Code: 23EE4602A

III B.Tech - II Semester - Regular Examinations – APRIL 2026

ELECTRIC DRIVES
(ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	List the components of an electric drive.	L1	CO1
b)	What is dynamic braking?	L1	CO1
c)	Write the expression for average output voltage of a 3-phase full converter.	L2	CO2
d)	What is a dual converter?	L1	CO2
e)	Draw four quadrant diagram of DC motor drive.	L2	CO4
f)	Define continuous current mode (CCM) of chopper fed DC drive.	L1	CO4
g)	What is a Static Scherbius drive?	L1	CO3
h)	Explain why V/f ratio is kept constant in speed control of induction motor.	L2	CO5
i)	Relate advantages of PMSM over conventional synchronous motor.	L2	CO5
j)	What is meant by separate control of synchronous motor?	L2	CO3

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Explain steady state stability of electric drive.	L2	CO1	5 M
	b)	Discuss fundamental torque equation for stable operation of drive.	L2	CO1	5 M
OR					
3	a)	Explain load equalization using hoist for four quardrant operation with suitable diagram.	L2	CO1	5 M
	b)	Compare dynamic braking, plugging and regenerative braking in terms of operation, advantages and applications.	L2	CO1	5 M
UNIT-II					
4	a)	Illustrate the operation of a three-phase fully controlled rectifier fed DC series motor for continuous conduction, also draw the voltage and current waveforms.	L3	CO2	5 M
	b)	Demonstrate circulating and non-circulating current modes in dual converter fed dc motor drive.	L3	CO2	5 M
OR					
5	A separately excited dc motor rated at 10 kW, 240 V, 1000 rpm is supplied from a fully controlled six pulse bridge converter. The converter is supplied at 250 V, 50 Hz supply. An extra inductance is connected in the load circuit to make the conduction continuous. Determine the speed, power factor and efficiency of operation		L4	CO4	10 M

		for thyristor firing angles of 0° and 60°, assuming the armature resistance of 0.40 Ω and an efficiency of 87% at rated conditions. Assume constant torque load.			
		UNIT-III			
6	a)	Demonstrate with a neat block diagram explain closed loop operation of dc to dc converter fed dc motor drive.	L3	CO2	5 M
	b)	Explain conditions required for continuous current operation and discuss one quadrant operation of DC drive.	L4	CO4	5 M
		OR			
7		Discuss in detail four-quadrant operation of dc motor drive using four quadrant dc to dc converter with suitable diagrams.	L4	CO4	10 M
		UNIT-IV			
8		A 440 V, 3 phase 50 Hz, 6-pole cage induction motor has the following equivalent circuit parameters: $R_s = 0.2\ \Omega$, $X_s = 0.5\ \Omega$, $R_r = 0.3\ \Omega$, $X_r = 0.5\ \Omega$ and $X_m = 20\ \Omega$, all quantities referred to stator side. The motor is operating on full load slip of 0.04. If the two stator terminals are suddenly interchanged, calculate the primary current and the torque.	L4	CO5	10 M
		OR			
9		Illustrate slip power recovery scheme in detail. Compare Static Scherbius and Static Kramer drives.	L3	CO3	10 M

UNIT-V					
10	a)	Illustrate in detail about the self-control of synchronous motors.	L3	CO3	5 M
	b)	Interpret separate control of synchronous motors.	L3	CO3	5 M
OR					
11	a)	Explain closed loop speed control of synchronous motor drive with block diagram.	L4	CO5	4 M
	b)	Explain PMSM for speed control operation.	L4	CO5	6 M

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I B.Tech - II Semester - Regular /Supplementary Examinations

APRIL 2026

ELECTRICAL DRIVES-- SCHEME OF VALUATION

(ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours Max. Marks: 70

a) Any two components-2M
b) Explanation-2M
c) Expression-2M
d) Explanation-2M
e) Diagram-2M
f) Explanation-2M
g) Explanation-2M
h) Explanation-2M
i) Explanation-2M
j) Explanation-2M

