SYLLABUS

EE3012 ELECTRICAL DRIVES L T P C

2 0 2 3

COURSE OBJECTIVES:

At the end of the course, students should have the:

- To understand steady state operation and transient dynamics of a motor load system.
- To study and analyze the operation of the converter / chopper fed dc drive, both qualitatively and
- quantitatively. To study and understand the operation and performance of AC Induction motor drives.
- To study and understand the operation and performance of AC Synchronous motor drives.
- To analyze and design the current and speed controllers for a closed loop solid state DC motor drives.

UNIT I DRIVE CHARACTERISTICS 6

Electric drive – Equations governing motor load dynamics – steady state stability – multi quadrant Dynamics: acceleration, deceleration, starting & stopping – typical load torque characteristics – Selection of motor.

UNIT II CONVERTER / CHOPPER FED DC MOTOR DRIVE 6

Steady state analysis of the single and three phase converter fed separately excited DC motor drive – continuous and discontinuous conduction – Time ratio and current limit control – 4 quadrant operation of converter / chopper fed drive.

UNIT III INDUCTION MOTOR DRIVES 6

Stator voltage control – energy efficient drive – v/f control – constant air gap flux – field weakening mode – voltage / current fed inverter – closed loop control,

UNIT IV SYNCHRONOUS MOTOR DRIVES 6

V/f control and self-control of synchronous motor: Margin angle control and power factor control – permanent magnet synchronous motor.

UNIT V DESIGN OF CONTROLLERS FOR DRIVES **6**

Transfer function for DC motor / load and converter – closed loop control with current and speed feedback – armature voltage control and field weakening mode – design of controllers; current controller and speed controller-converter selection and characteristics.

30 PERIODS

LAB COMPONENT: 30 PERIODS

1. Simulation of converter and chopper fed DC drive
2. Simulation of closed loop operation of stator voltage control of induction motor drive
3. Simulation of closed loop operation of v/f control of induction motor drive
4. Simulation of synchronous motor drive

TOTAL: 30+30 = 60 PERIODS

COURSE OUTCOMES:

After completion the above subject, students will be able to

CO1: Understand the basic requirements of motor selection for different load profiles.

CO2: Analyse the steady state behavior and stability aspects of drive systems.

CO3: Analyse the dynamic performance of the DC drive using converter and chopper control.

CO4: Simulate the AC drive.

CO5: Design the controller for electrical drives.

TEXTBOOKS:

1. Gopal K.Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 2nd Edition January 2010.
2. Bimal K.Bose. Modern Power Electronics and AC Drives, Pearson Education, 2002 1st Edition.

LAB COMPONENT:

1. Simulation of converter and chopper fed DC drive.

2. Simulation of closed loop operation of stator voltage control of induction motor drive.

3. Simulation of closed loop operation of v/f control of induction motor drive.

4. Simulation of synchronous motor drive.

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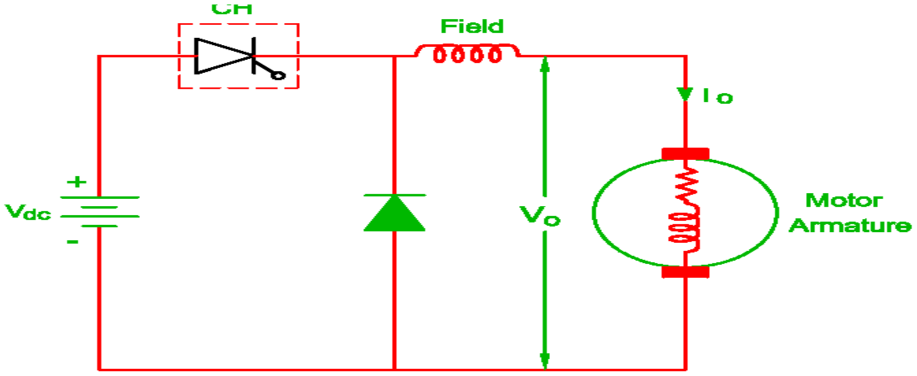
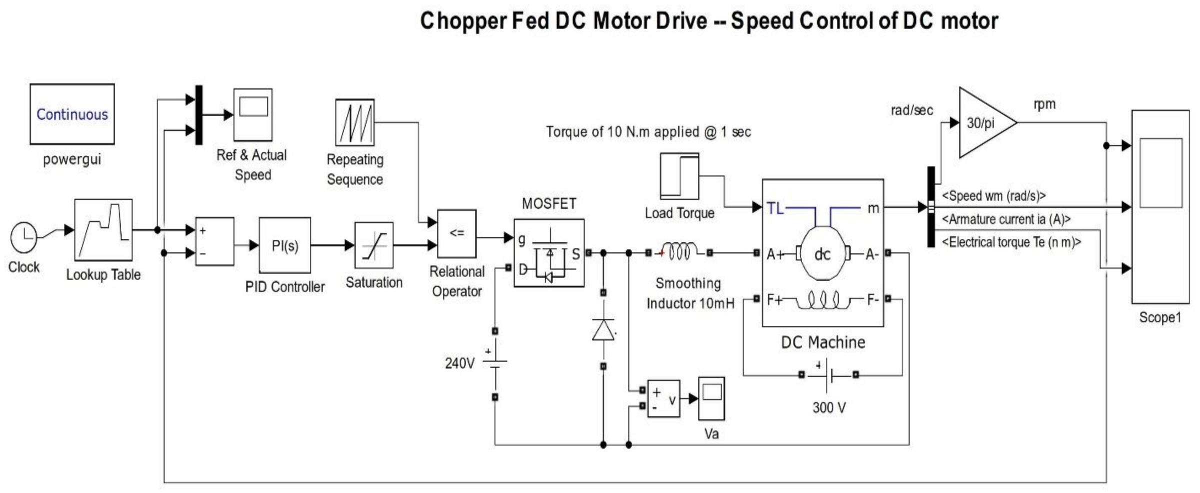
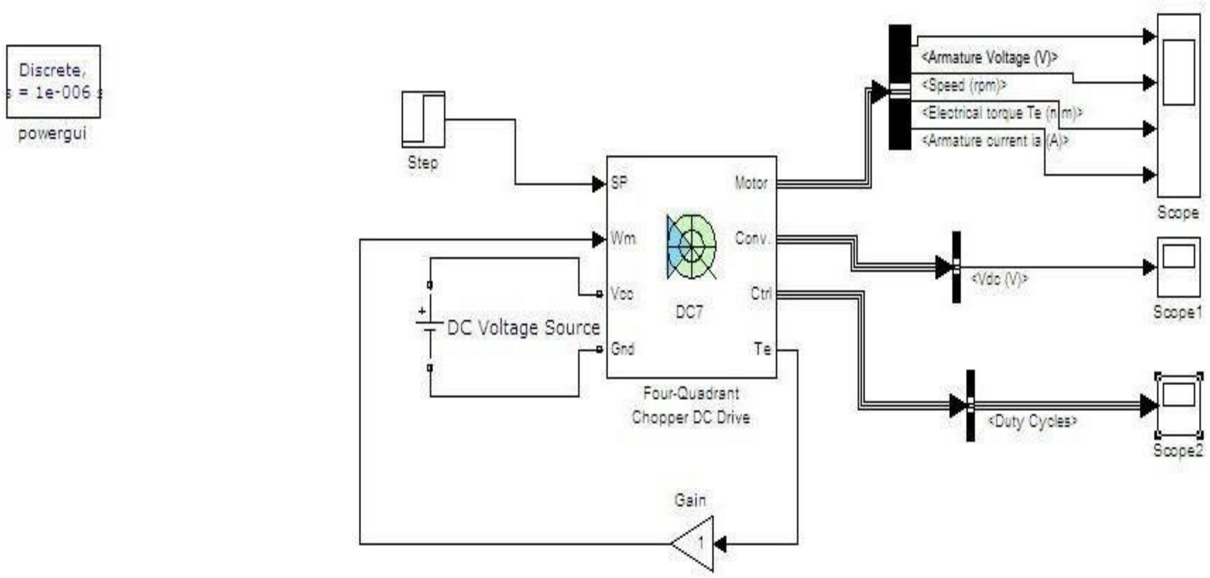
Expt No.1 SIMULATION OF CHOPPER FED DC DRIVE

CIRCUIT DIAGRAM:



SIMULATION DIAGRAM:





Ex. No.1 SIMULATION OF CHOPPER FED DC DRIVE

AIM:

To simulate Chopper fed DC motor to find it's armature current Vs Time and Speed Vs Time Characteristics using MATLAB SIMULINK

INTRODUCTION:

The variable voltage to the armature of a dc motor for speed control can be obtained from a dc chopper which is a single stage dc to dc conversion device. The voltage variation at the load terminals can be obtained by using either current limit control or time ratio control.

In the current limit control, the chopper is controlled such that the load current has a variation between two limits. When the current reaches the upper limit the chopper is turned off to disconnect the motor from the supply. The load current freewheels through freewheeling diode and decays. When it falls to the lower limit the chopper is turned on, connecting the motor to the supply. An average current is always maintained.

When the chopper is controlled by TRC the ratio of T_{ON}/T_{OFF} of the chopper is changed. In this case the operation is at fixed frequency if ($T_{ON}+T_{OFF}$) is kept constant. T_{ON} only is varied to obtain voltage control. The operation will be at variable frequency with T_{ON} kept constant and ($T_{ON}+T_{OFF}$) varied. But owing to several advantages of simplicity, a fixed frequency TRC is normally used. Chopper circuits are used to control both separately excited and dc series motors.

PWM (Pulse Width Modulation) Converter:

PWM converters use high-frequency switching to control the average voltage delivered to the motor. By adjusting the duty cycle of the PWM signal, the effective voltage can be controlled, offering smoother control and reduced motor noise.

Control System:

A control system, often based on a microcontroller or a programmable logic controller (PLC), is used to set and maintain the desired motor speed and direction. The control system takes input from an operator or a feedback system (e.g., speed sensors or encoders) and adjusts the converter's output accordingly.

Feedback Loop:

To achieve precise control, a feedback loop is often incorporated into the system. Speed sensors or encoders on the motor provide real-time information about the motor's actual speed. This information is compared to the desired speed set by the operator, and the control system adjusts the converter's output to minimize the error.

Current Limiting:
To protect the motor from overcurrent and prevent damage, many converter-fed DC drives incorporate current-limiting circuits. These circuits can limit the current supplied to the motor under certain conditions, such as when the motor is stalled

THEORY:

The chopper converts the fixed DC voltage to variable DC voltage. Self-commutated devices (directly on or off devices via gate) like MOSFET, IGBT, power transistors, GTO and IGCT are used for making choppers because they can be commutated by low power control signal and do not need commutation circuit.

The chopper was operated at high frequency due to which it upgrades the motor performances by decreasing the ripple and removing the discontinuous conduction. The most important feature of chopper control is that the regenerative braking is carried out at very low generating speed when the drive is fed from a fixed voltage to low DC voltage. The transistor T_r is operated periodically with period T_r and remains open for a duration T_{on}. Chopper for regenerative braking operation is shown in the figure below. The transistor T_r is operated periodically with a period T and on-period of t_{on}.

