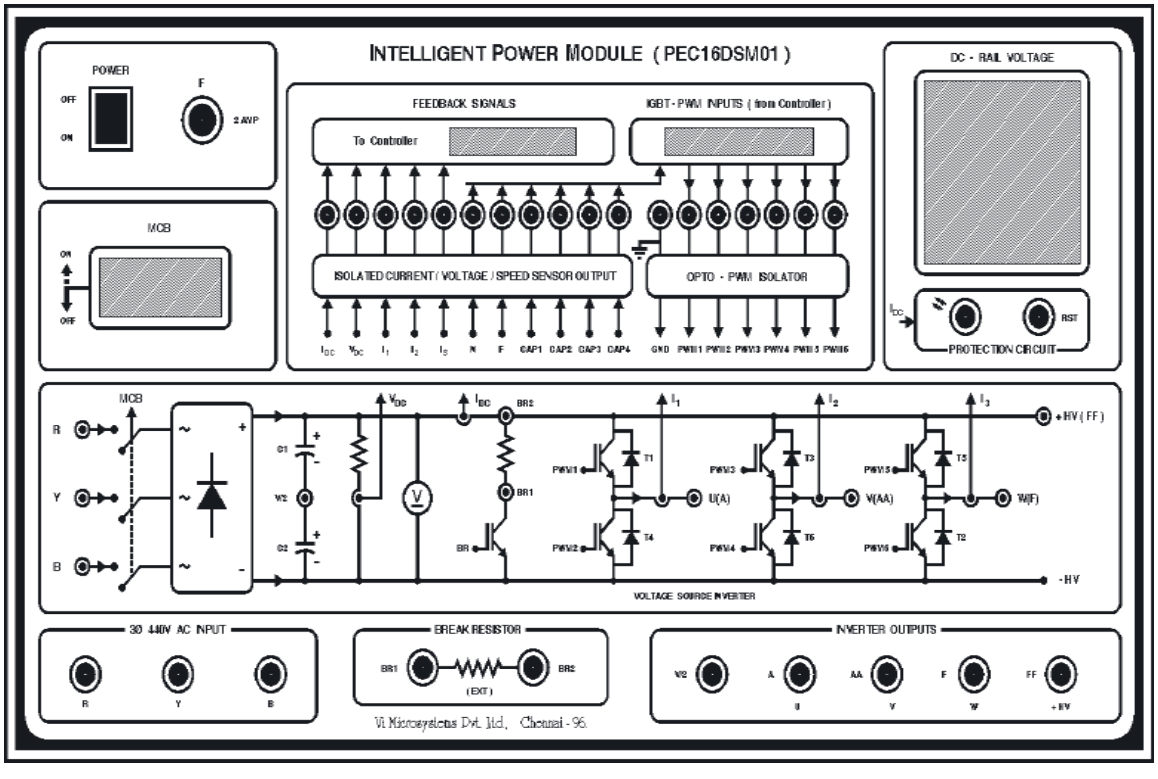
Input voltage (V)	K_P	K_I	Set Speed (rpm)	Actual Speed (rpm)	Error speed (rpm)

INTELLIGENT POWER MODULE:

Features of PEC16DSMO1

- ✓ Various test points to check waveforms at different stages of operation.
- ✓ Flexibility to work with different controller modules developed by us.
- ✓ Necessary protections are provided through fuses and MCBs. A separate protection circuit for input over current faults.
- ✓ Power supply to the Eddy Current load coil is also provided from the module.
- ✓ Required connectors are provided for motor input supply connection and feedback signal connection.

Front Panel View



Description

- ✓ R,Y,B = Applied to 3 phase AC input supply.
- ✓ U,V,W = Three phase R, Y, B output terminals.
- ✓ BR1 & BR2 = Breaking Rheostat (470S - 2A).
- ✓ +HV = Rectifier with filter DC output voltage (DC link voltage).
- ✓ Voltmeter = Read the DC link voltage.
- ✓ V/2 = Voltage across V/2 is half of the DC link voltage.

Feed back signals (Isolated current/voltage/speed sensor output)

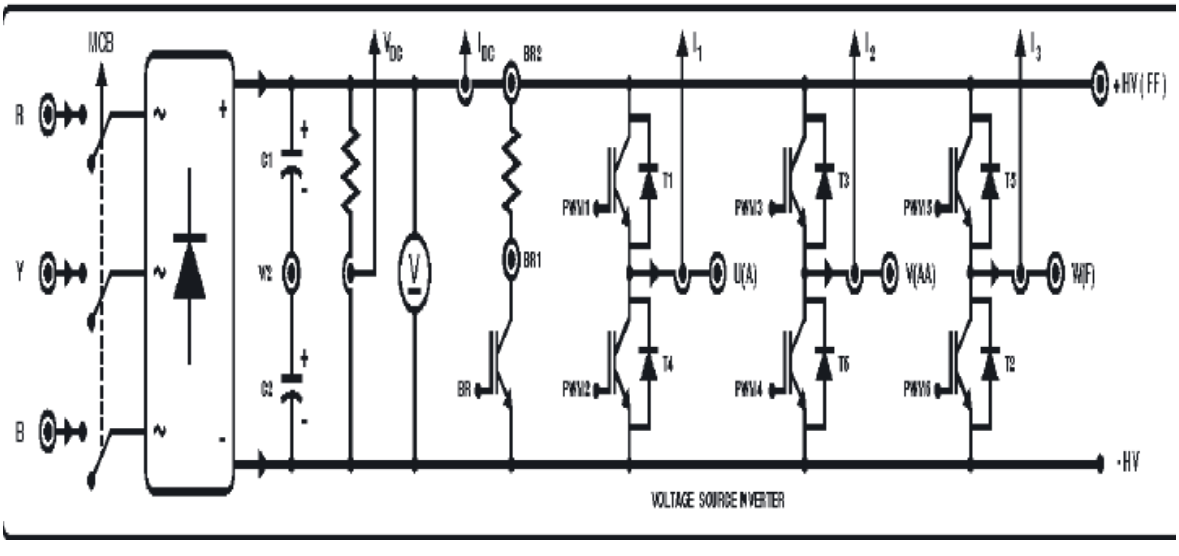
- ✓ I1, I2, I3 = 3 phase R,Y,B current transducer output currents are I1, I2,
- ✓ I3 respectively and measure this current across the
- ✓ terminals U, V and W.
- ✓ VDC = DC link voltage (voltage transducer output).
- ✓ IDC = DC link current (current transducer output).
- ✓ N(Speed) = Analog voltage (0 - 5V).
- ✓ F = Fault output signal comes from IPM, when over
- ✓ temperature/current occurs.
- ✓ MCB = Power ON/OFF the 3 phase AC supply.
- ✓ Power = Power ON/OFF the control circuits.

IGBT - PWM Inputs (from controller)

- ✓ PWM1.... PWM6 = PWM pulses are coming from controller.
- ✓ PWM output
- ✓ High - 5V = IGBT ON.
- ✓ Low - 0V = IGBT OFF.
- ✓ CAP1.....CAP6 = Capture input to processor.

Protection Circuit

- ✓ RST = Reset the protection circuit, then 'SD' LED will be off.
- ✓ SD = Shut down LED will glow, when over voltage/current occurs in power circuit.



Power Converter for Squirrel Cage Induction motor

Theoretical Details of dsPIC controller MICRO-4011

Features:

High Performance Modified RISC CPU:

- Modified Harvard architecture
- C compiler optimized instruction set architecture with flexible addressing modes
- 84 base instructions
- 24-bit wide instructions, 16-bit wide data path
- 48 Kbytes on-chip Flash program space (16K Instruction words)
- 2 Kbytes of on-chip data RAM
- 1 Kbytes of non-volatile data EEPROM
- Up to 30 MIPs operation:
  - DC to 40 MHz external clock input
  - 4 MHz-10 MHz oscillator input with PLL active (4x, 8x, 16x)
- 30 interrupt sources
  - 3 external interrupt sources
  - 8 user selectable priority levels for each interrupt source
  - 4 processor trap sources
- 16 x 16-bit working register array

DSP Engine Features:

- Dual data fetch
- Accumulator write back for DSP operations
- Modulo and Bit-Reversed Addressing modes
- Two, 40-bit wide accumulators with optional saturation logic
- 17-bit x 17-bit single cycle hardware fractional/ integer multiplier
- All DSP instructions single cycle
- ± 16-bit single cycle shift

Peripheral Features:

- High current sink/source I/O pins: 25 mA/25 mA
- Timer module with programmable prescaler:

  Five 16-bit timers/counters; optionally pair 16-bit timers into 32-bit timer modules
- 16-bit Capture input functions
- 16-bit Compare/PWM output functions
- 3-wire SPI™ modules (supports 4 Frame modes)
- I2C™ module supports Multi-Master/Slave mode and 7-bit/10-bit addressing

• 2 UART modules with FIFO Buffers

• 1 CAN modules, 2.0B compliant

Motor Control PWM Module Features:

• 6 PWM output channels - Complementary or Independent Output modes - Edge and Center Aligned modes • 3 duty cycle generators

• Dedicated time base

• Programmable output polarity

• Dead-time control for Complementary mode

• Manual output control

• Trigger for A/D conversions

Quadrature Encoder Interface Module Features:

• Phase A, Phase B and Index Pulse input

• 16-bit up/down position counter

• Count direction status

• Position Measurement (x2 and x4) mode

Connection Procedure

- Connect the 3-pin power chord of the Micro-4011 trainer to the supply.
- Connect the power module to the 1N power supply.
- Connect the 26 pin FRC cable one end to P2 connector in Micro-4011 trainer and the other end to "FEEDBACK SIGNALS" of the PEC16DSMO1.
- Connect the 34 pin FRC cable one end to 34 pin FRC connector in Micro-4011 trainer and the other end to QEP sensor interface chord.
- Connect the 34 pin FRC cable one end to QEP sensor interface chord and the other end to "IGBT- PWM INPUTS" of the PEC16DSMO1.
- Connect the output power terminal of PEC16DSMO1 to the power input terminal of induction motor.
- Connect the PC with dsPIC micro controller.