UNIT-1

2a) Explanation-5M
2b) Equations and Explanation-3M, Diagram-2M

OR

3a) Explanation-2M, Diagram-3M
3b) Comparison and Explanation-4M, Diagram-1M

UNIT-II

4a) Equations and Explanation-2M,Diagrams-3M
4b) Explanation-2M,Diagram-3M

OR

5 Equations-6M, Procedure-3M,Result-1M

UNIT-III

6a) Explanation-2M, Diagram-3M
6b) Explanation-2M, Diagram-3M

OR

7a) Explanation-2M, Diagram-3M
7b) ~~Explanation-2M, Diagram-3M~~

UNIT-IV

8 Equations-6M,Procedure-3M,Result-1M

OR

9 Comparison and Explanation-7M, Diagram-3M

UNIT-V

10a) Explanation-2M, Diagram-3M
10b) Explanation-2M, Diagram-3M

OR

11a) Explanation-2M, Diagram-2M
11b) Explanation-4M, Diagram-2M

Code: 23EE4602A PVP 23

I B.Tech - II Semester - Regular /Supplementary Examinations

APRIL 2026

ELECTRICAL DRIVES

(ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours Max. Marks: 70

1.

a) List the components of an electric drive

An electric drive system consists of:

1. Electric motor
2. Power modulator (converter/chopper/inverter)
3. Control unit
4. Sensing devices (speed, current, voltage sensors)
5. Power source
6. Mechanical load

b) What is dynamic braking?

Dynamic braking is a method of stopping a motor by disconnecting it from the supply and connecting it to a braking resistor so that the motor acts as a generator and kinetic energy is dissipated as heat.

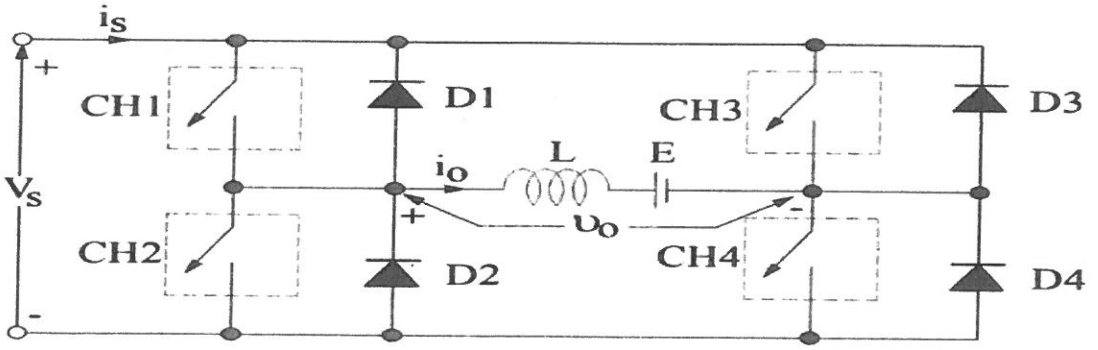
c) Expression for average output voltage of a 3-phase full converter

$$V_{dc} = \frac{3V_{ml}}{\pi}\cos(\alpha) = \frac{3\sqrt{3}\,V_{mp}}{\pi}\cos(\alpha)$$

d) What is a dual converter?

A dual converter consists of **two fully controlled converters connected in anti-parallel** to provide reversible DC voltage and current, enabling **four-quadrant operation** of a DC motor.

e) Four-quadrant diagram of DC motor drive



f) Define Continuous Current Mode (CCM) of chopper-fed DC drive

Continuous Current Mode occurs when **load current never falls to zero** during operation of the chopper within a switching cycle.

g) What is a Static Scherbius drive?

Static Scherbius drive is a **slip power recovery system** used for speed control of slip-ring induction motors where rotor slip power is converted using power electronic converters and fed back to the supply.

h) Why is V/f ratio kept constant in induction motor speed control?

The (V/f) ratio is kept constant in induction motor speed control to **maintain a constant air-gap magnetic flux** . Keeping the ratio constant ensures the motor produces its rated torque across various speeds below the base speed, prevents magnetic core saturation,

i) Advantages of PMSM over conventional synchronous motor

1. No field winding losses
2. Higher efficiency
3. Higher power density
4. Better dynamic performance
5. Compact size
6. Low maintenance (no brushes/slip rings)

j) What is meant by separate control of synchronous motor?

Separate control means **independent control of stator supply frequency and rotor excitation**, allowing flexible speed and torque control in synchronous motor drives.