APPARATUS REQUIRED:

PC with MATLAB simulation software

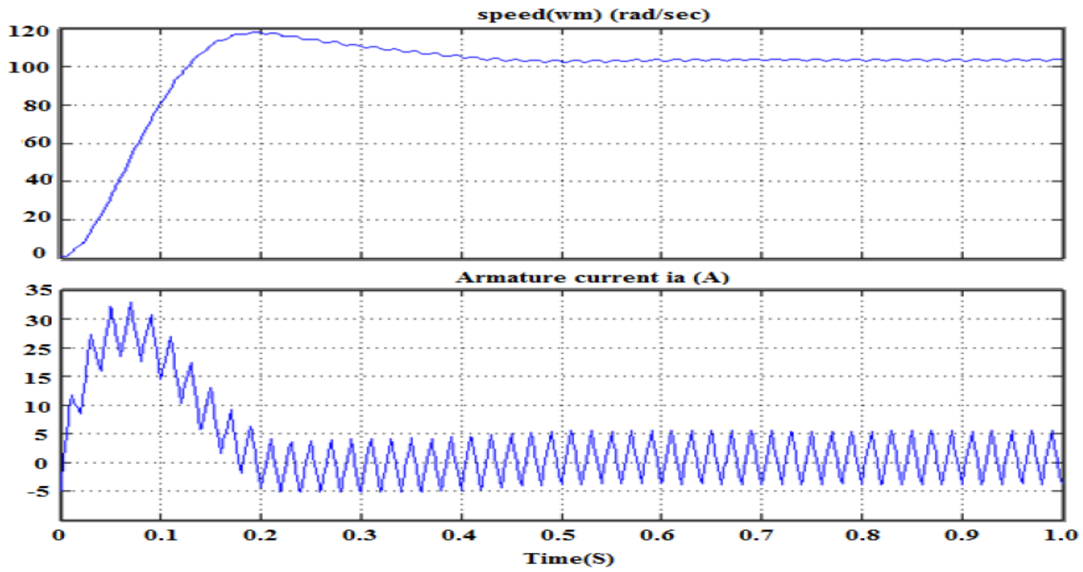
SPECIFICATION OF EQUIPMENTS IN SIMULATION:

MOTOR : 220V,40A,1200 RPM

IGBT : 40A

Simulation Results:

Speed Vs Time; Armature Current Vs Time;



PROCEDURE:

1. Open the MATLAB software
2. Open the SIMULINK Tools menu
3. In SIMULINK tools, Create a new file.
4. In SIMULINK tool menu, Search and take the powergui. In this powergui we need to change the continuous to discrete from configuration parameters.
5. Pick four quadrant DC Motor drive from sim power system-Application library.
6. For chopper fed DC motor drive, select four quadrant chopper drive.
7. Connect the all elements as per the circuit diagram.
8. Set the values for Source and drive parameters.
9. Select Ode 23tt solver in simulation parameters and save the file
10. Run the simulation and verify the output in scope.

VIVA QUESTIONS AND ANSWERS:

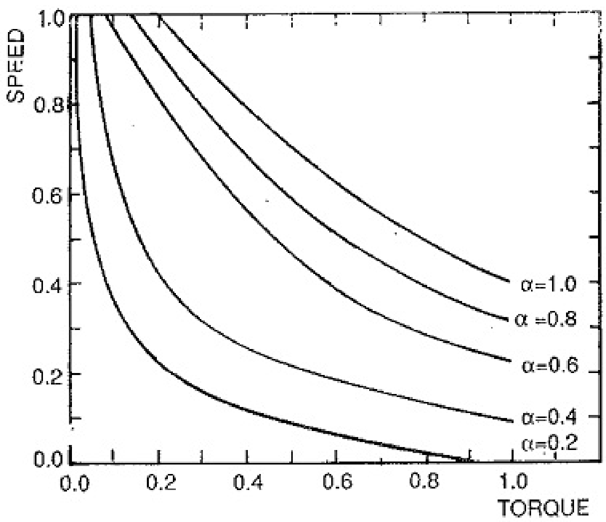
1. What are the control strategies for chopper circuit?

There are two kinds of control strategies used in DC choppers namely time ratio control and current limit control.

2. State the advantages of chopper fed dc drives.

- It has greater efficiency.
- It has faster response.
- It requires less maintenance.
- It has compact size.

3. Draw the speed torque characteristics of class A chopper.



4. Define current limit control of dc chopper.

The chopper is turned on when the output current i_0 equals a pre-set value I_2. The chopper is kept on till i_0 increases to another pre-set value I_1. The chopper is turned off when i_0 equals I_1 and is kept off till the current i_0 decays to I_2.

5. Define TRC and CLC.

TRC: It is a stratergy to control the average output voltage by varying ON time (Ton) and the frequency. Tis implemented in two ways such as,

a) Constant frequency system
b) Variable frequency system

CLC: It refers to current limit control. The chopper is switched ON and OFF so that current in the load is maintained between two limits (I_{min} to I_{max}).

6. What are the disadvantages of frequency modulation scheme compared with the pulse width modulation scheme?

The chopping frequency has to be varied over a wide range for tge control of output voltage. In frequency modulation the filter design is very difficult for wide range of frequency variation.

This type of control would generate harmonics at unpredictable frequency which would produce interference with signaling and telephone lines.

7. Compare CCM and DCM in chopper drives.

Continuous conduction mode (CCM)

In continuous conduction, the armature current flows in continuous manner. Output voltage ripple in steady state is low. Load current in steady state is high and low settling time.

Discontinuous conduction mode (DCM)

In continuous conduction, the armature current flows in discontinuous manner. Output voltage ripple and settling time under steady state is high and low Load current.

8. State the functions of freewheeling diode in converter fed DC motor drives.

A freewheeling diode is a crucial component in converter fed DC motor drives, serving several essential functions:

1. Preventing voltage spike in negative direction.
2. Improved input power factor.
3. Enabling regenerative braking.
4. Reducing switching losses and protecting the converter.

SUGGESTED OTHER EXCERSIES:

- Simulate DC motor drive with Jones Chopper with suitable values.
- Simulate four quadrant chopper (type E) fed separately excited DC motor drives.

POSSIBLE RESEARCH OPPORTUNITIES:

- Reducing switches and ripples in chopper circuits.

DESCRIPTION OF RESULTS AND GRAPH:

- It is seen that speed of the motor is constant.
- Also, it is seen that the armature current has less ripples.

RESULT:

The chopper fed DC motor drive was simulated using MATLAB and the motor speed and armature current characteristics were studied.

EXPECTED RESULTS AND LIKELY SOURCES OF ERRORS:

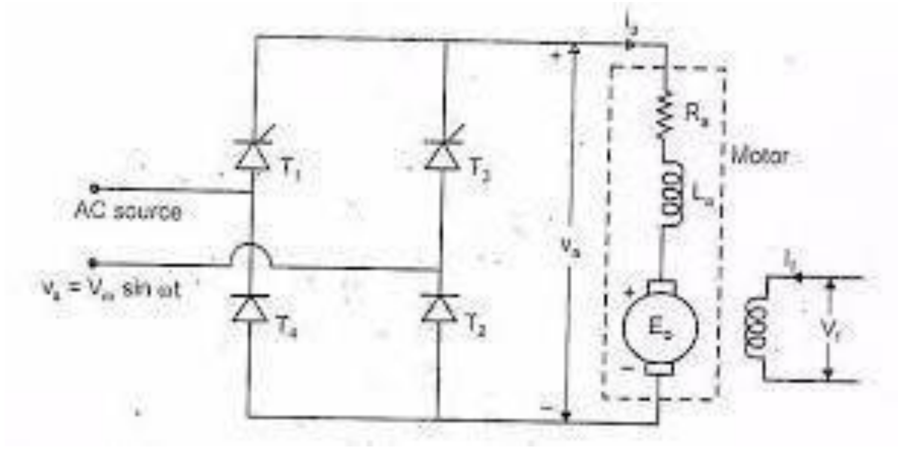
The armature current must have lesser amount if ripples. But the inductance value may be of wrong and it may create excessive ripples.

REFERRENCES:

1. M H Rashid, “Power Electronic Devices, Circuits and Publications”, Pearson Education,2017.
2. Gopal K. Dubbey, Fundamentals of electrical drives, Narosa publishing House, 2nd Edition January 2010.
3. A text book of solid state drives by Gnanavadivel, Anuradha publications. 2014.

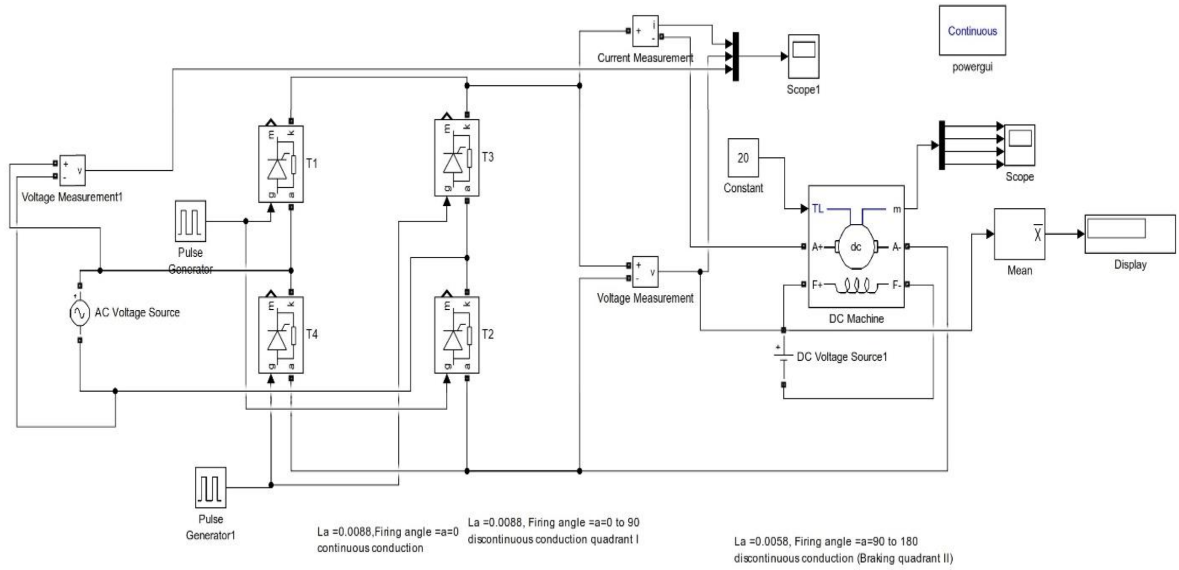
Ex. No.2 **SIMULATION OF CONVERTER (AC – DC) FED DC DRIVE**

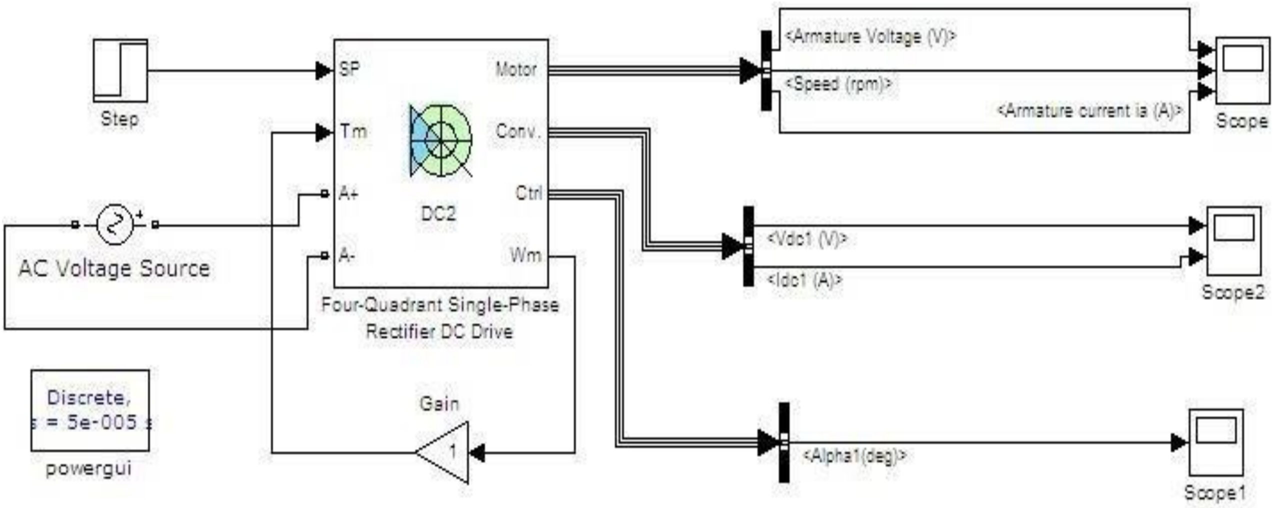
CIRCUIT DIAGRAM:



SIMULATION CIRCUIT:

Converter (AC – DC converter (or) Rectifier) fed DC drive





Ex. No.2 **SIMULATION OF CONVERTER FED DC DRIVE**

AIM:

To simulate the single phase fully controlled converter fed separately excited DC motor by using MATLAB Simulink

INTRODUCTION:

A converter-fed DC drive is a system used to control the speed and direction of a direct current (DC) motor by varying the voltage and current supplied to it. This type of drive is commonly used in various industrial applications where precise control of motor speed and direction is required. Here's an explanation of how a converter-fed DC drive works.