Experiment Procedure

1. Verify the connections as per the connection procedure and connection diagram.
2. Switch ON the Micro-4011 trainer kit.
3. Switch ON the power ON/OFF switch in the Intelligent Power Module
4. Check whether shut down LED "SD" glows or not. If 'SD' LED glows press the Reset switch, the LED gets OFF.

5. Switch on the MCB and gradually increase the voltage upto 415 V using 3 ph variac.
6. Switch ON the PC (personal computer) and then press Reset switch of the Micro-4011 trainer.
7. Download and execute the program which is in the personal computer.
8. Select the open loop mode in the Micro -4011 trainer kit.
9. Set the supply voltage and control the speed of motor by varying duty cycle.
10. Repeat the step 9 for different supply voltages.
11. Select the closed loop mode in the Micro -4011 trainer kit.
12. Set the input voltage and give the reference speed by varying the set speed in the Micro -4011 trainer kit.
13. Note down the actual speed and calculate the error.
14. .Repeat the steps 12 and 13 for different reference speeds.

RESULT:

Thus the speed control of induction motor using dsPIC controller for open loop & closed loop was verified and corresponding readings were tabulated.

POST-LAB QUESTIONS:

1. **What is meant by stator voltage control?**

2. **What is meant by regenerative braking?**

3. **Compare FPGA with micro controller?**

4. **What is need of PI and PID controller?**

5. **What are the registers used in dsPIC controller?**

DEPT. OF ELECTRICAL & ELECTRONICS ENGINEERING

SRM UNIVERSITY, Kattankulathur – 603203

Title of Experiment :
Name of the student : Register Number : Date of Experiment : Date of Submission :

S.No	Marks Split up	Maximum Marks	Marks Obtained
1	Pre viva questions	5	
2	Execution of experiment	15	
3	Calculation/evaluation of result	15	
4	Post viva questions	5	
	Total	40	

Signature of the Faculty

PRELAB QUESTIONS:

1. **What is meant by servo motor?**

2. **What are advantages of servo motor?**

3. **Write the different types of servo motor.**

4. **Write the working principle of servo motor?**

5. **Compare DSP controller with micro controller.**

4. SPEED AND POSITION CONTROL OF SERVO MOTOR BY DSP CONTROLLER

AIM:

To visualize the speed and position control of servo motor by various inputs of DSP CONTROLLER kit**.**

APPARATUS REQUIRED:

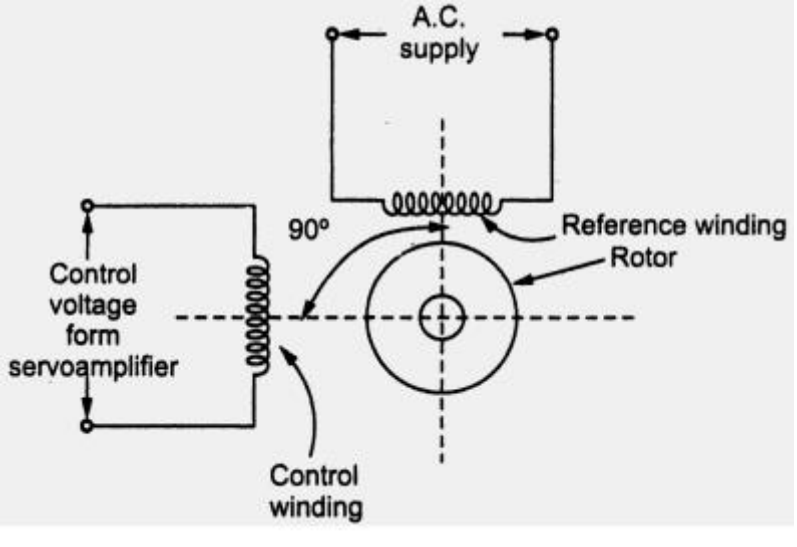
S.No	Apparatus	Specifications	Quantities
1	servo motor	-	1
2	DSP	Micro 2047	1
3	Connecting probes	Male/female connector	As per requirements
4	Multimeter	Digital	2

Theory :

Construction

The a.c. servomotor is basically consists of a stator and a rotor. The stator carries two windings, uniformly distributed and displaced by 90^o in space, from each other .On winding is called as main winding or fixed winding or reference winding. The reference winding is excited by a constant voltage a.c. supply.

The other winding is called as control winding. It is excited by variable control voltage, which is obtained from a servo amplifier. The winding are 90^o away from each other and control voltage is 90^o out of phase with respect to the voltage applied to the reference winding. This is necessary to obtain rotating magnetic field.



Operating Principle

The operating principle of two phase a.c. servomotor is same as that of normal three phase induction motor. The control voltage applied to the control winding and the voltage applied to the reference winding are 90^o out of phase. Hence the flux produces by current through control winding is also 90^o out of phase with respect to the flux produced by the current through the reference winding. The resultant flux in the air gap is hence rotating flux sweeps over the rotor, the e.m.f. gets induced in the rotor. This e.m.f. circulates the current through the rotor. The rotor current produces its own flux called as rotor flux. This flux interacts with the rotating magnetic field, producing a torque on the rotor and rotor starts rotating.

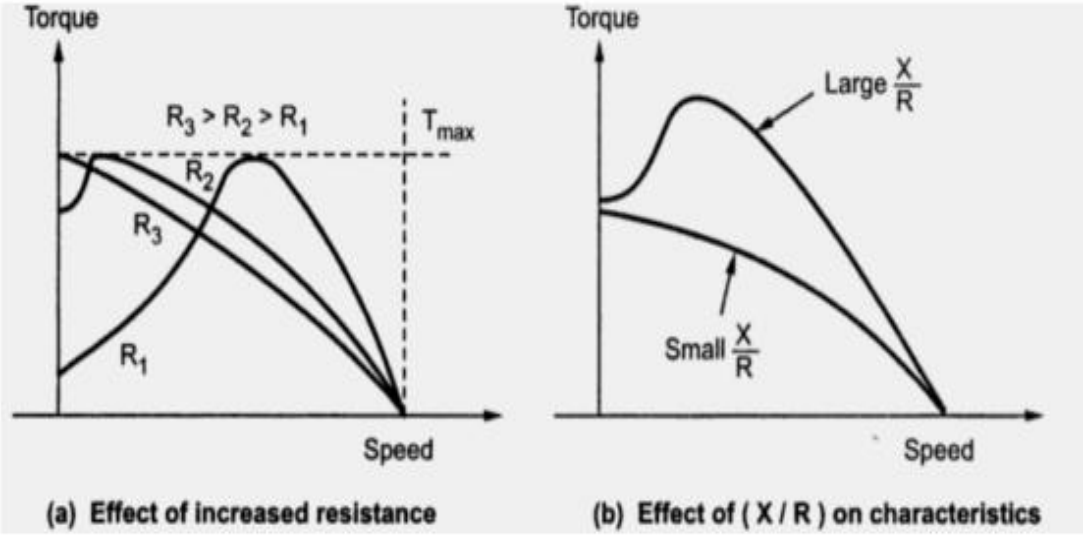
In the two phase a.c. servomotors, the polarity of the control voltage determines the direction of rotation. A change in the sign of the control voltage reverses the direction of rotation of the motor. Since the reference voltage is constant, the torque and the angular speed are the functions of the control voltage.