UNIT-1

2a)

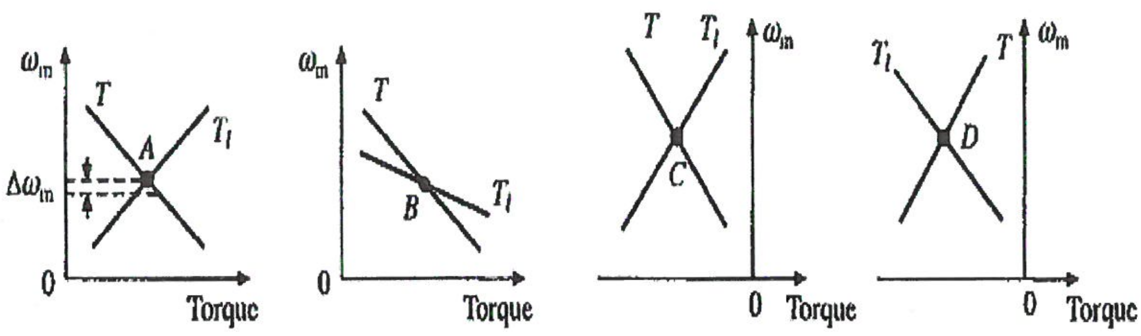


Fig. 2.9 Points A and C are stable and B and D are unstable

Steady-state stability of an electric drive refers to **its ability to regain equilibrium speed after small, slow disturbances**. It occurs when motor torque (T_m) equals load torque (T_l) and is maintained if $\frac{dT_l}{d\omega} > \frac{dT_m}{d\omega}$ (load torque sensitivity exceeds motor torque sensitivity), ensuring speed returns to normal. Scribd +2

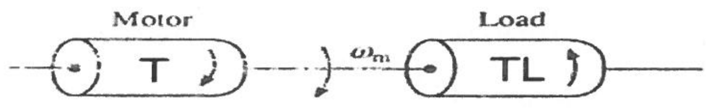
- **Equilibrium Condition:** The drive operates in a steady state when the developed motor torque (T_m) equals the load torque (T_l) at a specific operating speed.
- **Stability Criterion:** The operating point is stable if a small decrease in speed makes $T_m > T_l$ (accelerating the motor back to equilibrium), and a small increase in speed makes $T_m < T_l$ (decelerating the motor back to equilibrium).
- **Mathematical Condition:** Stability is achieved when the rate of change of load torque with respect to speed is greater than the rate of change of motor torque with respect to speed:

$$\frac{dT_l}{d\omega} > \frac{dT_m}{d\omega}$$

- **Transient vs. Steady State:** Unlike dynamic stability, which considers transient electrical/mechanical time constants, steady-state stability assumes the motor is in electrical equilibrium, making it simpler to analyze using speed-torque curves.
- **Unstable Operation:** If $\frac{dT_l}{d\omega} < \frac{dT_m}{d\omega}$, a slight disturbance will cause the speed to increase uncontrollably or stop the motor completely. Scribd +7

b)

- **A motor generally drives a load (machine) through some transmission system.**
- **While motor always rotates, the load may rotate or undergo translational motion, or both simultaneously.**
- **Load speed may be different from that of the motor.**
- **Representation of motor-load system may seem the following.**



- **Motor-load system can be described by the following fundamental torque equation (Equation of motion).**

$$T - T_L = \frac{d}{dt}(J\omega_m) = J\frac{d\omega_m}{dt} + \omega_m\frac{dJ}{dt} \qquad \text{---- 3.1}$$

For drives with constant inertia, (dJ/dt) = 0; thus,

$$T = T_L + J\frac{d\omega_m}{dt} \qquad \text{------------------} \quad 3.2$$

Where, T = developed motor torque

T_L = Load torque referred to motor shaft.

J = polar moment of inertia of motor load system referred to motor shaft

ω_m = angular velocity of motor shaft

This equation shows that, torque developed by the motor is Counter balanced by a load torque T_L and a dynamic torque J(dω/dt).