Direct-current motors are extensively used in variable-speed drives and position control systems where good dynamic response and steady-state performance are required. Examples are in robotic drives, printers, machine tools, process rolling mills, paper and textile industries, and many others.

Control of a dc motor, especially of the separately excited type, is very straight forward, mainly because of the incorporation of the commutator within the motor. The commutator and brush allows the motor-developed torque to be proportional to the armature current if the field current is held constant. Classical control theories are then easily applied to the design of the torque and other control loops of a drive system.

When a DC supply is applied to the armature of the dc motor with its field excited by a dc supply, torque is developed in the armature due to interaction between the axial current carrying conductors on the rotor and the radial magnetic flux produced by the stator. If the voltage V is the voltage applied to the armature terminals, and E is the internally developed motional E.M.F.

Control System:

A control system, often based on a microcontroller or a programmable logic controller (PLC), is used to set and maintain the desired motor speed and direction. The control system takes input from an operator or a feedback system (e.g., speed sensors or encoders) and adjusts the converter's output accordingly.

Feedback Loop:

To achieve precise control, a feedback loop is often incorporated into the system. Speed sensors or encoders on the motor provide real-time information about the motor's actual speed. This information is compared to the desired speed set by the operator, and the control system adjusts the converter's output to minimize the error.

Current Limiting:

To protect the motor from overcurrent and prevent damage, many converter-fed DC drives incorporate current-limiting circuits. These circuits can limit the current supplied to the motor under certain conditions, such as when the motor is stalled.

Forward and Reverse Control:

Converter-fed DC drives can easily change the direction of the motor by reversing the polarity of the voltage supplied to the motor terminals. This is achieved by controlling the converter accordingly, making it suitable for applications that require bidirectional motor operation.

In summary, a converter-fed DC drive is a control system that utilizes power electronics to vary the voltage and current supplied to a DC motor, allowing precise control of the motor's speed and direction. These drives are commonly used in industrial settings for applications such as conveyor systems, cranes, rolling mills, and more, where precise and adjustable motor control is essential.

WORKING PRINCIPLE:

Discontinuous conduction mode:

Thyristors T_1 and T_2 are gated at $\omega t = \alpha$ .The SCR's will get turned on only if input supply voltage $Vs = Vm \sin\omega t$ greater than motor back EMF. Thyristors T_1 & T_2 are trigged by gate pulses from α to π and thyristors T_3 ' and T_4 ' are triggered by gate pulses from $(\pi + \alpha)$ to 2π .

When armature current does not flow continuously the motor is said to operate in discontinuous conduction mode (DCM). When current flows continuously, the conduction is said to be continuous (CCM). In discontinuous modes, the current starts flowing with the turn on thyristors T_1 and T_2 at $\omega t = \alpha$ to π. Motor gets connected to the source and its terminal voltage equals Vs.

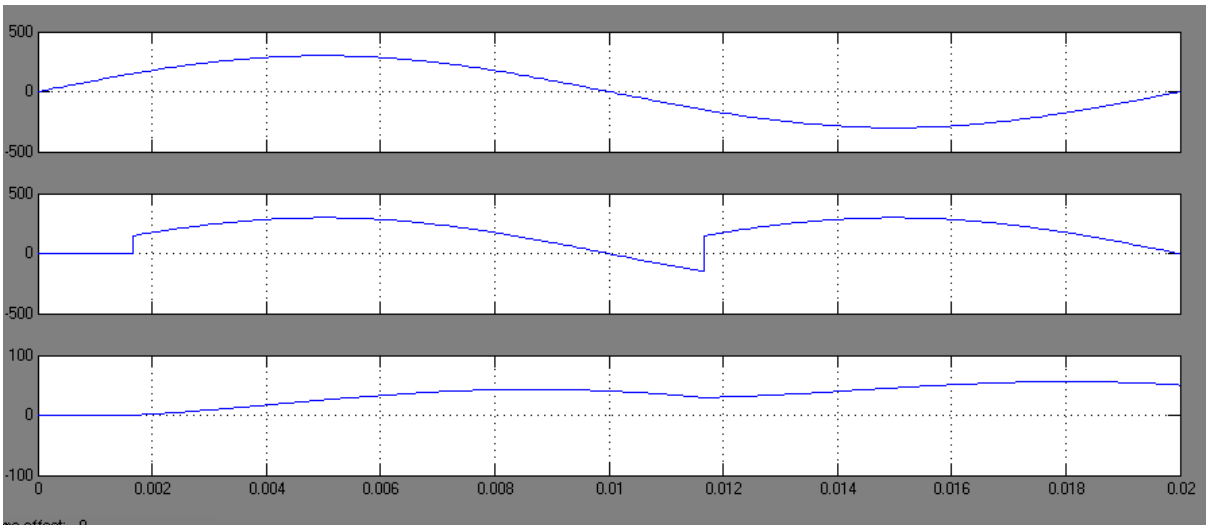
At some angle β known as extinction angle, load current decays to zero. Here $\beta > \pi$. As T_1 and T_2 are reversed biased after $\omega t = \pi$, this pair is commutated at $\omega t = \beta$ when $Ia=0$. From β to $(\pi + \alpha)$, no SCR's conducts, the terminal voltage jumps from $E \sin \beta$ to Vm .

At $\omega t = \beta$ as pair T_3 ' and T_4 ' is triggered, load current starts to build up again as before and load voltage Va follows Vs waveform.

Continuous conduction mode

In continuous conduction mode, during the positive half cycle thyristors T_1 and T_2 are forward biased. At $\omega t = \alpha$, T_1 and T_2 are turned ON. Motor is connected to the supply from the duration α to $(\pi + \alpha)$. At the instant $(\pi + \alpha)$ the previously conducting thyristors are turn off due to supply voltage Vm sinα immediately appears across thyristors T_1' and T_2 ' as a reverse bias, they are turned off by natural commutation. At ωt = (π +α) forward biased SCR's T_3' and T_4' are triggered causing turn off of T_1 and T_2. So the load is connected to the source for (π +α) to 2π.

OUTPUT WAVEFORMS:



SOFTWARE REQUIRED:

1. Sim Power System
2. MATALAB

PROCEDURE:

1. Open the MATLAB software
2. Open the SIMULINK Tools menu
3. In SIMULINK tools, Create a new file.
4. In SIMULINK tool menu, Search and take the powergui. In this powergui we need to change the continuous to discrete from configuration parameters.
5. Pick four quadrant DC Motor drive from sim power system-Application library.
6. For converter fed DC motor drive, select single phase converter drive.
7. Connect the all elements as per the circuit diagram.
8. Set the values for Source and drive parameters.
9. Select Ode 23tt solver in simulation parameters and save the file
10. Run the simulation and verify the output in scope.

VIVA QUESTIONS AND ANSWERS:

1. **Which motor is used in DC drive?**

These types include brushed, brushless, servo, linear, and voice coil motors. Brushed motors commutate via physical contacts, often spring-loaded graphite brushes biased against the commutation bar. Brushless motors commutate electronically with no physical brush contact.

2. **What is the working principle of DC drive?**

DC drives have become popular in industrial drive applications due to their ability to provide extremely precise control. Working Principle: The speed of a direct current motor is proportional to the armature voltage and inversely proportional to the field current.

3. **How does DC drive control speed?**

The speed of a DC motor can be controlled in three ways: By varying the supply voltage. By varying the flux, and by varying the current through the field winding. By varying the armature voltage, and by varying the armature resistance.

4. **What causes poor input power, factor in converter fed DC motor drives?**

The input power factor in the phase controlled rectifier is low when the output voltage is less than the maximum that is when the firing angle is large when the firing increases the converter draws more lagging reactive power. Therefore the input power factor is low.

5. **Draw the torque speed characteristics of 1∅ and 3∅ fully controlled rectifier fed separately excited DC motor with different firing angle.**

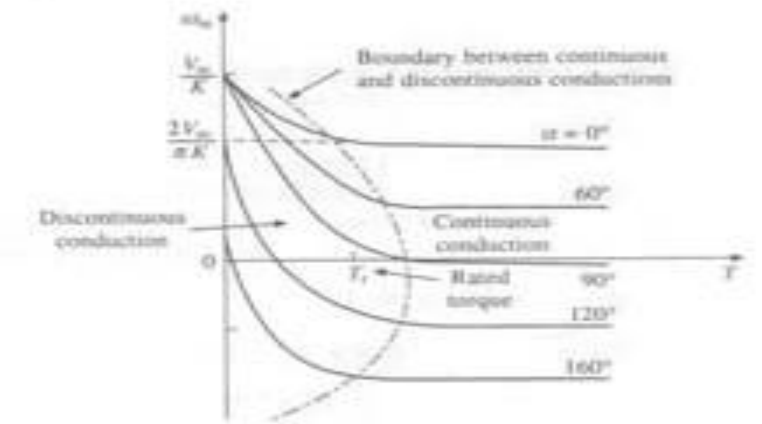


Fig. Speed torque characteristics of single-phase fully-controlled rectifier fed dc separately excited motor

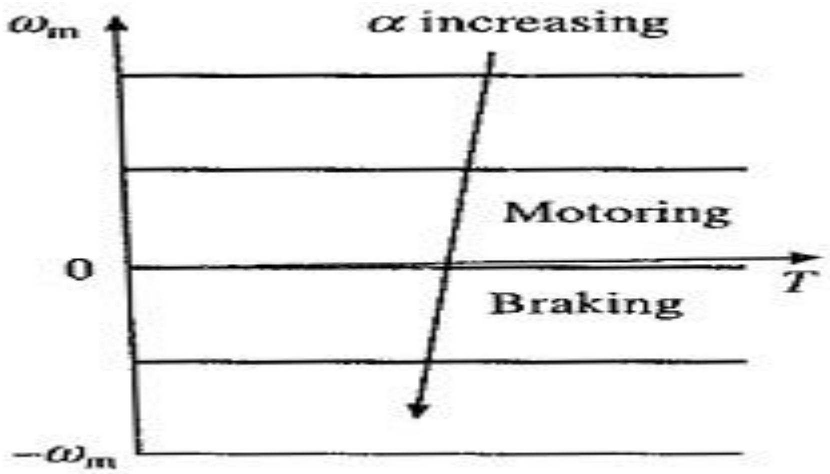


Fig. 5.33 Speed torque curves of drive of Fig. 5.32(a) neglecting discontinuous conduction

6. **State the functions of freewheeling diode in converter fed DC motor drives.**

A freewheeling diode is a crucial component in converter fed DC motor drives, serving several essential functions:

1. Preventing voltage spike in negative direction.
2. Improved input power factor.
3. Enabling regenerative braking.
4. Reducing switching losses and protecting the converter.