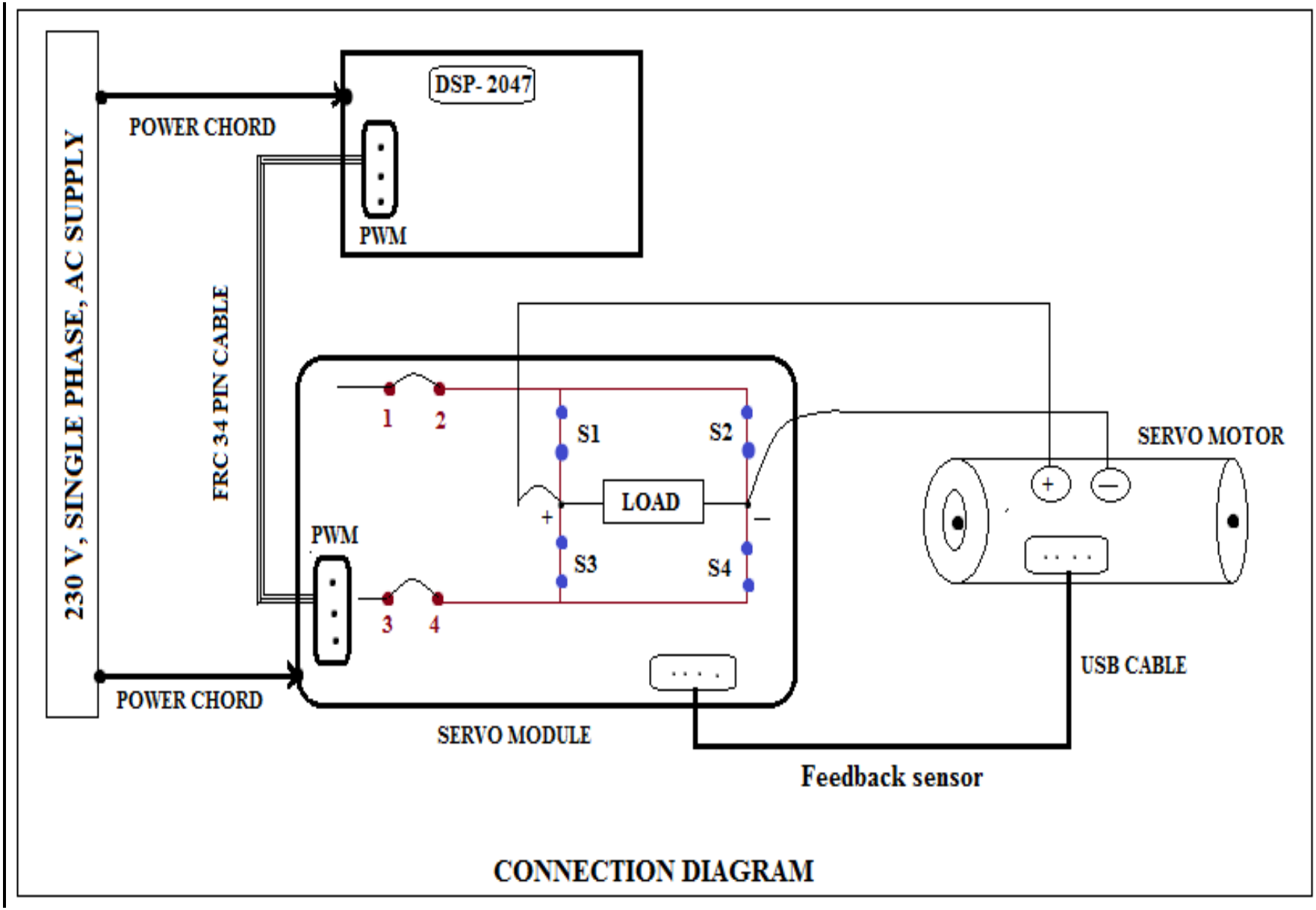
Torque-Speed Characteristics

The usual torque-speed characteristics of an induction motor with high inductance to resistance ratio are not suitable for the servomotor. A servomotor must have

1. Linear torque-speed characteristics
2. Slope of the torque-speed characteristics must be negative.
3. The characteristics must be parallel to one another for various values of the control voltage apply.

It is seen that when rotor resistance is increased the torque-speed characteristics becomes more and more linear. In general for low inductance to resistance ratio, the torque-speed characteristics are almost linear.





CONNECTION DIAGRAM

Tabulation:

SPEED CONTROL

Duty cycle	Velocity	Actual Speed	Voltage	Current

SALIENT FEATURE/SPECIFICATIONS

Software architecture

By the standards of general-purpose processors, DSP instruction sets are often highly irregular. One implication for software architecture is that hand-optimized assembly-code routines are commonly packaged into libraries for re-use, instead of relying on advanced compiler technologies to handle essential algorithms.

Instruction sets

- multiply–accumulates (MACs, including fused multiply–add, FMA) operations
- used extensively in all kinds of matrix operations
- convolution for filtering
- dot product
- polynomial evaluation
- Fundamental DSP algorithms depend heavily on multiply–accumulate performance
- FIR filters
- Fast Fourier transform (FFT)
- Instructions to increase parallelism:
- SIMD
- VLIW
- superscalar architecture
- Specialized instructions for modulo addressing in ring buffers and bit-reversed addressing mode for FFT cross-referencing
- Digital signal processors sometimes use time-stationary encoding to simplify hardware and increase coding efficiency.
- Multiple arithmetic units may require memory architectures to support several accesses per instruction cycle
- Special loop controls, such as architectural support for executing a few instruction words in a very tight loop without overhead for instruction fetches or exit testing

Data instructions

Saturation arithmetic, in which operations that produce overflows will accumulate at the maximum (or minimum) values that the register can hold rather than wrapping around (maximum+1 doesn't

overflow to minimum as in many general-purpose CPUs, instead it stays at maximum). Sometimes various sticky bits operation modes are available.

- Fixed-point arithmetic is often used to speed up arithmetic processing
- Single-cycle operations to increase the benefits of pipelining

Program flow

- Floating-point unit integrated directly into the datapath
- Pipelined architecture
- Highly parallel multiplier–accumulators (MAC units)
- Hardware-controlled looping, to reduce or eliminate the overhead required for looping operations

Hardware architecture:

Memory architecture

DSPs are usually optimized for streaming data and use special memory architectures that are able to fetch multiple data and/or instructions at the same time, such as theHarvard architecture or Modified von Neumann architecture, which use separate program and data memories (sometimes even concurrent access on multiple data buses).

DSPs can sometimes rely on supporting code to know about cache hierarchies and the associated delays. This is a tradeoff that allows for better performance.In addition, extensive use of DMA is employed.

Addressing and virtual memory

DSPs frequently use multi-tasking operating systems, but have no support for virtual memory or memory protection. Operating systems that use virtual memory require more time for context switching among processes, which increases latency.

- Hardware modulo addressing
- Allows circular buffers to be implemented without having to test for wrapping
- Bit-reversed addressing, a special addressing mode
- useful for calculating FFTs
- Exclusion of a memory management unit

Precautions:

- Don’t connect the circuit in the presence of supply.
- Circuit connections should be in an order.
- Proper connecting probe should be used.
- Switch on the circuit in the presence of lab instructor.

Procedure:

- Give the connections as per the circuit diagram.
- Follow the proper switching conditions of the system.

- By changing the different PWM pulse note down the different speed and position angle of AC servo motor.
- Switch of the circuit
- Disconnect the circuit

RESULT:

Thus the visualization of speed and position control of AC SERVO motor was done properly as per the requirements.

POST- LAB QUESTIONS:

1. **What is the difference between stepper motor and servo motor?**

2. **Write the applications of servomotor?**

3. **What is meant by thermal modelling?**

4. **Draw the block diagram for closed loop position control of electrical drive.**

5. **What is the need of feedback sensor.**

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	Total	40	

Signature of the Faculty

PRELAB QUESTIONS:

1. **Define dc chopper.**

2. **What are advantages of dc chopper?**

3. **What are various speed control methods of DC motor?**

4. **What is the difference between half controlled and full controlled rectifier?**

5. **Mention the different types of braking methods.**

5. FPGA BASED DC MOTOR CONTROL USING DC-DC CHOPPER

AIM:

To study the operation of speed control of dc motor fed from four quadrant chopper using FPGA controller

APPARATUS REQUIRED:

Apparatus Name	Specifications / Range	Qty
Auto Transformer	440 V, 15A,50 Hz, 3 phase	1
Intelligent power module	PEC16DSMO1TRAINER KIT	1
FPGA controller - trainer kit	SPARTAN 6	1
DC Shunt Motor	Rated Power: 0.5 H.P Rated Voltage: 180 V Rated Current: 5.1A Rated Speed: 1500 rpm	1
QEP sensor interface chord	DC MOTOR	1
PC -PC serial port cable		2
Power Patch Chords	1 phase 3 pin chord	4
26 Pin FRC cable		1
34 Pin FRC cable		1
Personal Computer		1
Connecting wires		Required

THEORY:

DC CHOPPER:

A chopper is a static power electronic device that converts fixed dc input voltage to a variable dc output voltage. A Chopper may be considered as dc equivalent of an ac transformer since they behave in an identical manner. As chopper involves one stage conversion, these are more efficient. These are also used in trolley cars, marine hoist, forklift trucks and mine haulers. The future electric automobiles are likely to use choppers for their speed control and braking. Chopper systems offer smooth control, high efficiency, faster response and regeneration facility. The power semiconductor devices used for a chopper circuit can be force commutated thyristor, power BJT, MOSFET and IGBT.GTO based chopper are also used. These devices are generally represented by a switch. When the switch is off, no current can flow. Current flows through the load when switch is “on”. The power semiconductor devices have on-state voltage drop of 0.5V to 2.5V.

Four Quadrant Chopper:

- The switches in the four quadrant chopper can be switched in two different modes: The output voltage swings in both directions i.e. from+Vdc to -Vdc. This mode of switching is referred to as PWM with bipolar voltage switching.
- The output voltage swings either from zero to +Vdc or• zero to -Vdc. This mode of switching is referred to as PWM with unipolar voltage switching.

Speed control techniques in separately excited dc motor:

1. By varying the armature voltage for below rated speed.
2. By varying field flux should to achieve speed above the rated speed.

EXPERIMENT PROCEDURE:

1. Connect single phase AC supply to the points P and N on the chopper module.
2. Connect PMDC motor terminals to the points R and Y on front panel of chopper module.
3. Speed sensor output from motor is connected to 9-pin D connector (Speed feedback) on front panel.