- **Torque component J(dω/dt) is called the dynamic torque because it appears during the transient operation.**

OR

3a)

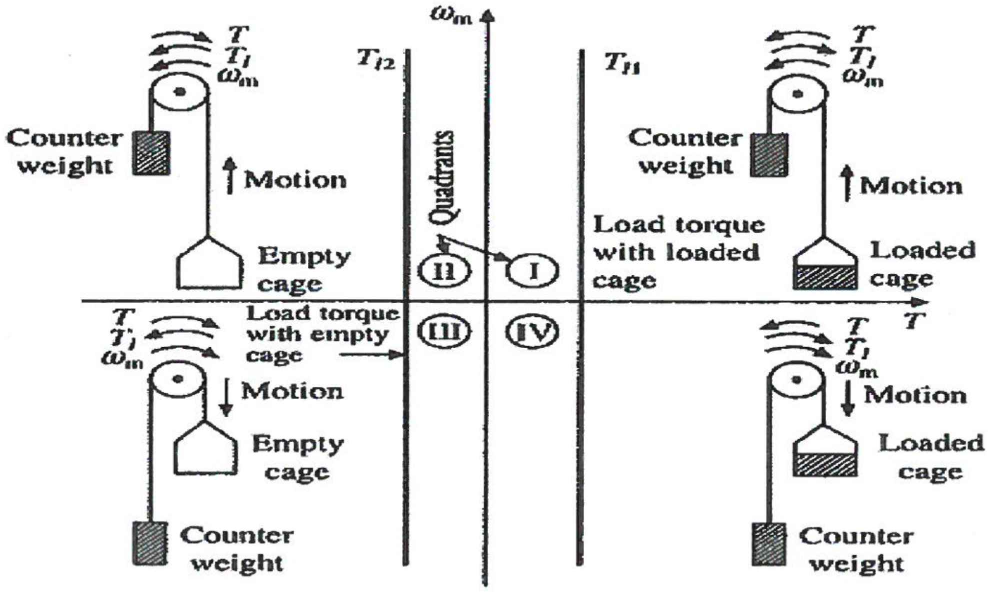


Fig. 2.3 Four quadrant operation of a motor driving a hoist load

Multiquadrant operation of electric drives involves controlling a motor to operate in all four quadrants of the torque-speed plane—Forward Motoring, Forward Braking, Reverse Motoring, and Reverse Braking

The operation is defined by the signs of speed (ω) and torque (T), where power $P = T \times \omega$. Testbook

- **Quadrant I: Forward Motoring ($+\omega$, $+T$)**
  - Motor accelerates or drives the load in the forward direction. Power is positive.
- **Quadrant II: Forward Braking ($+\omega$, $-T$)**
  - Also known as regenerative braking. The motor operates in the forward direction but generates torque in the reverse direction to slow down, returning energy to the source.
- **Quadrant III: Reverse Motoring ($-\omega$, $-T$)**
  - The motor drives the load in the reverse direction. Power is positive.
- **Quadrant IV: Reverse Braking ($-\omega$, $+T$)**
  - The motor rotates in the reverse direction but produces forward torque to slow down, acting as a generator. Testbook +4

3b)

Brakes are used to reduce or cease the speed of motors. We know that there are various types of motors available (DC motors, induction motors, synchronous motors, single phase motors etc.) and the specialty and properties of these motors are different from each other, hence this braking methods also differs from each other. But we can divide braking in to three parts mainly, which are applicable for almost every type of motors.

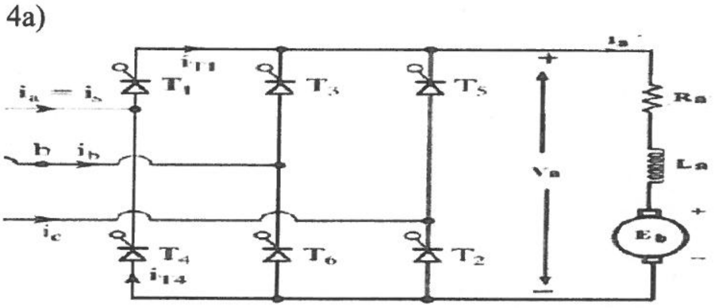
1. Regenerative Braking.
2. Plugging type braking.