SUGGESTED OTHER EXCERSISES:

- MATLAB Simulation based on other types of Converters.

POSSIBLE RESEARCH OPPORTUNITIES:

- Research Opportunities exist in the aspect of finding new converter topologies

TROUBLESHOOTING:

If firing angles of both pair of switches are not correct, then the switches may get short circuited.

DESCRIPTION OF RESULTS AND GRAPH:

The output is variable DC and it has negative going waveforms. To avoid this a diode is added in parallel to the motor.

RESULTS:

The Converter Fed DC Motor Drive was simulated and the waveforms were plotted.

Electromagnetic Torque and Armature Current is always positive in both quadrants and goes through fluctuation due to change in firing angle. Field current becomes constant after certain amount of time as a result of separate excitation.

Armature voltage drops to negative value after change in firing angle. Instantaneous and Average power values that remained positive for first five seconds also became negative for the next five seconds as a result of change in firing angle. Reverse regenerative braking mode of operation of DC machines using full wave controlled rectifier are observed and studied

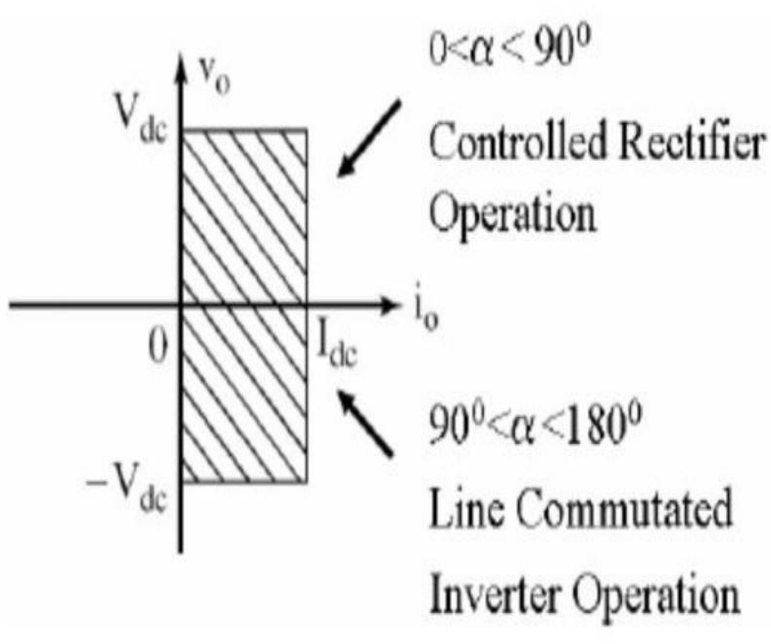
EXPECTED RESULTS AND LIKELY SOURCES OF ERRORS:

The armature current must have lesser amount if ripples. But the inductance value may be of wrong and it may create excessive ripples.

REFERRENCES:

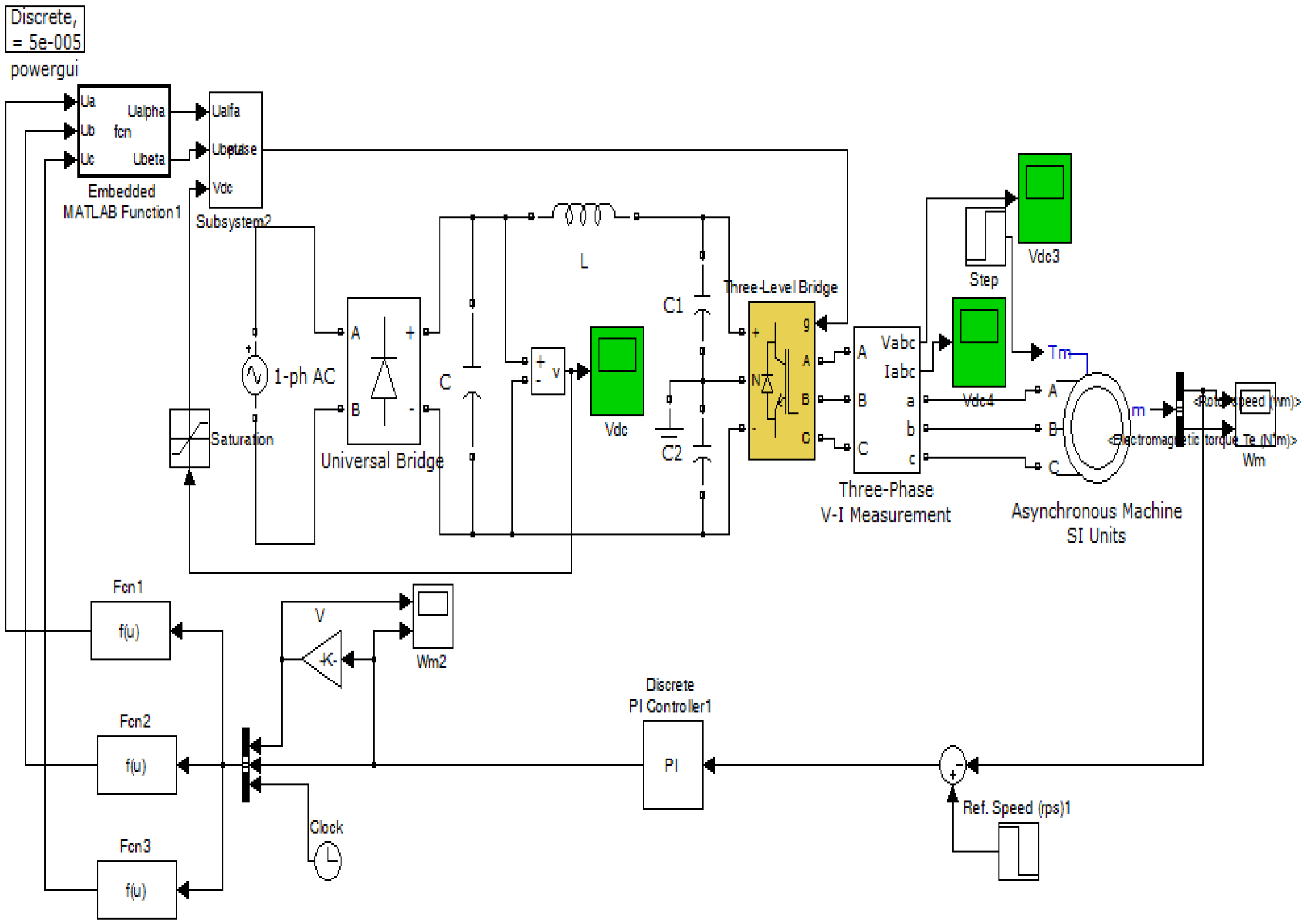
1. Gopal K.Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 1992. New Delhi, 2004.
2. M H Rashid, "Power Electronic Devices, Circuits and Publications", Pearson Education,2017
3. A text book of solid state drives by Gnanavadivel, Anuradha publications. 2014.

TWO QUADRANT OPERATION OF A SINGLE PHASE FULL CONVERTER



Ex. No.3 SIMULATION OF CLOSED LOOP OPERATION OF STATOR VOLTAGE CONTROL OF INDUCTION MOTOR DRIVE.

SIMULATION DIAGRAM:



Ex. No.3 SIMULATION OF CLOSED LOOP OPERATION OF STATOR VOLTAGE CONTROL OF INDUCTION MOTOR DRIVE.

Aim:

To simulate the closed loop operation of speed control of three phase inverter fed induction motor by using MATLAB software.

INTRODUCTION:

It employs inner slip-speed loop with a slip limiter and outer speed loop. Since for a given current, slip speed has a fixed value, the slip speed loop also functions as an inner current loop. Further it also ensures that the motor operation always occurs on the portion of speed-torque curve between synchronous speed and the speed at the maximum torque for all frequencies, thus ensuring high torque to current ratio.

The drive uses a PWM inverter fed from a dc source, which has capability for regenerative braking and four-quadrant operation. The drive scheme is however applicable to any VSI or cycloconverter drive having regenerative or dynamic braking capability.

THEORY:

By varying the supplying voltage, the speed can be controlled. The voltage is varied until the torque required by the load is developed, at the desired speed. The torque developed is proportional to the square of the supply voltage and the current is proportional to the voltage. Hence, to reduce the speed for the same value of the same current, the value of the voltage is reduced and as a result, the torque developed by the motor is reduced.

This stator voltage control method is suitable for applications where the load torque decreases with the speed, example - in the fan type load. This method gives a speed control only below the normal rated speed as the operation of the voltages if higher than the rated voltage is not admissible. This method is suitable where the intermittent operation of the drive is required and also for the fan and pump drives.

As in fan and pump the load torque varies as the square of the speed. These types of drives required low torque at lower speeds. This condition can be obtained by applying a lower voltage without exceeding the motor current.

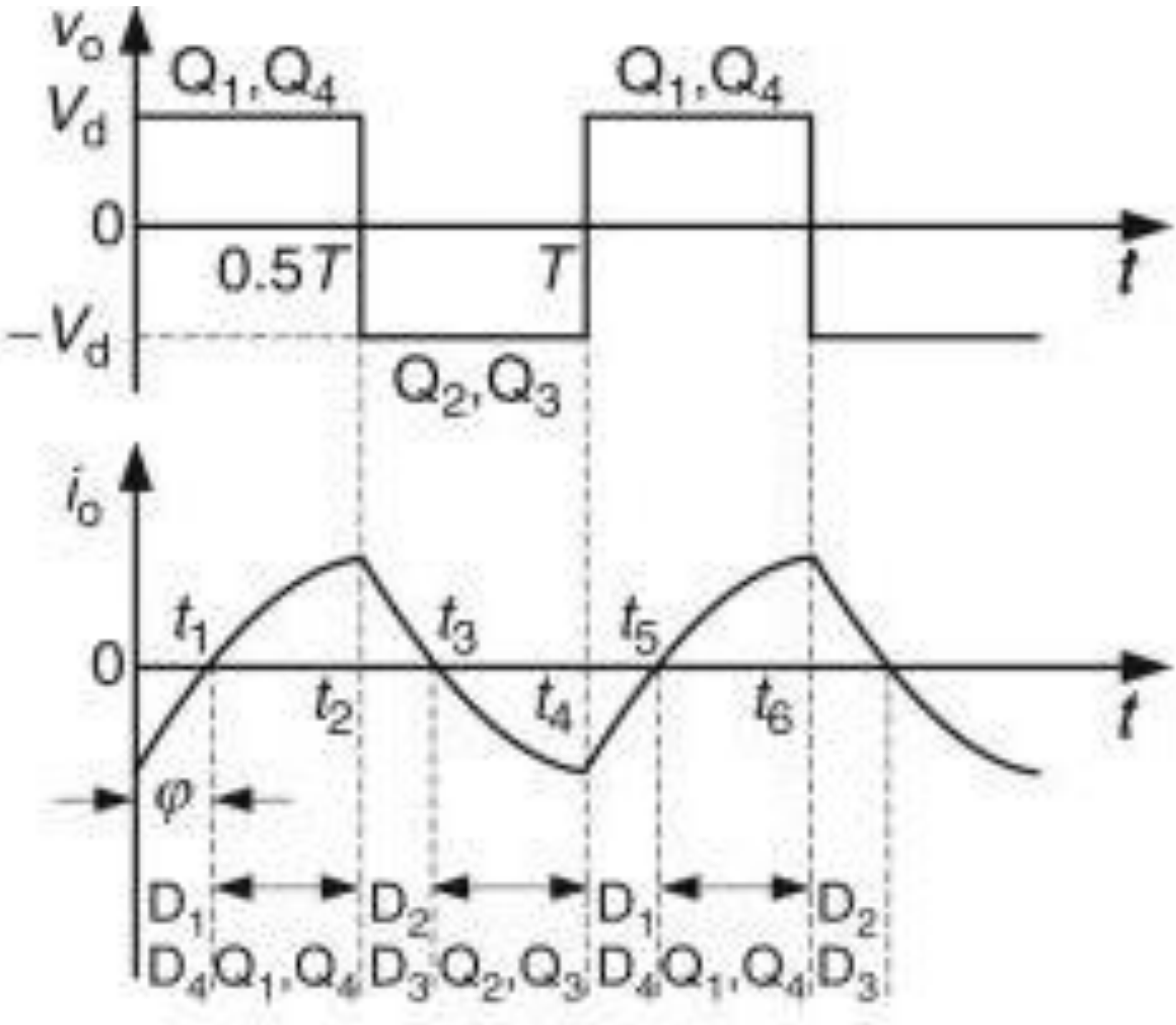
SOFTWARE REQUIRED:

1. Sim Power System
2. MATALAB

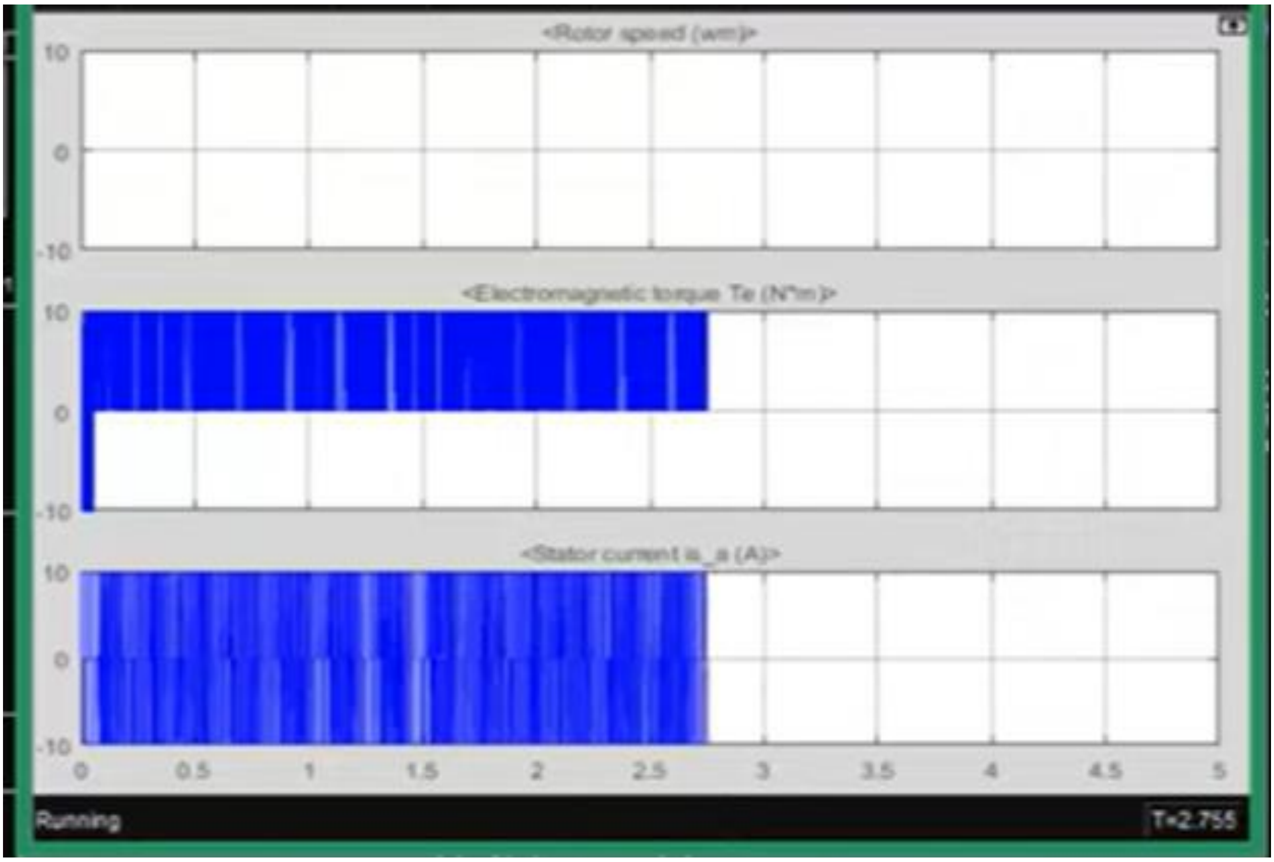
PROCEDURE:

1. Open the MATLAB software
2. Open the SIMULINK Tools menu
3. In SIMULINK tools, Create a new file.
4. In SIMULINK tool menu, Search and take the powergui. In this powergui we need to change the continuous to discrete from configuration parameters.
5. Pick four quadrant AC Motor drive from sim power system-Application library.
6. For closed loop stator voltage control of induction motor drives select three phase inverter block.
7. Connect the all elements as per the circuit diagram.
8. Set the values for Source and drive parameters.
9. Select Ode 23tt solver in simulation parameters and save the file
10. Run the simulation and verify the output in scope.

MODEL GRAPH:



MATLAB OUTPUT WAVEFORMS:



VIVA QUESTIONS AND ANSWERS:

1. **What is the principle of stator voltage control?**

The supply voltage is decreased to reduce the speed for the same current, the torque developed by the motor is reduced. Therefore, the stator voltage control method is suitable for applications where the load torque decreases with the speed, as in the case of a fan load

2. What is the closed loop control of induction motor?

It employs inner slip-speed loop with a slip limiter and outer speed loop. Since for a given current, slip speed has a fixed value, the slip speed loop also functions as an inner current loop.

3. What is the operation of VSI Fed induction motor?

A VSI is a self or separate control feeding Induction motor. Open loop and closed loop operation is possible but VSI provides instability and hunting problems. The stator current drawn by the motors when fed to VSI has sharp peaks and is rich in harmonic content which causes additional losses and heating.

4. Compare VSI & CSI fed AC drives.

SI.NO	VOLTAGE SOURCE INVERTER	CURRENT SOURCE INVERTER
1	Input voltage is maintained as constant.	Input current is maintained as constant.
2	Output voltage does not dependent on the load	Output current does not dependent on the load.
3	It requires feedback diodes.	It does not require feedback diodes.
4	VSI is suitable for multimotor drives.	CSI is not suitable for multimotor drives.
5	Low cost.	High cost.
6	Less reliable	More reliable

5. What is meant by v/f control? Mention its advantages?

When the frequency is reduced, the input voltage must be reduced proportionally so as to maintain constant flux. Otherwise the core will get saturated resulting in excessive iron loss and magnetizing current. The maximum torque also remains constant under this condition. This type of control is known as v/f control.

Advantage:

1. Smooth speed control.
2. Small input current and improved power factor at low frequency start.
3. Higher starting torque for low cage resistance.

6. What is meant by slip power? What is meant by slip power recovery scheme?

Slip power:

The portion of air gap power, which is not converted into mechanical Power, is called slip power. Slip power is nothing but multiplication of Slip (s) and air gap power (Pag). Slip power = s Pag.

Slip power recovery scheme:

In chopper method of speed control for SRIM, the slip power is wasted in the external resistance and the efficiency also reduced. However, instead of wasting the slip power can be recovered by various schemes for the speed control of slip ring induction motor. This system is called as slip power recovery scheme.

7. **Why stator voltage controlled Induction Motor drive is suitable for fan type loads?**

Hence, when the supply voltage is decreased to reduce the speed for the same current, the torque developed by the motor is reduced. Therefore, the stator voltage control method is suitable for applications where the load torque decreases with the speed, as in the case of a fan load.

8. **What is meant by field – weakening mode operation in the stator frequency control?**

With constant supply voltage and increased supply frequency operation, air gap flux gets reduced. Therefore, during this control, induction motor is said to be working in field-weakening mode. Such type of induction motor behaviour is similar to the working of dc series motors.

9. **Constant torque loads are not suitable for AC voltage controller fed Induction Motor drive. Why?**

By reducing stator voltage, the torque also changes, because torque is proportional to voltage squared. Therefore this method is not suitable for constant torque loads.

10. **In Inductive motor drives speed control justify the following ;**
    i) Constant supply voltage & reduces supply frequency.
    ii) Constant supply voltage & increases supply frequency.

i) When the supply voltage is kept constant and the supply frequency is reduced, the flux will increase. Due to this, saturation of air gap flux, and the motor parameters would not be valid in determining the speed – torque characteristics. At low frequency, the reactance will decrease and motor current will increase. Also increased motor torque capability.

ii) In an induction motor drive, increasing the supply frequency while keeping the supply voltage constant the air gap flux gets reduced. Therefore, during this control, induction motor is said to be working in field-weakening mode. Which results will reduces the maximum torque.

SUGESTED OTHER EXCERCISES:

1. Control the speed of induction motor using stator voltage control in which rectifier is provided with different angles for control.
2. Using AC voltage controller simulate the stator side speed control of induction motor.
3. Simulate slip power controlled wound rotor induction motor drives using two three phase fully controlled converters connected in antiparallel.

POSSIBLE RESEARCH OPPORTUNITIES:

One can use different sorts of converters in AC to DC conversion and test the above.

DESCRIPTION OF RESULTS AND GRAPH:

The speed of Induction motor remains constant as the switching angles of converter are varied to vary the voltage of inverter and hence stator voltage.

RESULTS:

Thus the speed of induction motor is held almost constant by varying the stator voltage according to the speed.

EXPECTED RESULTS AND LIKELY SOURCE OF ERRORS:

The motor speed must be constant and due to error in switching angles of converter, the speed may vary.