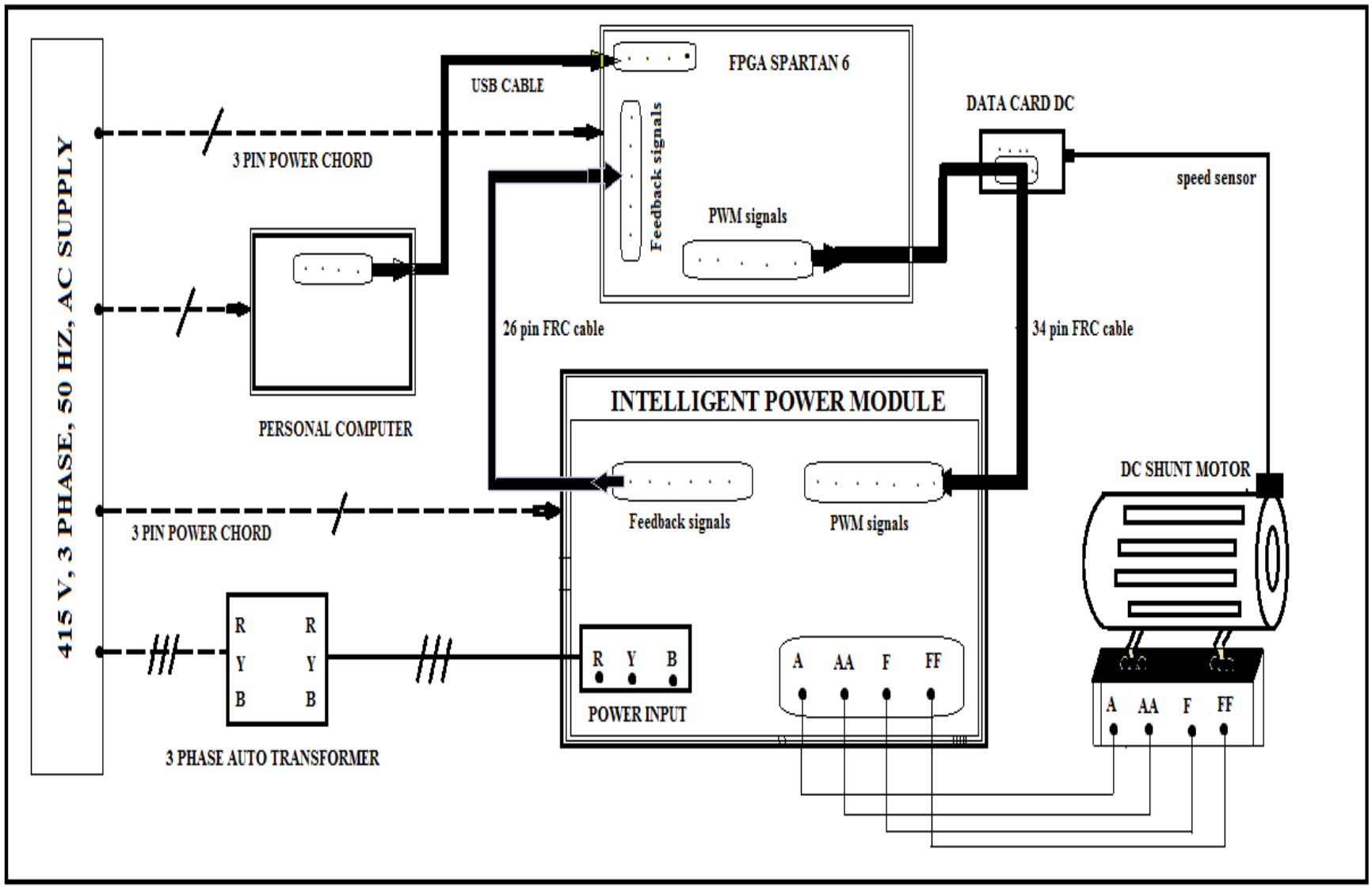
OPEN LOOP:

1. Switch on the power supply to the chopper module
2. LCD displays forward/reverse option. Using movement key select forward option.
3. Now it displays closed loop or open loop option. In that select open loop option.
4. Set the input voltage to 200V.
5. Now vary the duty cycle using Increment/Decrement keys and note down the readings of actual speed and armature voltage of dc motor.

CLOSED LOOP:

1. Switch on the power supply to the chopper module.
2. LCD displays forward/reverse option. Using enter key select forward option.
3. Now it displays closed loop or open loop option. In that select closed loop option using movement keys.
4. Now vary the set speed using Increment/Decrement keys and note down the readings of actual speed and armature voltage of dc motor.

CONNECTION DIAGRAM



TABULATION:

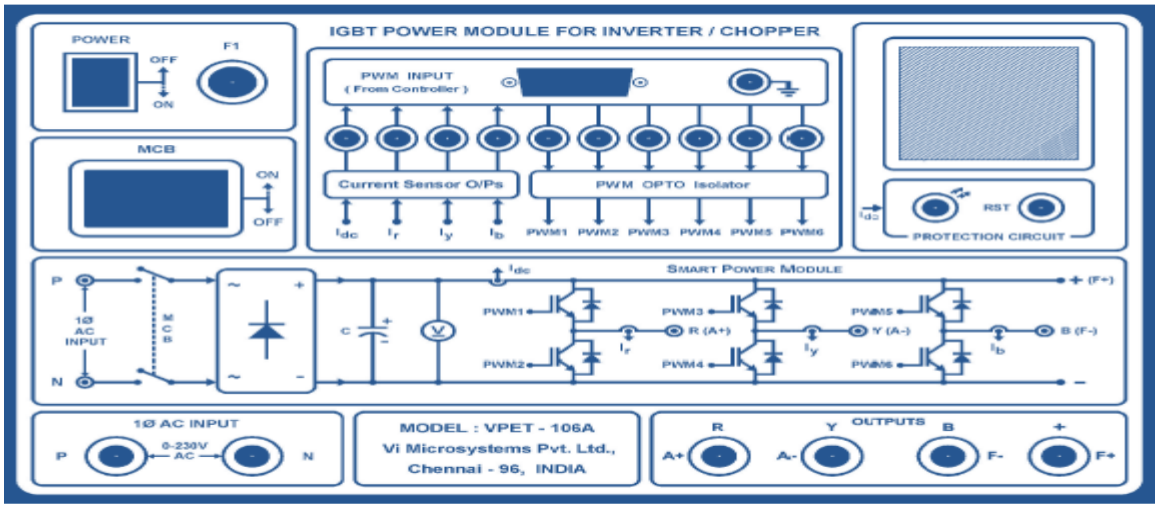
a) OPEN LOOP (Field duty cycle =)

Armature Current (A)	Armature Duty Cycle	Actual Speed (rpm)	Armature Voltage (in V)

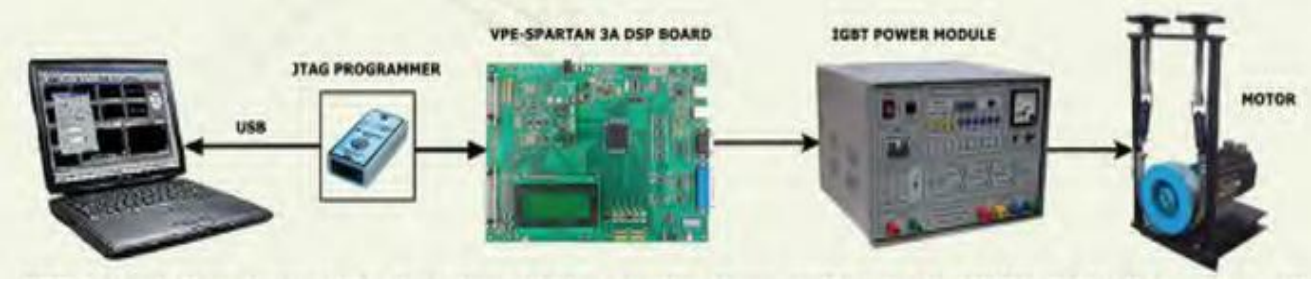
b) CLOSED LOOP

Armature Voltage (V)	Set Speed (rpm)	Armature Current (in Ampere)	Actual Speed (rpm)	Error (rpm)

Front Panel View

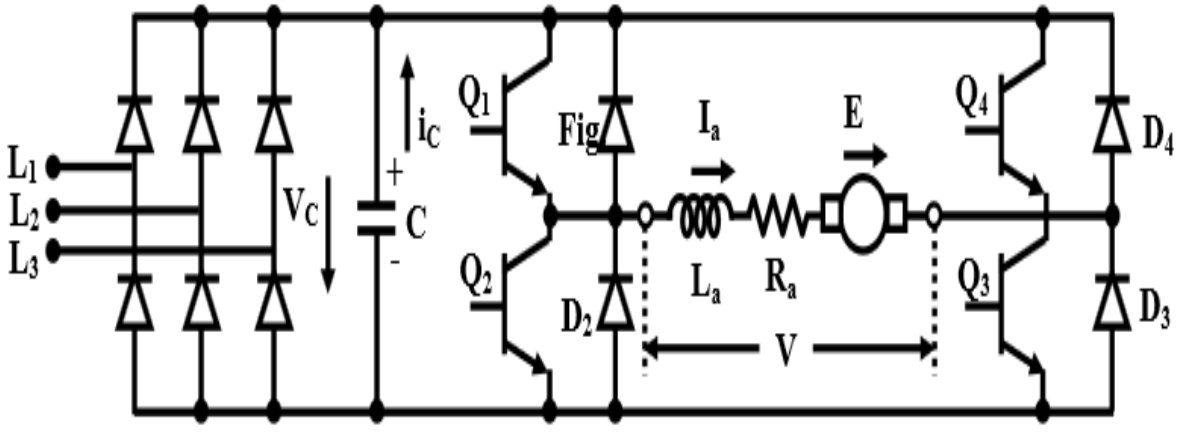


PROCESS:



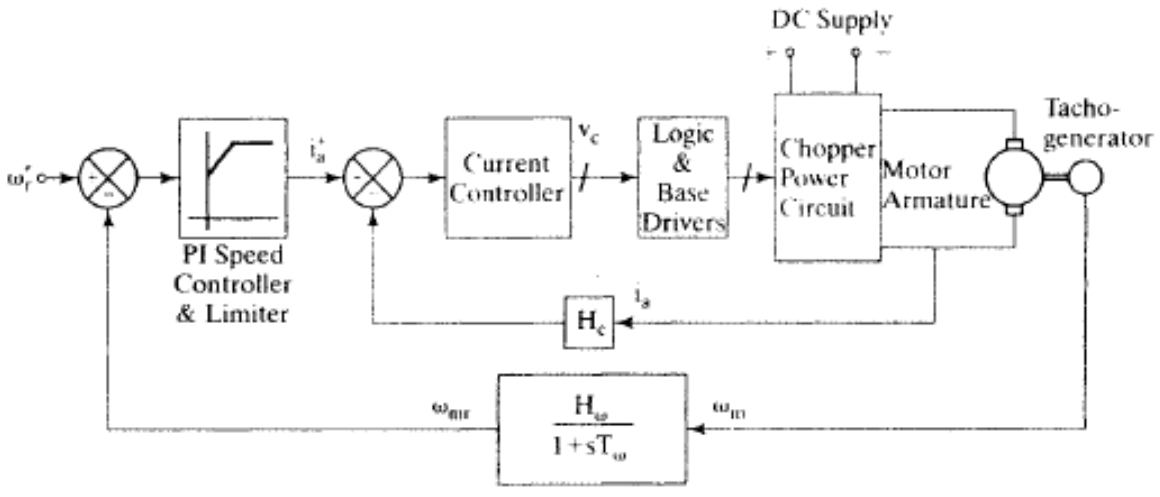
Description:

- Power ON/OFF switch - To switch ON/OFF power to the module.
- MCB - To control input AC voltage to the power circuit.
- PWM INPUT - To connect the PWM input / feedback signal from / to the controller unit
- R, Y, B - To connect 3· output to the load.
- Voltmeter - To display DC link voltage.
- P, N - To connect AC input to the module.
- A+, A-, F+, (+) - To connect the DC output to the load.
- RST - To reset the module.
- PWM1, PWM 2...PWM 6 - Test points to view the PWM signal to the switches with respect to ground point.
- Idc, Ir, Iy, Ib - Test points to view the sensed input DC current & output R, Y and B phase currents.
- PWM Isolation - To isolate the gate signals.



Chopper Fed DC Motor

CLOSED LOOP CONTROL OF CHOPPER FED DC MOTOR



Theoretical Details of SPARTAN 6 FPGA Features:

- Spartan-6 Family:
  - Spartan-6 LX FPGA: Logic optimized
  - Spartan-6 LXT FPGA: High-speed serial connectivity
- Designed for low cost
  - Multiple efficient integrated blocks
  - Optimized selection of I/O standards
  - Staggered pads
- High-volume plastic wire-bonded packages
- Low static and dynamic power
  - 45 nm process optimized for cost and low power
  - Hibernate power-down mode for zero power
  - Suspend mode maintains state and configuration with multi-pin wake-up, control enhancement
  - Lower-power 1.0V core voltage (LX FPGAs, -1L only)
  - High performance 1.2V core voltage (LX and LXT FPGAs, -2, -3, and -3N speed grades)
- Multi-voltage, multi-standard SelectIO™ interface banks
  - Up to 1,080 Mb/s data transfer rate per differential I/O
  - Selectable output drive, up to 24 mA per pin
  - 3.3V to 1.2V I/O standards and protocols
  - Low-cost HSTL and SSTL memory interfaces
  - Hot swap compliance
  - Adjustable I/O slew rates to improve signal integrity
- High-speed GTP serial transceivers in the LXT FPGAs
  - Up to 3.2 Gb/s
  - High-speed interfaces including: Serial ATA, Aurora, 1G Ethernet, PCI Express, OBSAI, CPRI, EPON, GPON, DisplayPort, and XAUI

- Integrated Endpoint block for PCI Express designs (LXT)
- Low-cost PCI® technology support compatible with the 33 MHz, 32- and 64-bit specification.
- Integrated Memory Controller blocks
    - DDR, DDR2, DDR3, and LPDDR support
    - Data rates up to 800 Mb/s (12.8 Gb/s peak bandwidth)
    - Multi-port bus structure with independent FIFO to reduce design timing issues
- Abundant logic resources with increased logic capacity
    - Optional shift register or distributed RAM support
    - Efficient 6-input LUTs improve performance and minimize power
    - LUT with dual flip-flops for pipeline centric application
- Block RAM with a wide range of granularity
    - Fast block RAM with byte write enable
    - 18 Kb blocks that can be optionally programmed as two independent 9 Kb block RAMs
- Clock Management Tile (CMT) for enhanced performance
    - Low noise, flexible clocking
    - Digital Clock Managers (DCMs) eliminate clock skew and duty cycle distortion
    - Phase-Locked Loops (PLLs) for low-jitter clocking
    - Frequency synthesis with simultaneous multiplication, division, and phase shifting
    - Sixteen low-skew global clock networks
- Simplified configuration, supports low-cost standards
    - 2-pin auto-detect configuration
    - Broad third-party SPI (up to x4) and NOR flash support
    - Feature rich Xilinx Platform Flash with JTAG
    - MultiBoot support for remote upgrade with multiple bitstreams, using watchdog protection
- Enhanced security for design protection
    - Unique Device DNA identifier for design authentication
    - AES bitstream encryption in the larger devices
- Faster embedded processing with enhanced, low cost, MicroBlaze soft processor
- Industry-leading IP and reference designs

JTAG has four control lines to Configure FPGA

* **TCK** - JTAG Test Clock
The TCK clock signal synchronizes all JTAG port operations.

* **TDI** - JTAG Test Data Input
TDI is the serial data input for all JTAG instruction and data registers.

* **TMS** - JTAG Test Mode Select
The serial TMS input controls the operation of the JTAG port.
* **TDO** - JTAG Test Data Output
TDO is the serial data output for all JTAG instruction and data registers.

RESULT:

Thus the speed control of dc motor fed from four quadrant chopper is studied and readings are tabulated.

POST- LAB QUESTIONS:

1. **What is meant by regenerative braking?**

2. **What are applications of dc chopper?**

3. **Draw the block diagram for closed loop speed control of dc drive.**

4. **Write the average output voltage equation of dc chopper.**

5. **Mention the classifications of dc chopper.**

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PRE- LAB QUESTIONS:

1. **What is meant by Voltage Source Inverter?**

2. **Compare VSI and CSI.**

3. **What is the need of POWERGUI in matlab simulation?**

4. **What are the advantages of VSI?**

5. **Draw the general block diagram for VSI fed IM dive.**

6. SIMULATION OF THREE PHASE VOLTAGE SOURCE INVERTER USING SPWM

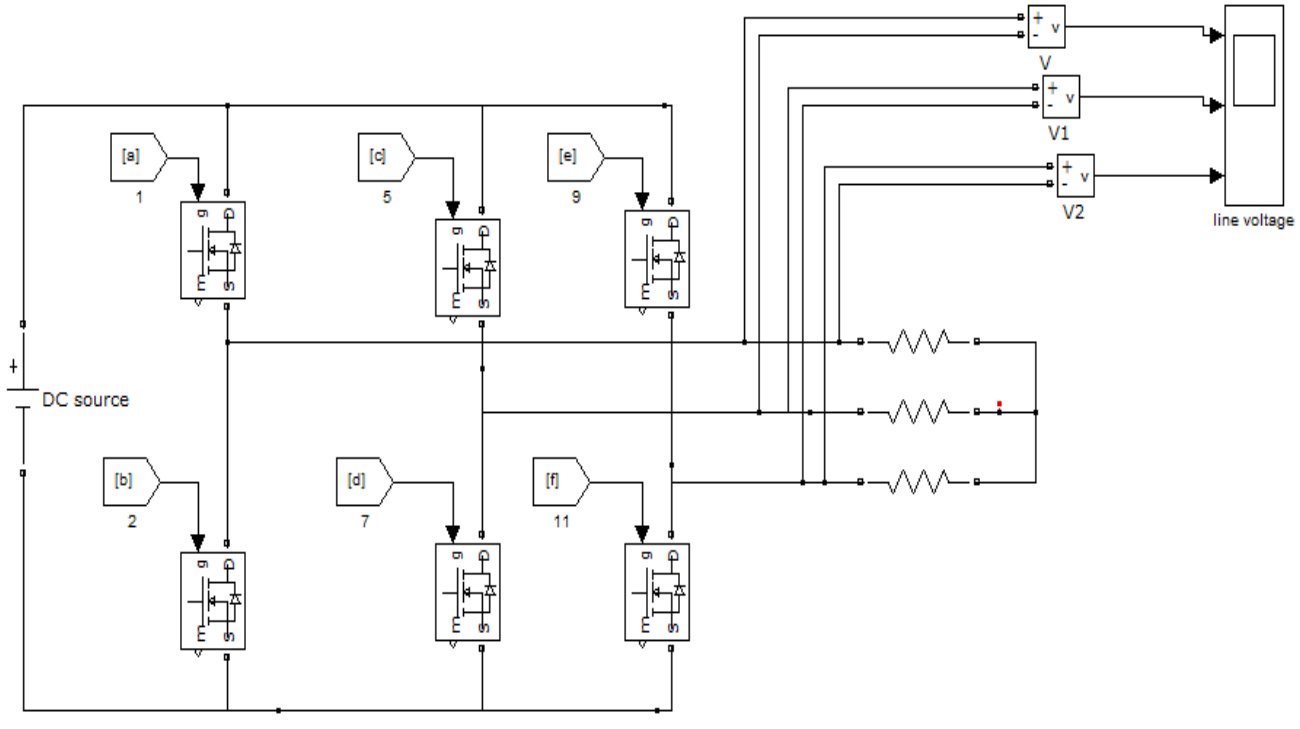
AIM:

To simulate the three phase voltage source inverter with resistive load using SPWM.