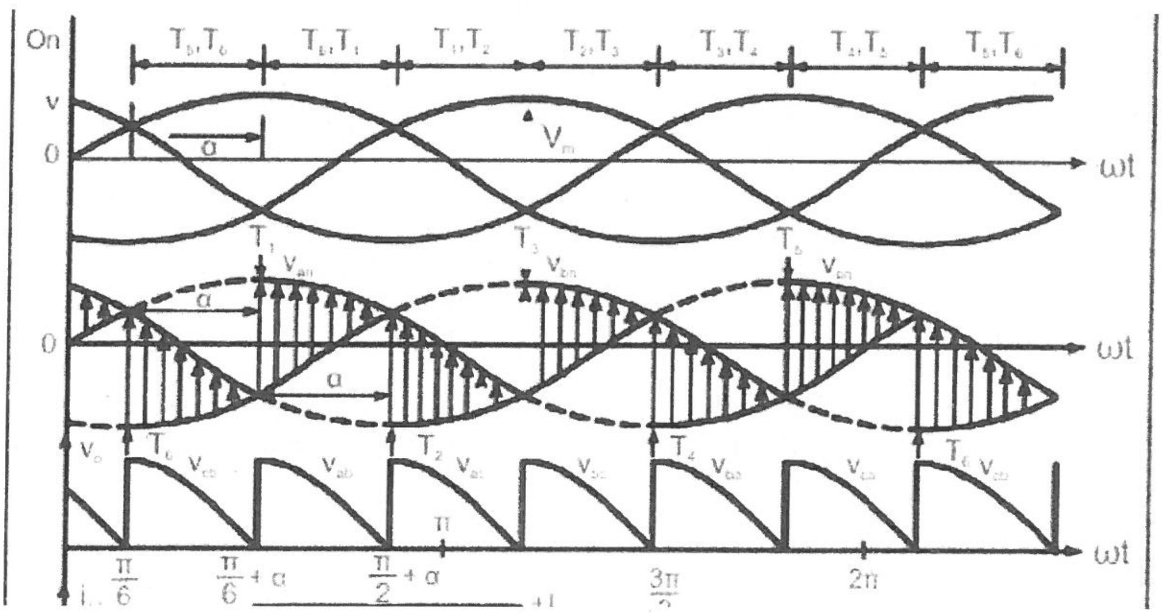
3. Dynamic braking.

Feature	Regenerative	Dynamic (Rheostatic)	Plugging
Main Mechanism	Motor acts as a generator; feeds power back to source	Motor acts as a generator; dissipates power in a resistor	Terminals are reversed to create opposing torque
Energy Efficiency	**Highest** (recovers energy)	Moderate (wastes energy as heat)	**Lowest** (wastes source + kinetic energy)
Braking Torque	Moderate	Decreases as speed drops	**Highest** (aggressive)
Stopping Ability	Cannot stop motor to zero	Effective near zero speed	Extremely rapid stop
Complexity	High (requires complex control)	Simple (resistor-based)	Simple (terminal reversal)

UNIT-II

4a)





$$V_a = \frac{3}{\pi}\int_{\alpha+\pi/3}^{\alpha+2\pi/3} V_m \sin\omega t \, d(\omega t)$$

$$= \frac{3}{\pi} V_m \cos\alpha$$

$$\Rightarrow \omega_m = \frac{V_a}{K_a K_f I_a} - \frac{I_a(R_a+R_f)}{K_a K_f I_a}$$

$$\omega_m = \frac{V_a}{\sqrt{K_a K_f T_d}} - \frac{R_a+R_f}{K_a K_f}$$

Speed – torque characteristics:

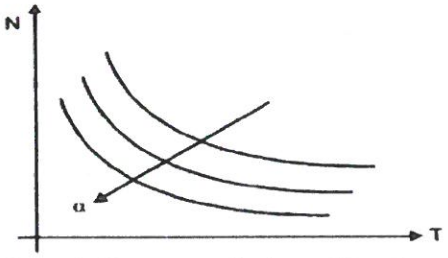


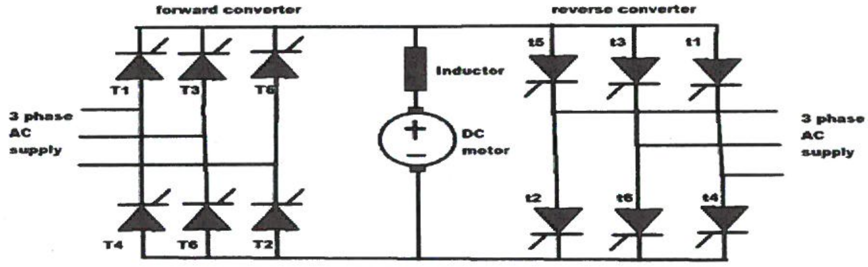
Fig (7): Torque – Speed Characteristics of 3-phase fully controlled converter fed dc series motor