REFERRENCES:

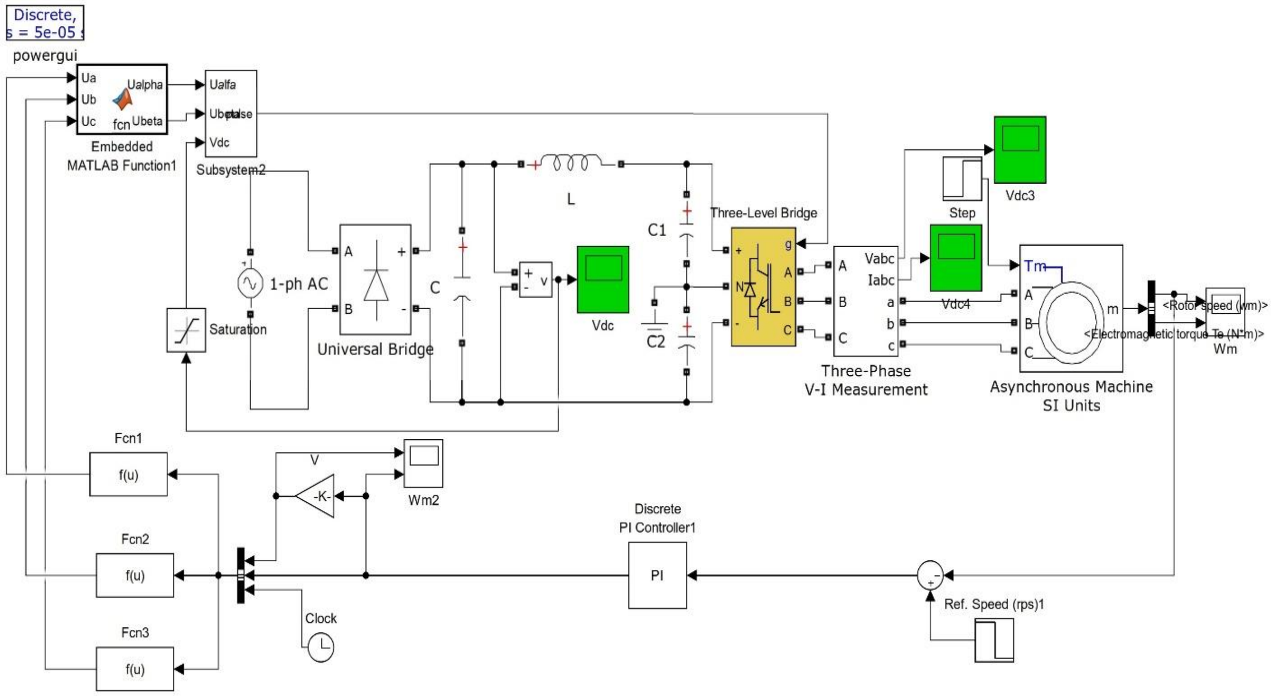
1. GopalK.Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 1992. New Delhi, 2004

2. Bimal K.Bose. Modern power Electronics and AC Drives, Pearson Education, 2002 1st Edition.

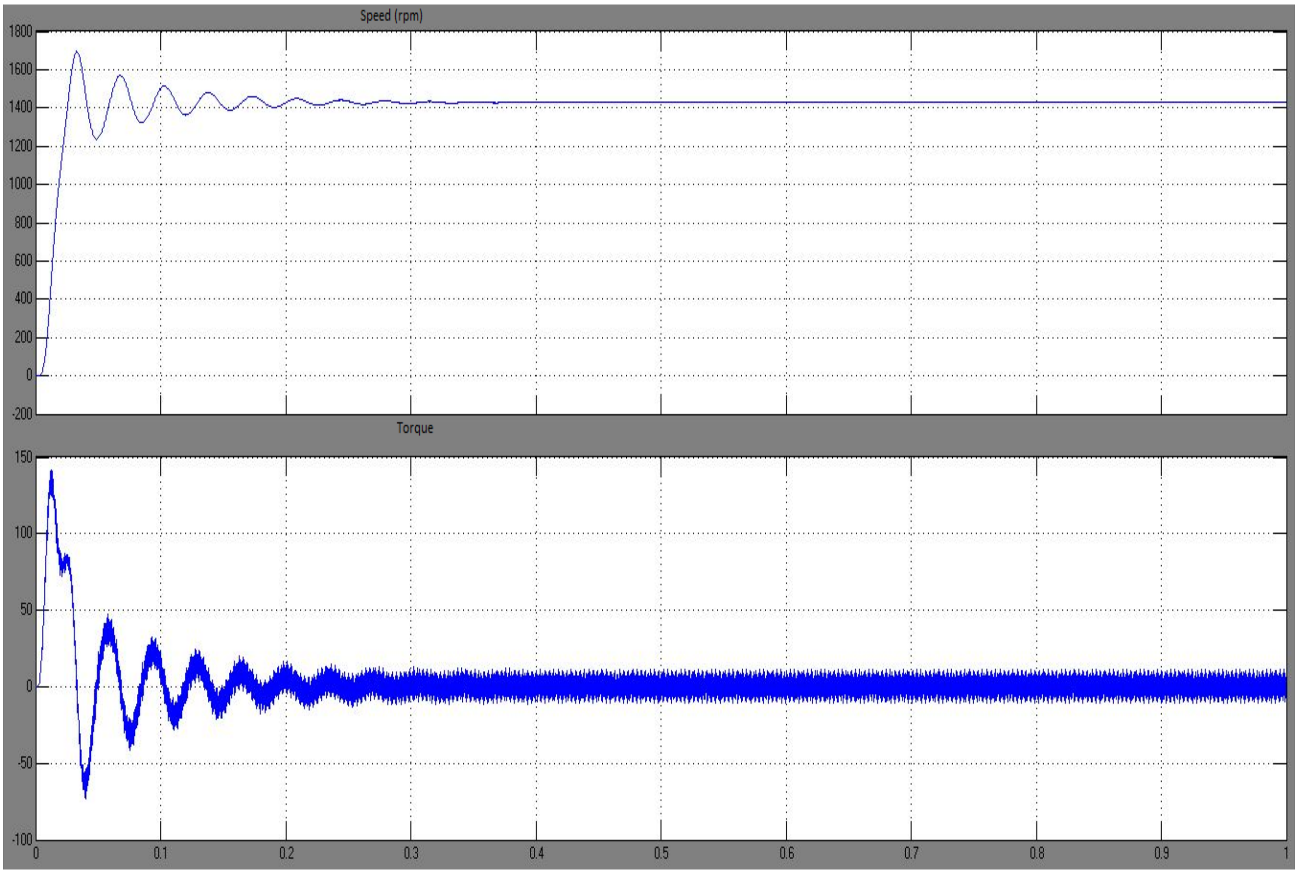
3. Murphy J.M.D and Turnbull, Thyristor control of AC Drives, Pergamon press, Oxford 1988, 1st Edition.

Ex. No.4 SIMULATION OF CLOSED LOOP OPERATION OF V/F CONTROL OF INDUCTION MOTOR DRIVE

SIMULINK DIAGRAM:



OUTPUT WAVEFORMS:



Ex. No.4 **SIMULATION OF CLOSED LOOP OPERATION OF V/F CONTROL OF INDUCTION MOTOR DRIVE**

Aim:

To simulate the Three Phase Induction motor with V/f control.

INTRODUCTION:

V/f is abbreviated from voltage/frequency. V/f control is an induction motor control method which ensures the output voltage proportional with the frequency, so it maintains a constant motor flux, preventing weak magnetic and magnetic saturation phenomenon from happening.

V/f control principle is to produce a circuit called voltage-controller oscillator with oscillator frequency. It is a voltage-dependent capacitance, when subjected to a change in voltage, its capacity will change, and then the change in capacity will cause changes in the oscillation frequency, resulting in variable frequency. This controlled frequency is used to control the frequency of the output voltage, in order to achieve speed changes of the controlled electric motors.

THEORY:

Steady-state per-phase equivalent circuit, the s terms have been replaced by the complex variable $j\omega$. This is justified by the fact that the electrical time constant of practical induction motors are orders of magnitude lower than that of the mechanical time constant. Thus, while designing a controller to control the motor's mechanical rotational speed, the transients associated with the electromagnetic circuit of the motor can be reasonably ignored.

Hence, the per-phase steady state equivalent circuit can be assumed to be a good enough model to derive the motor's non-mechanical transfer function. The flux in the air-gap is a function of the current flowing through the magnetizing inductance L_m,.. If the drop across the stator resistance R_s and stator leakage inductance L_{ls} is ignored, the voltage across the magnetizing inductance V_m equals the applied terminal voltage $V_{s.}$

The motor speed is controlled by controlling the frequency of the applied voltage. This is achieved by using a PI controller. To tune this controller for desired performance, the system transfer function needs to be established that links the applied frequency to the rotor speed,

SOFTWARE REQUIRED:

1. Sim Power System
2. MATALAB

PROCEDURE:

1. Open the MATLAB software
2. Open the SIMULINK Tools menu
3. In SIMULINK tools, Create a new file.
4. In SIMULINK tool menu, Search and take the powergui. In this powergui we need to change the continuous to discrete from configuration parameters.
5. Pick induction motor drive from sim power system-Application library.
6. For closed loop operation of V/f control of induction motor drives select three phase inverter block.
7. Connect the all elements as per the circuit diagram.
8. Set the values for Source and drive parameters.
9. Select Ode 23tt solver in simulation parameters and save the file
10. Run the simulation and verify the output in scope.

VIVA QUESTIONS AND ANSWERS:

1. **What are the roles of inner current control and outer speed control loop?**

Inner current control loop:

It limits the motor current and torque to a safe value. It's a simple closed control loop that keeps the torque output below a safe limit.

Outer speed control loop:

It is the responsible for speed control. Here are some other roles of speed control loop, which are speed feedback, speed error feedback, inner loop, etc.

2. **What is field weakening mode control?**

The DC motor speed can be varied by varying the field current and armature voltage is kept constant. The field current can be controlled by using power converter. By using this method the motor field flux decreases i.e., field weakening mode this method only applicable for above base speed because speed is inversely proportional to flux.

3. **Name any four simulation packages that can be used for electrical drive system?**

- Matlab / Simulink,
- PSpice,
- EMTP,
- ACSL,
- MATRIX,
- SIMNON,
- PSim

4. **What is Electrical and Mechanical time constant for DC machines?**

The electrical time constant is a measure of the response time of the current change in the terminal voltage.

The mechanical time constant is a measure of the RPM's reaction time upon change in the terminal voltage.

5. **Highlight the factors to be considering for the converter selection.**

- Input voltage,
- Output voltage,
- Output regulation,
- Temperature sensitivity,
- Overload capacity,
- Topology,
- Compatibility.

6. **Write down the transfer function of speed controller.**

$$\frac{N(s)}{E_r(s)} = \frac{K_1}{1+s\tau_1}$$

Where ,

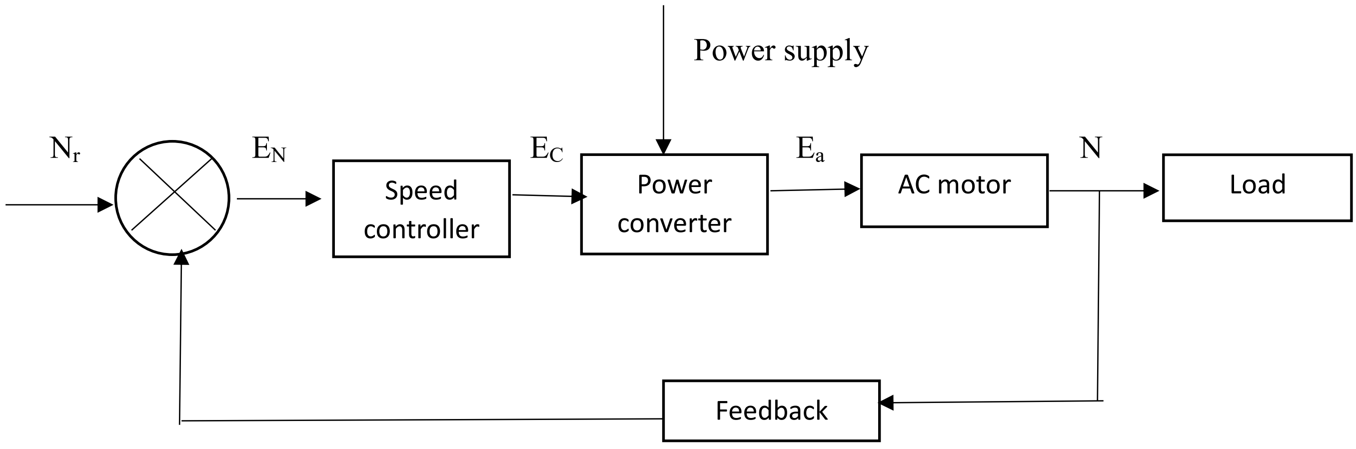
$$K = \frac{K_s K_c K_{m1} K_{m2}}{K_s K_c K_{m1} K_{m2} K_t + 1}$$

$$\tau_1 = \frac{\tau_{m1}}{K_s K_c K_{m1} K_{m2} K_t + 1}$$

7. **What are the functions of feedback loops in an electrical drives?**

1. Protection
2. Improvement of speed response
3. To improve steady state accuracy.

8. **Draw the basic block diagram of closed loop control of AC motor.**



9. **What is the closed loop control of induction motor?**

   It employs inner slip-speed loop with a slip limiter and outer speed loop. Since for a given current, slip speed has a fixed value, the slip speed loop also functions as an inner current loop.