SOFTWARE TOOLS REQUIRED:

MATLAB/SIMULINK.

SIMULATION DIAGRAM:



THEORY:

3-PHASE VOLTAGE SOURCE INVERTER:

Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium to high-power applications. The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal voltage waveforms (e.g., ASDs, UPSs, FACTS, VAR compensators), arbitrary voltages are also required in some emerging applications (e.g., active filters, voltage compensators). The standard three-phase VSI topology is shown in Fig. 1. The switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would

result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. Thus the resulting ac output line voltages consist of discrete values of voltages that are Vi , 0, and -Vi.

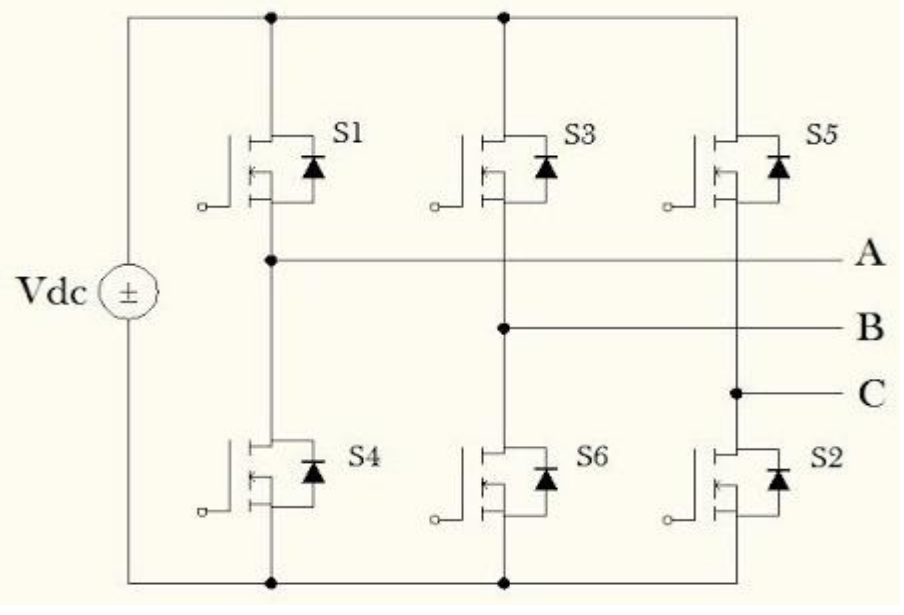


Fig.1. Three-phase VSI topology

SINUSOIDAL-PULSE-WIDTH-MODULATION (SPWM):

PWM (Pulse Width Modulation)refers to adjusting the duty cycles(on and off periods) of inverter switch components so that they convert the dc input into ac output.[10]It is advantageous as it reduces the harmonic level in the output waveform. Sinusoidal PWM (SPWM) is one such technique where the pulse width varies sinusoidally with respect to its position angle in a switching cycle .A Reference wave is compared with a carrier wave and the resultant pulse is generated. Here a sinusoidal and triangular waveform is the reference and carrier waveform respectively is shown in fig.2. A comparator gives an output signal whenever the sinusoidal wave amplitude at that time instant is higher than that of the triangular waveform and a pulse is generated according to the comparator output.

The amplitude modulation index is defined as,

$$ma=Vc/Vcar$$

where, Vc = peak magnitude of control signal (modulating sine wave).

Vcar = peak magnitude of carrier signal (triangular signal).

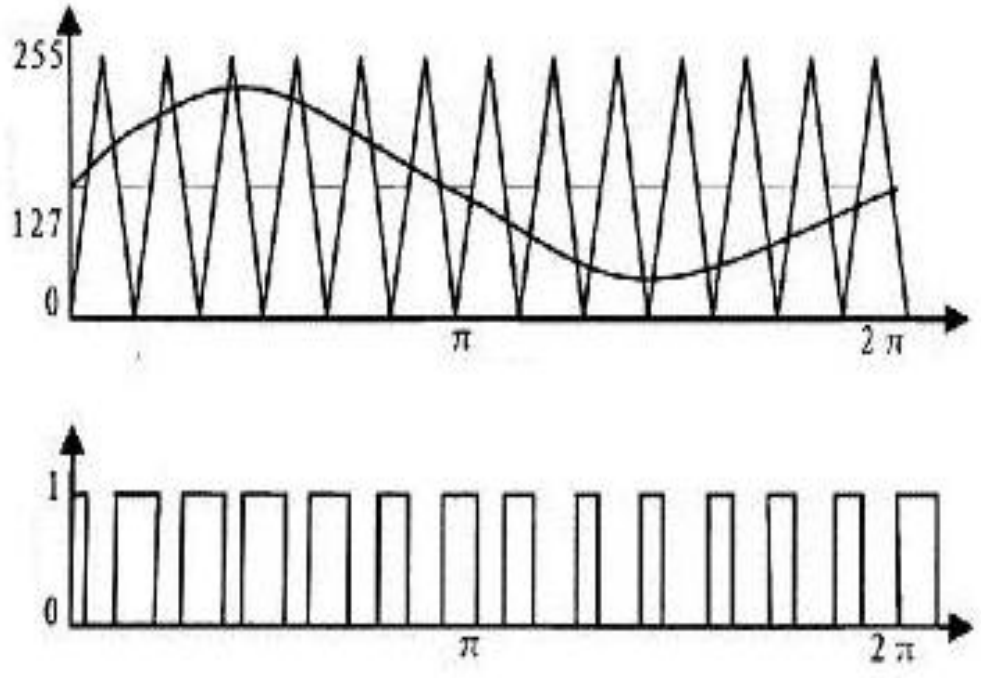
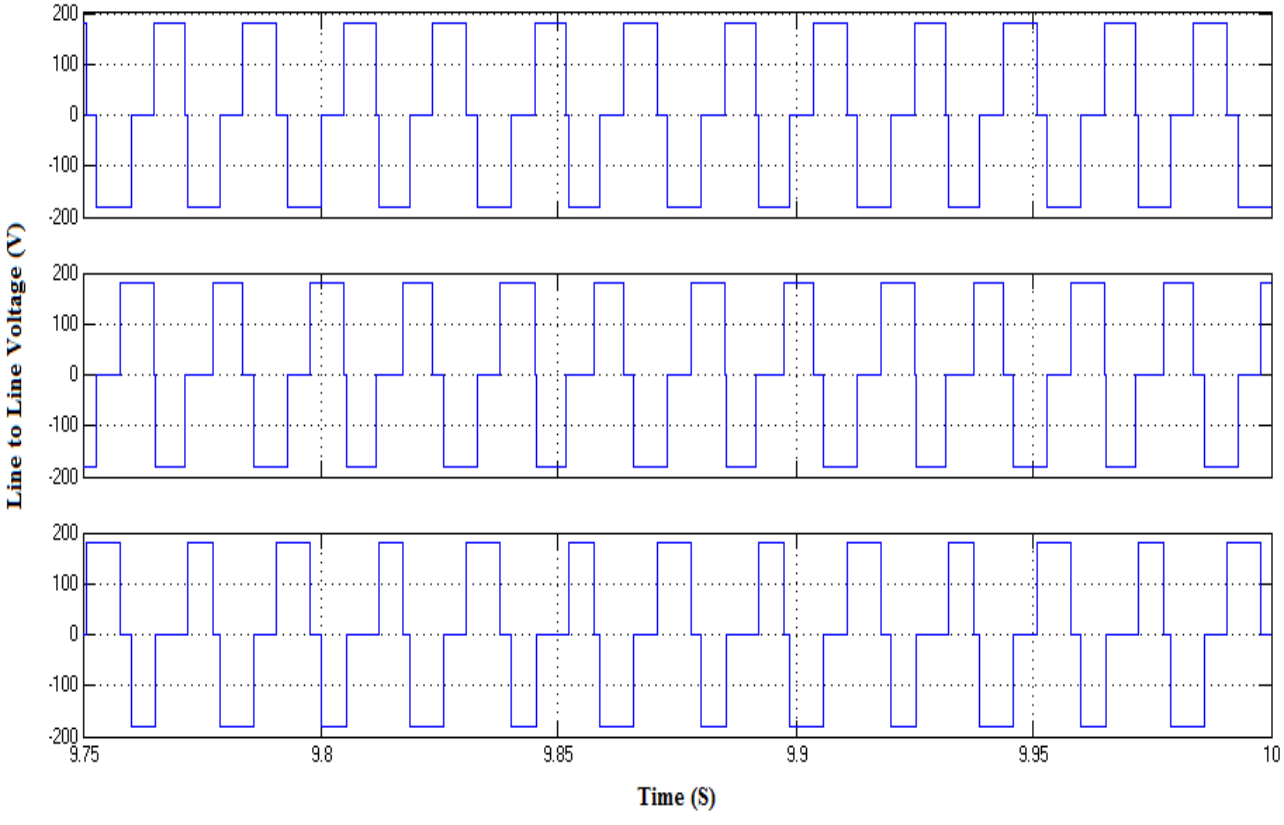


Fig.2. SPWM Technique

SIMULATION OUTPUT: LINE TO LINE VOLTAGE



Result:

Thus the three phase voltage source inverter with R load using SPWM was simulated and verified.