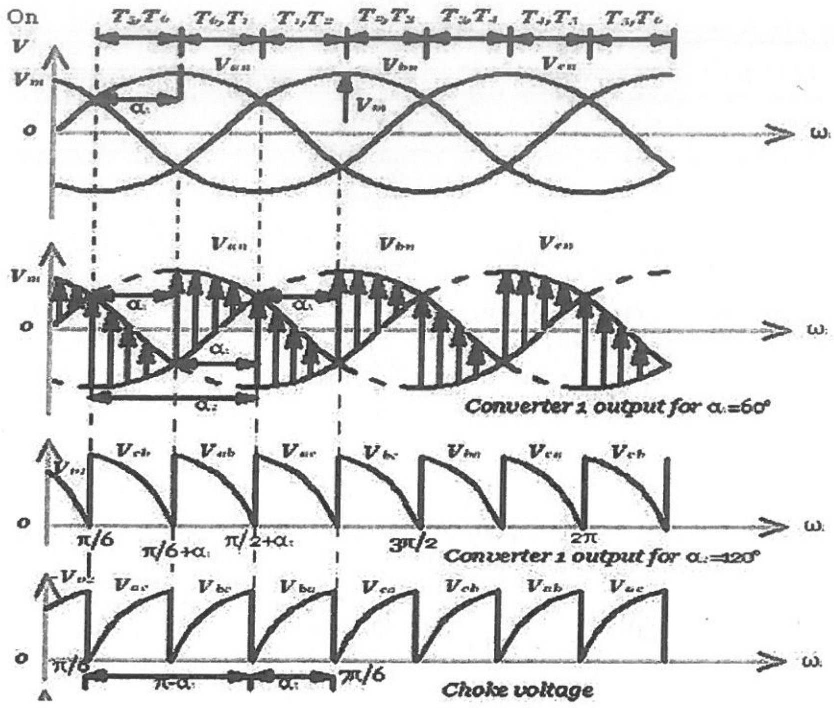
4b)

Non-Circulating Current Mode (NCCM):

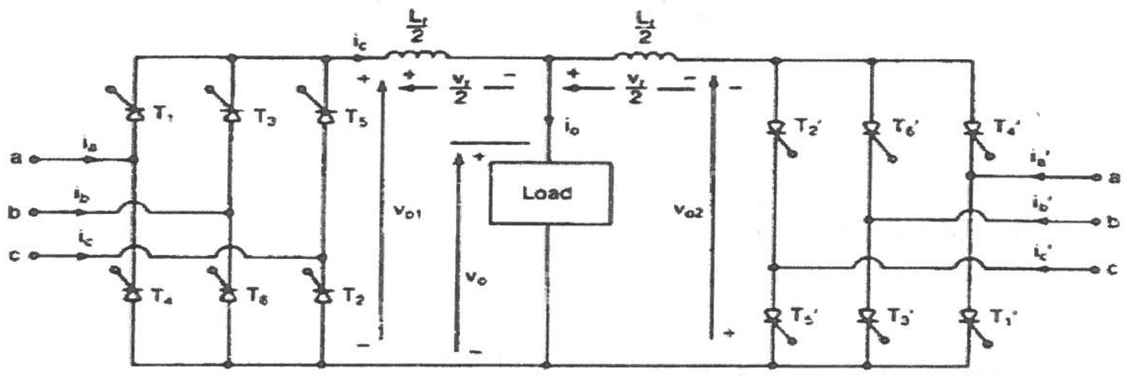
- **Operation:** Only one converter is active at a time; when Converter 1 acts as a rectifier, Converter 2 is blocked (turned off).
- **Switching:** When reversing the voltage, the first converter is turned off and a small delay is provided to ensure it is completely off before the second converter is enabled.