10. **What is the operation of VSI Fed induction motor?**

   A VSI is a self or separate control feeding Induction motor. Open loop and closed loop operation is possible but VSI provides instability and hunting problems. The stator current drawn by the motors when fed to VSI has sharp peaks and is rich in harmonic content which causes additional losses and heating.

SUGESTED OTHER EXCERCISES:

1. Control the speed of induction motor using stator voltage control in which rectifier is provided with different angles for control.
2. Simulate using cycloconverter fed induction motor drives.
3. Simulate closed loop control of induction motor by current source inverters.

POSSIBLE RESEARCH OPPORTUNITIES:

One can use different sorts of inverter topologies and test the above.

DESCRIPTION OF RESULTS AND GRAPH:

The speed of Induction motor remains constant as the switching angles of inverter is varied so that ratio of voltage and frequency is constant to vary the speed

RESULTS:

Thus the speed of induction motor is held almost constant by varying the stator voltage and frequency thus by keeping V/f ratio constant according to the speed.

EXPECTED RESULTS AND LIKELY SOURCE OF ERRORS:

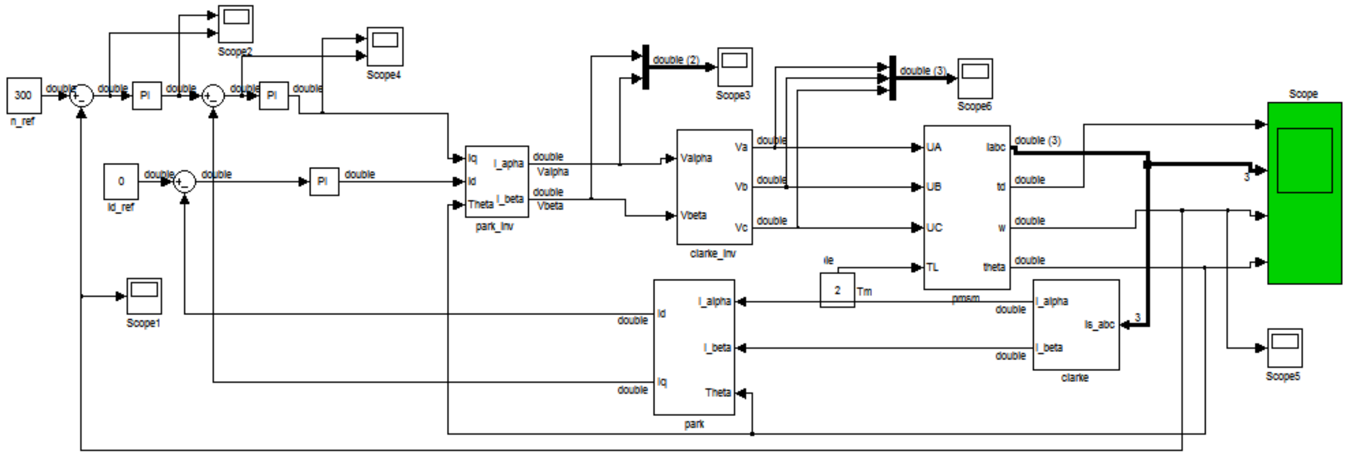
The motor speed must be constant and due to error in switching angles of converter, the speed may vary.

REFERRENCES:

1. Bimal K.Bose. Modern power Electronics and AC Drives, Pearson Education, 2002 1st Edition.
2. Murphy J.M.D and Turnbull, Thyristor control of AC Drives, Pergamon press, Oxford 1988, 1st Edition

Expt.No.5 - SIMULATION OF SYNCHRONOUS MOTOR DRIVE

SIMULINK DIAGRAM:



Expt.No.5 - SIMULATION OF SYNCHRONOUS MOTOR DRIVE

AIM:

To simulate Synchronous motor drive to find it's Speed- torque Characteristics using MATLAB SIMULINK

INTRODUCTION:

The name synchronous motors stems from its characteristic to develop the torque only when the rotor operates at the synchronous speed. Traditionally, large-sized synchronous machines have been mainly used as generators. As motors, they have been used to improve the power factor in the power grid by changing the field current, i.e., excitation. In this case, they are called synchronous condensers. In small sizes, they have been often used in applications requiring a constant speed operation.

However, recently, synchronous motors with a permanent magnet rotor are growing rapidly in use for variable speed drives instead of DC motors. This is because permanent magnet synchronous motors (PMSMs) have many advantages over other motors such as high efficiency, high power density, high dynamic response, and high power factor. However, one disadvantage is its higher cost in comparison to an induction motor.

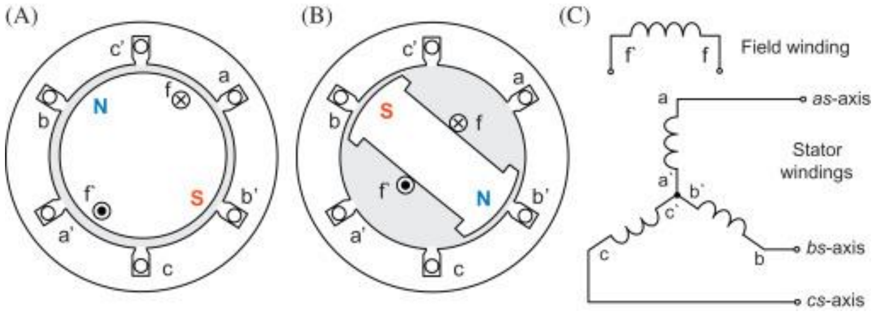
A synchronous motor has the same stator configuration as an induction motor, but a different rotor structure. Unlike an induction motor, a synchronous motor has independent excitations for the stator and rotor windings, i.e., AC excitation to the stator winding and DC excitation to the rotor winding. The function of the stator winding, which is commonly called an armature winding, is to generate a rotating magnet field through its connection to a three-phase AC power source such as an induction motor. The rotor winding, which is called the field winding, generates a field flux with a DC excitation or by a permanent magnet.

THEORY:

In industrial, high-power variable-speed synchronous motor drives are commonly employed. A large synchronous motor drive can have a power rating of up to 100 MW and a voltage of up to 13.8 kV. In applications where great dynamic performance is required, such as rolling mills and mine hoists, the synchronous motor drive is commonly employed.

Synchronous motors are used for extruders, pumps, fans, and compressors, the synchronous motor drive's variable-speed operation can save a lot of energy when compared to fixed-speed operation. Large vessels' propulsion systems have also benefited from synchronous motor drives. Synchronous electric drives for pipeline oil and gas transportation infrastructure must be modernized nowadays.

It is important to know about synchronous motor drives simulation to analyze and modernize. In this chapter, step-by-step process of synchronous motor drives with simulation is given.



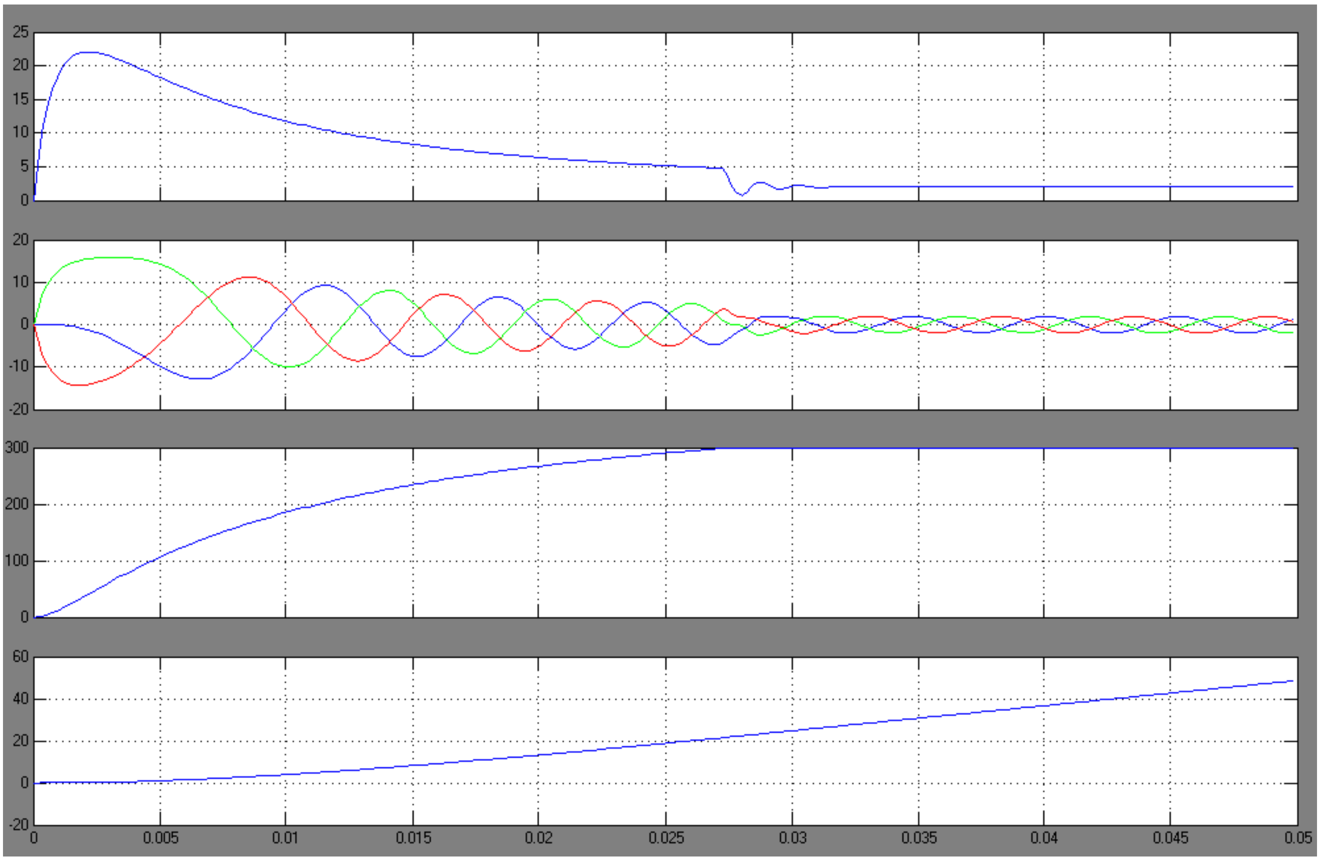
SOFTWARE REQUIRED:

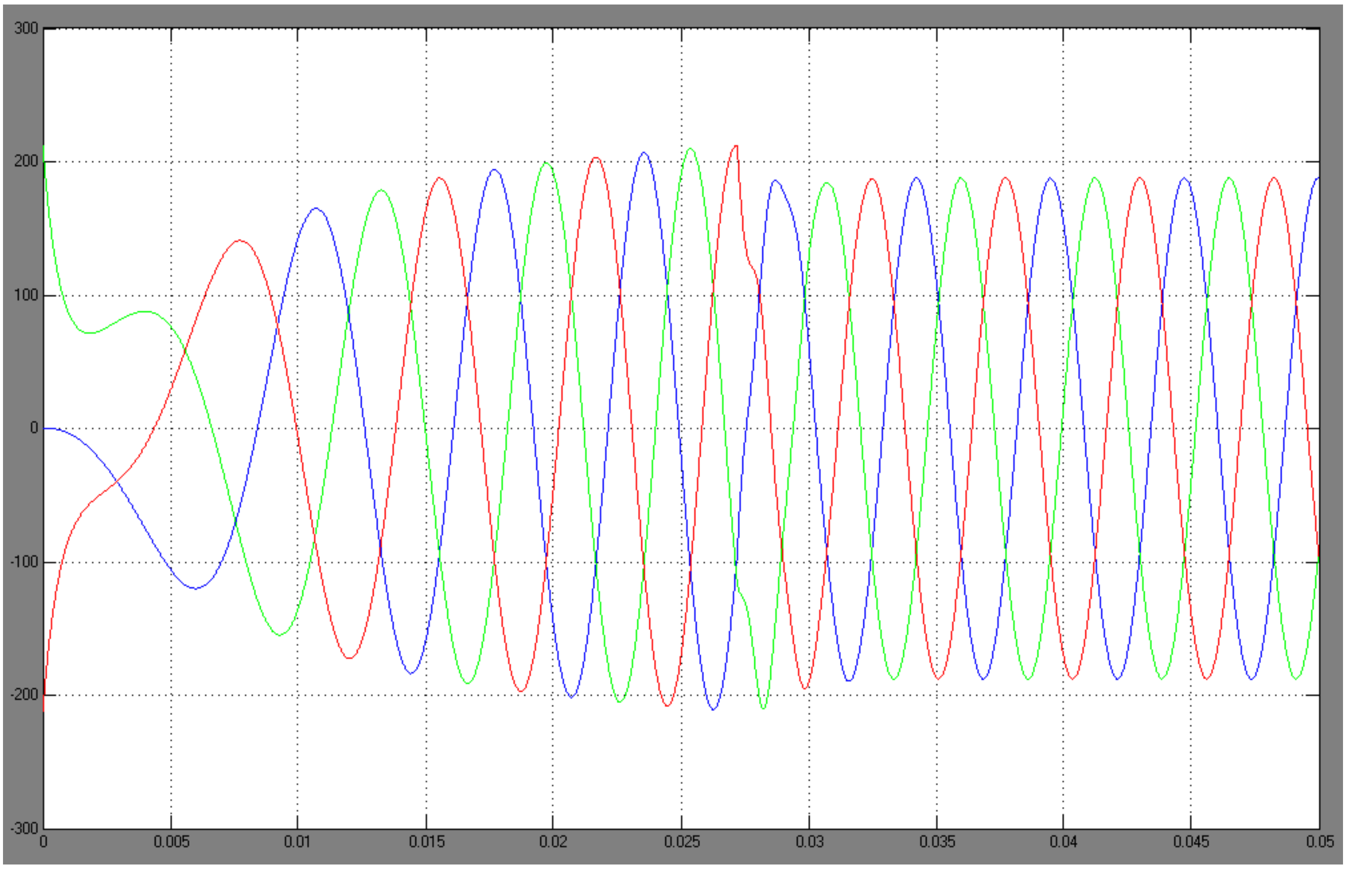
1. Sim Power System
2. MATLAB

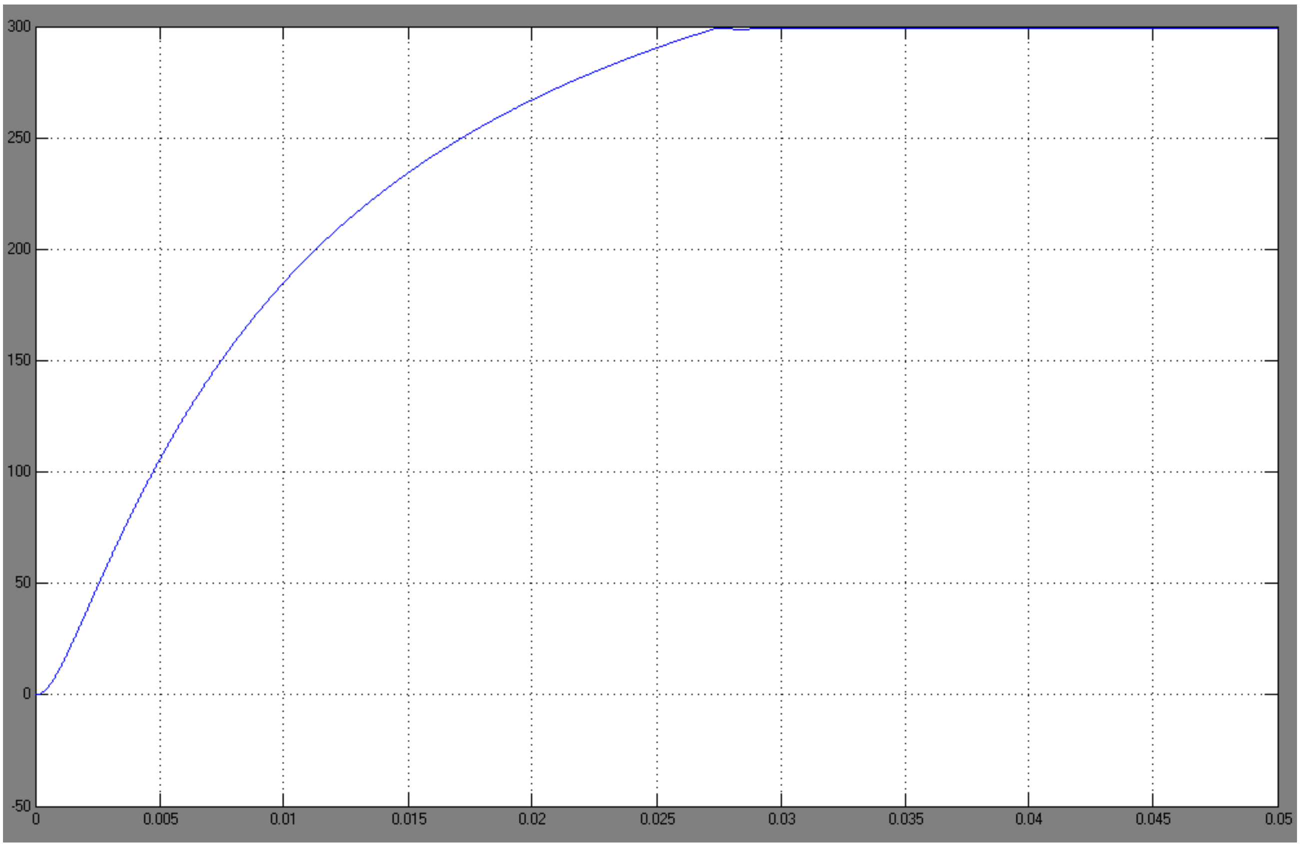
PROCEDURE:

1. Open the MATLAB software
2. Open the SIMULINK Tools menu
3. In SIMULINK tools, Create a new file.
4. In SIMULINK tool menu, Search and take the powergui. In this powergui we need to change the continuous to discrete from configuration parameters.
5. Pick synchronous motor drive from sim power system-Application library.
6. For closed loop synchronous motor drives select three phase inverter block.
7. Connect the all elements as per the circuit diagram.
8. Set the values for Source and drive parameters.
9. Select Ode 23tt solver in simulation parameters and save the file
10. Run the simulation and verify the output in scope.

MATLAB OUTPUT WAVEFORMS:







VIVA QUESTIONS AND ANSWERS:

1) What is self-control mode of synchronous motors?

In self-controlled synchronous motors, the supply frequency is adjusted to match the rotor speed, ensuring that the motor operates at synchronous speed and preventing rotor pull-out and hunting. This control method involves using a power electronic converter to generate variable frequency AC power to supply the motor. No need of damper winding.

2) What is constant margin angle control of synchronous motor drive?

Constant Margin Angle Control (CMAC) is a control strategy employed in synchronous motor drives to maintain a constant angle between the stator current vector and the rotor field vector. This angle, known as the torque angle or power angle, is crucial for optimizing the motor's performance and ensuring stable operation.

3) What are the advantages and disadvantages of PMSM?

Advantages:

- **High Efficiency:** Due to the absence of rotor winding losses, PMSMs generally have higher efficiency compared to induction motors.
- **Torque Density:** PMSMs have excellent torque density, allowing them to produce high torque for their size.

- **High Power Factor:** PMSMs typically operate at a high power factor, reducing energy consumption and improving system efficiency

Disadvantages:

- **High Cost:** The permanent magnets used in PMSMs can be expensive
- **Complex Control:** PMSMs require more complex control strategies compared to induction motors

4) Comparison between characteristics of true synchronous mode and self-controlled mode operated synchronous motor?

True Synchronous Mode:

- Limited speed control, potential for hunting (rotor oscillations) at certain loads, and less efficient operation at low speeds.
- Multi motor operation is possible here.
- The open loop (separate control) have stability problem at low speeds.

Self-Controlled Mode

- It operated like DC motor also called commutator less motor (CLM).
- These machines have better stability behaviour.
- Do not have oscillatory behaviour.

5) Mention some applications of Synchronous motor drives?

- High power and high speed compressors
- Blowers
- Induced and forced draft fans
- Main line traction
- Servo drives

6) Why self-controlled synchronous motor is free from hunting oscillations?

Hunting oscillations occur in synchronous motors when the rotor speed deviates from the synchronous speed, causing the motor to oscillate or hunt. This can lead to instability and reduced performance. In self-controlled synchronous motors, the supply frequency is adjusted to match the rotor speed, ensuring that the motor operates at synchronous speed and preventing rotor pull-out and hunting.

7) Why the synchronous motor said to be self-controlled?

A synchronous motor is said to be self-controlled because it can automatically adjust its rotor speed to match the supply frequency without external intervention. This self-control mechanism is achieved through the following: Field excitation, Synchronous speed, Rotor speed and Self-control.

8) What is Commutator less motor (CLM)?

Synchronous motor drives operated under self-controlled mode it can be looked upon as a dc motor having commutator are replaced by a converter connected to stator. The self-controlled motor run has properties of a dc motor both under steady state and dynamic conditions and therefore it is called as CLM.

9) What are the advantages of the constant margin angle control of synchronous motor drive fed by an inverter?

1. Eliminate the hunting and stability problems.
2. It does not require commutation circuits.

SUGESTED OTHER EXCERCISES:

1. Development of electric vehicle with permanent magnet synchronous motor and its analysis with drive cycles in MATLAB/Simulink.
2. Torque ripples reduction of electric vehicle synchronous reluctance motor drive using the strong action controller.
3. Design of direct-drive permanent magnet synchronous motor for cryogenic valve

POSSIBLE RESEARCH OPPORTUNITIES:

Using of PMSM in high power application drives.

DESCRIPTION OF RESULTS AND GRAPH:

The speed of Synchronous motor remains constant as the switching angles of inverter is varied so that ratio of voltage and frequency is constant to vary the speed

RESULTS:

Thus the speed of synchronous motor is held almost constant by varying the stator voltage and frequency thus by keeping V/f ratio constant according to the speed.

EXPECTED RESULTS AND LIKELY SOURCE OF ERRORS:

The motor speed must be constant and due to error in switching angles of converter, the speed may vary.