POST- LAB QUESTIONS:

1. **What is meant by SPWM?**

2. **Mention the different types of PWM techniques.**

3. **Compare SPWM and Hysteresis control.**

4. **What is the need of feedback diode in inverter circuit?**

5. **Define THD.**

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PRE- LAB QUESTIONS:

1. **What are the advantages of SPWM?**

2. **What are the methods for reduction of harmonics?**

3. **What are the control strategies for chopper circuit?**

4. **State the types of chopper.**

5. **State the advantages of chopper fed dc drives.**

7. Simulation of Chopper fed dc motor

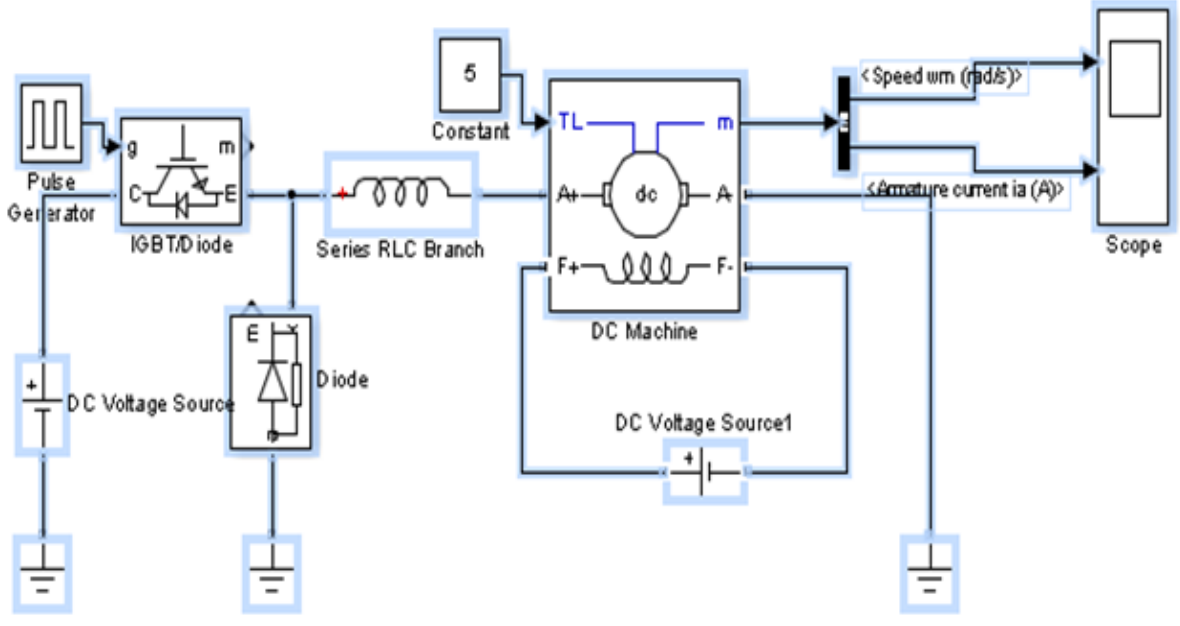
AIM:

To simulate the chopper fed dc motor

SOFTWARE TOOLS REQUIRED:

MATLAB/SIMULINK

SIMULATION DIAGRAM:



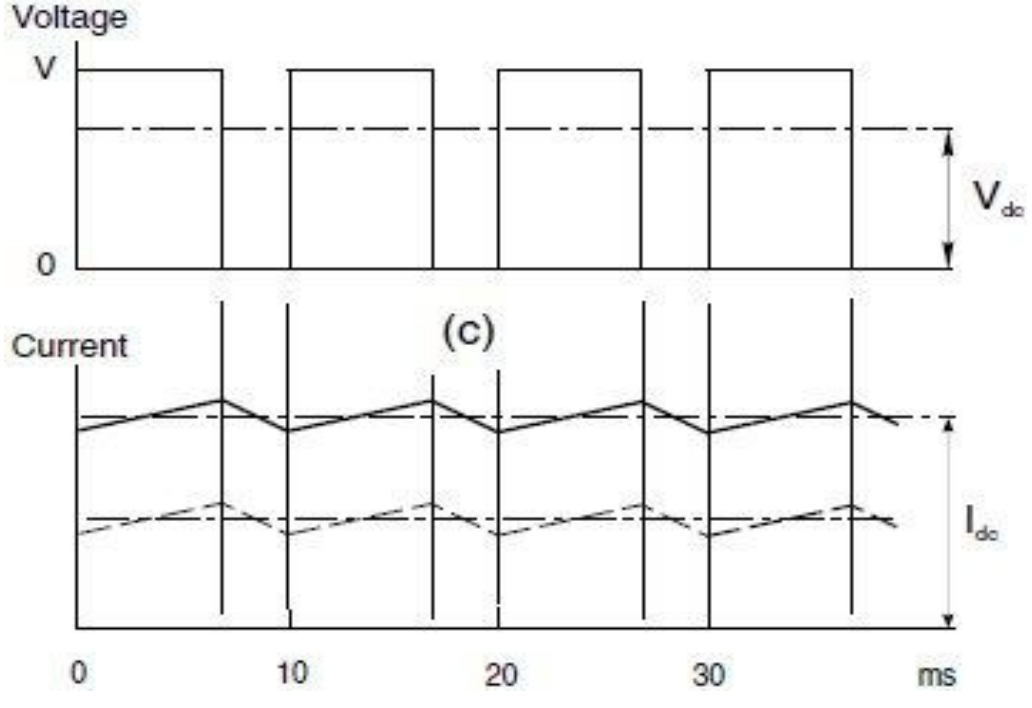
THEORY:

A single-switch chopper using a transistor, MOSFET or IGBT can only supply positive voltage and current to a d.c. motor, and is therefore restricted to quadrant 1 motoring operation. When regenerative and/or rapid speed reversal is called for, more complex circuitry is required, involving two or more power switches, and consequently leading to increased cost.

It provides an output voltage in the range $0 < E$, where E is the battery voltage, so this type of chopper is only suitable if the motor voltage is less than the battery voltage. Where the motor voltage is greater than the battery voltage, a 'step-up' chopper using an additional inductance as an intermediate energy store is used.

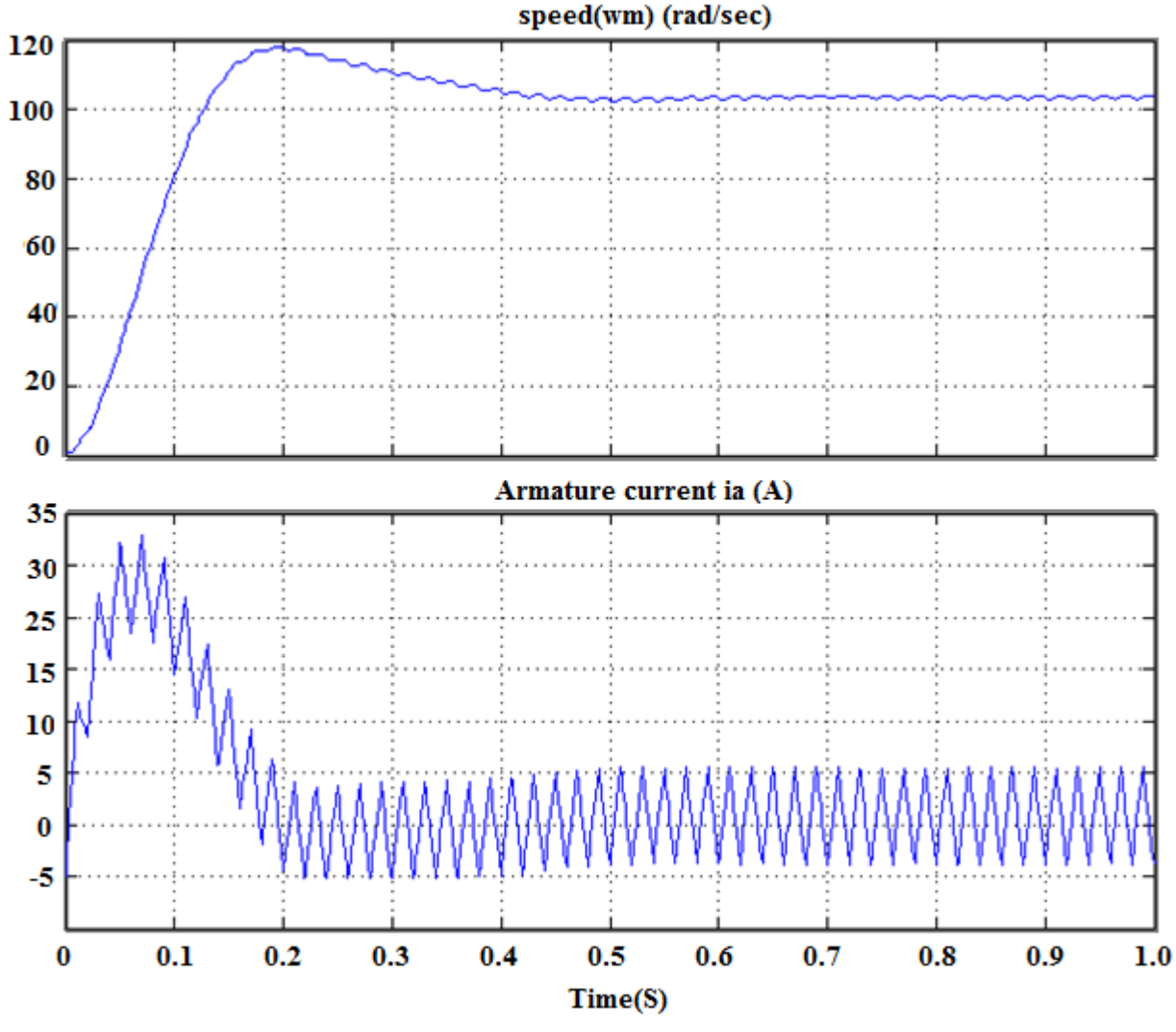
Performance of chopper-fed d.c. motor drives:

The chopper-fed motor is rather better than the phase-controlled; because the armature current ripple can be less if a high chopping frequency is used. Typical waveforms of armature voltage and current .These are drawn with the assumption that the switch is ideal. A chopping frequency of medium and large chopper drives, while small drives often use a much higher chopping frequency, and thus have lower ripple current. Assume that the speed remains constant despite the slightly pulsating torque, and that the armature current is continuous. when the transistor is switched on, the battery voltage V is applied directly to the armature, and during this period the path of the armature current is indicated by the dotted line in Figure For the remainder of the cycle the transistor is turned 'off ' and the current freewheels through the diode, as shown by the dotted line in Figure 4.13(b). When the current is freewheeling through the diode, the armature voltage is clamped at (almost) zero.The speed of the motor is determined by the average armature voltage, (V_{dc}), which in turn depends on the proportion of the total cycle time (T) for which the transistor is 'on'. If the on and off times are defined as $T_{on} = kT$ and $T_{off} = (1 - k)T$, where $0 < k < 1$, then the average voltage is simply given by $V_{dc} = kV$, from which we see that speed control is effected via the on time ratio, k.



Simulation Results:

Speed Vs Time; Armature Current Vs Time;



Result:

Thus the chopper fed dc motor was simulated and verified.

POST- LAB QUESTIONS:

1. **Draw circuit diagram for step up and step down chopper.**

2. **Draw the speed torque characteristics of class A chopper.**

3. **Define current limit control of dc chopper.**

4. **What is meant by duty cycle?**

5. **What are types of chopper with respect to commutation process.**

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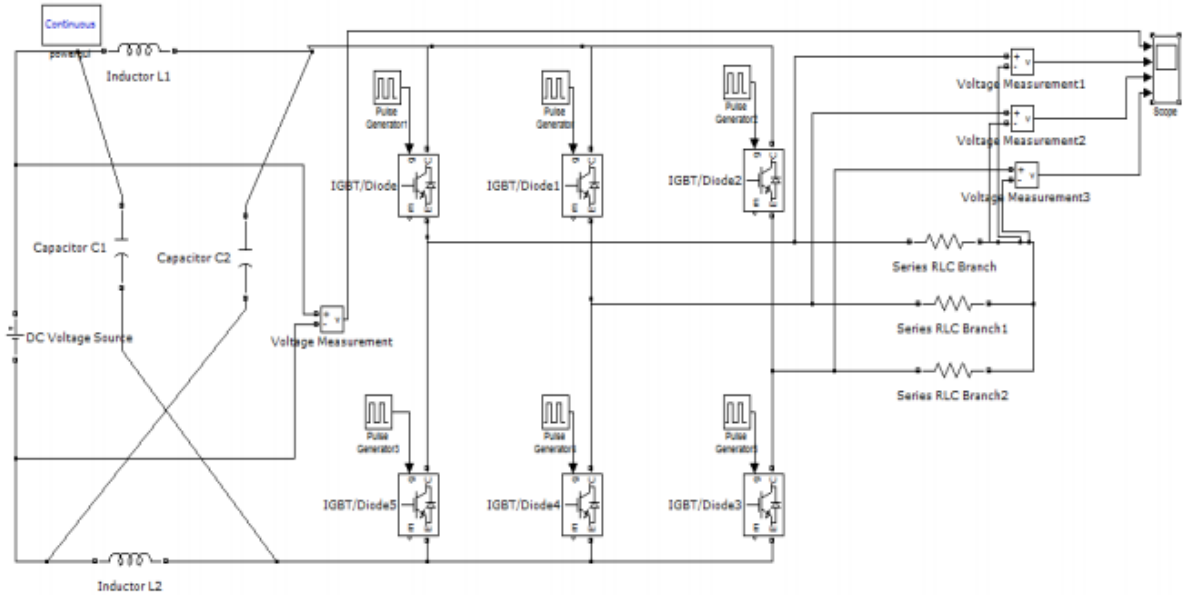
8. SIMULATE Z-SOURCE INVERTER

AIM: To study the simulation of Z source inverter using matlab - simulink.

APPARATUS:

1. MATLAB Software

CIRCUIT DIAGRAM:



THEORY:

A Z-source inverter is a type of power inverter, a circuit that converts direct current to alternating current. It functions as a buck boost inverter without making use of DC-DC Converter Bridge due to its unique circuit topology. Z source networks provide an efficient means of power conversion between source and load in a wide range of electric power conversion applications. The source can be either a voltage source or a current source. The DC source of a ZSI can either be abttery, a diode rectifier or a thyristor converter. The load of a ZSC can either be inductive or capacitive or another Z source network.

PROCEDURE:

1. Connect the circuit as per the circuit diagram.

2. Enter the command window of the MATLAB

3. Create a new M-File by selecting file new M-File.

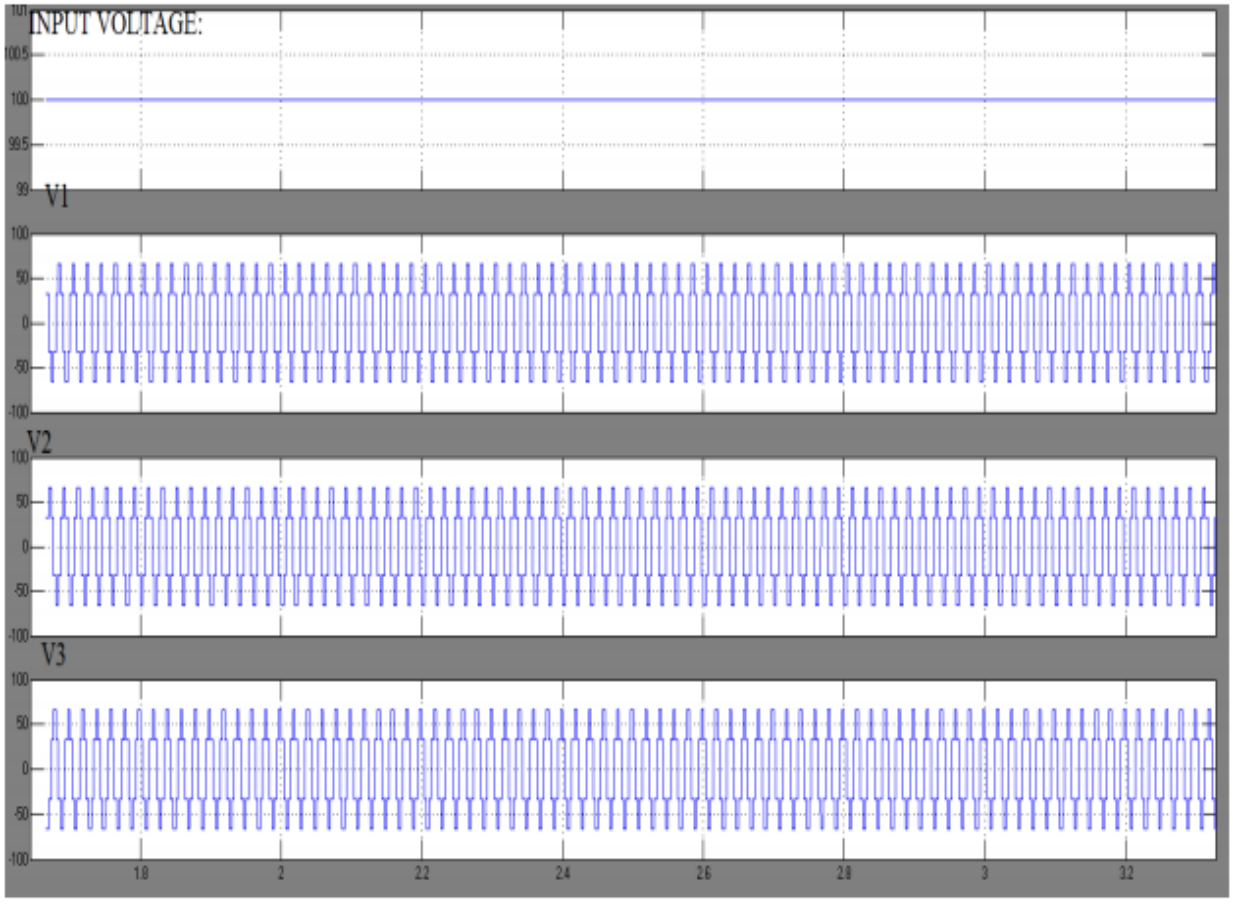
4. Develop MATLAB diagram.

5. Type and save the program in the editor window.

6. Execute the program by either pressing Tools-Run.

7. View the results in scope.

WAVE FORM:



TABULAR COLUMN:

SL.NO	INPUTVOLTAGE	OUTPUT VOLTAGE	OUTPUT CURRENT

RESULT:

Thus the simulation of Z source inverter using matlab – simulink was verified and output readings are tabulated.