- One converter will perform at a time. There is no circulating current between the converters.
- During the converter 1 operation, the firing angle (α1) will be $0<\alpha 1< 90^0$ (Vdc and Idc are positive)
- During the converter 2 operation, firing angle (α2) will be $0<\alpha 2< 90^0$ (Vdc and Idc are negative)

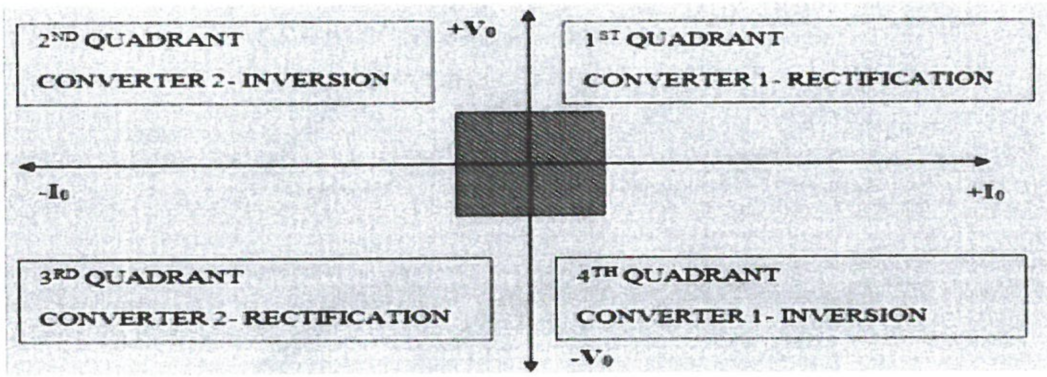




- Circulating Current Mode (CCM):
  - **Operation:** Both Converters 1 and 2 are active simultaneously.
  - **Firing Angles:** Maintained at $\alpha_1 + \alpha_2 = 180°$ to maintain equal average output voltages but opposite instantaneous polarity.
  - **Reactor Requirement:** A large circulating current reactor is necessary to limit the current flowing directly between the two converters, preventing high short-circuit current.



- In this mode, both converters will be in the ON condition at the same time. So circulating current is present.
- The firing angles are adjusted such that $\alpha1+ \alpha2=180^0$. Firing angle of converter 1 is α1 and firing angle of converter 2 is α2.
- In this mode, the Converter 1 works as a controlled rectifier when the firing angle is $0<\alpha1< 90^0$ and Converter 2 works as an inverter when the firing angle is $90^0 <\alpha2< 180^0$. In this condition, Vdc and Idc are positive.
- Converter 1 works as an inverter when firing angle be $90^0 <\alpha1< 180^0$and Converter 2 works as a controlled rectifier when the firing angle is $0<\alpha2< 90^0$ in this condition, Vdc and Idc are negative.



OR

5

$P_{out} = 10kW$, $V_t = 240V$, $N = 1000rpm$

$V_s = 240V$ $f = 50Hz$ $\alpha = 0^\circ$ & 60°

$R_a = 0.4\Omega$ $\eta = 87\%$

$P_{in} = \frac{P_{out}}{\eta} = \frac{10K}{0.87} = 11494.25W$

$I_a = \frac{P_{in}}{V_{rated}} = \frac{11494.25}{240} = 47.89A$

$E_{b1} = V_t - I_a R_a$

$E_{b1} = 220.84V$

$\alpha = 0^\circ$

$V_{oavg} = \frac{3\sqrt{2}V_s}{\pi}\cos\alpha$

$V_{oavg} = 337.6 \times 1 = 337.6V$

$e_{b2} = 337.6 - 19.16$
$= 318.44V$

$N_1 \times \frac{E_{b2}}{E_{b1}} = N_2 = 1442 rpm$

$pf = \frac{3}{\pi}\cos\alpha = 0.955$

$\eta = \frac{15250.1 - 576.6}{16167.6} = 90.76\%$

$\alpha = 60^\circ$

$V_{oavg} = \frac{3\sqrt{2}V_s}{\pi}\cos\alpha$

$V_{oavg} = 337.6 \times 0.5$
$= 149.64V$

$E_{b2} = 168.8 - 19.16$
$= 149.64V$

$N_2 = 667.6 rpm$

$pf = \frac{3}{2\pi} = 0.477$

$\eta = \frac{7166.3 - 576.6}{8084.6}$

$\eta = 81.51\%$

6a

A closed-loop system ensures precise speed control despite load variations. It typically consists of two nested loops: an **outer speed loop** and an **inner current loop.**

Block Diagram Description

- **Speed Controller:** Compares the reference speed (ω^*) with the actual speed (ω) from a tachometer/encoder. The error is processed (usually by a PI controller) to produce a current reference (I_a^*).
- **Current Controller:** Compares I_a^* with the actual armature current (I_a). This ensures the motor does not exceed safe current limits.
- **PWM Generator:** Converts the control signal into pulses with a specific duty cycle (D).
- **DC-DC Converter (Chopper):** Scales the input DC voltage to the required level for the motor based on the PWM signal.
- **DC Motor:** The load being controlled.

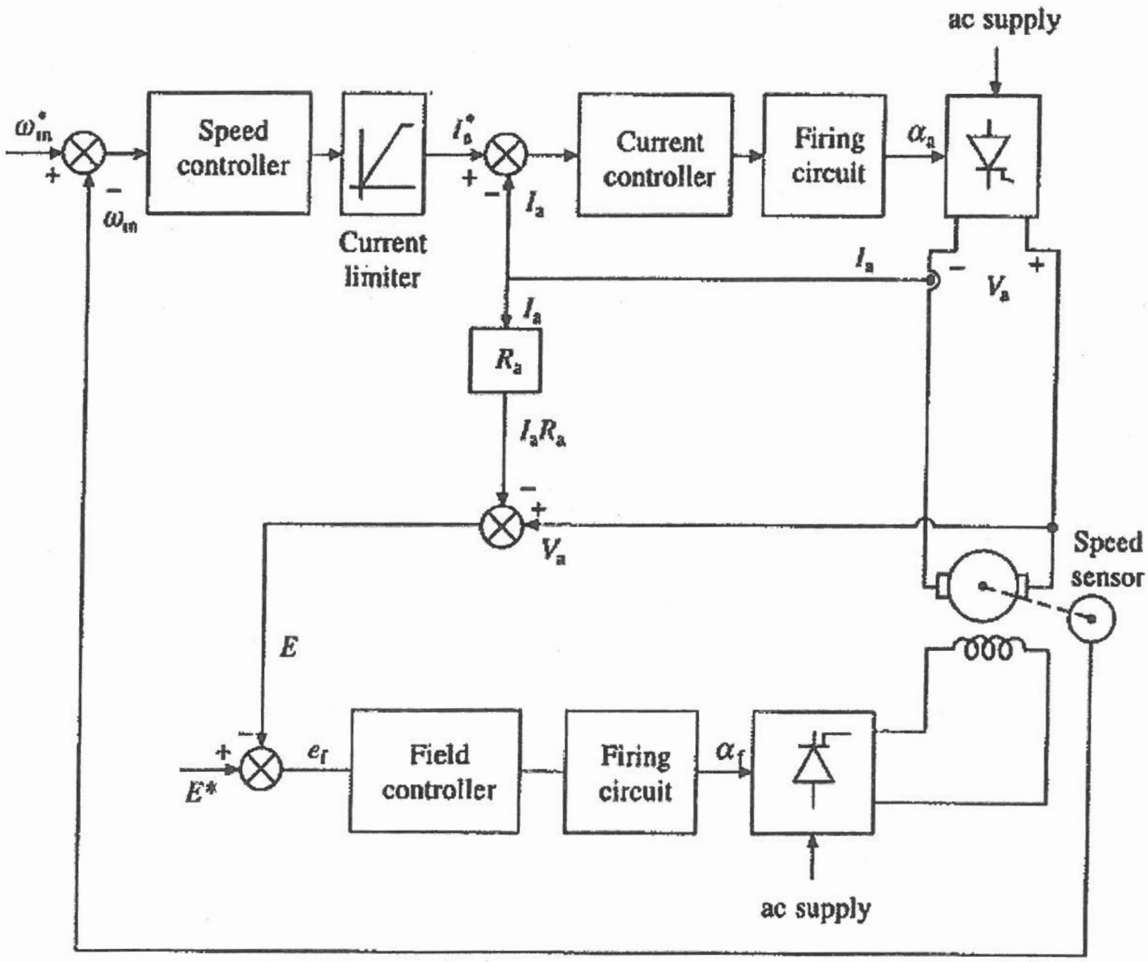
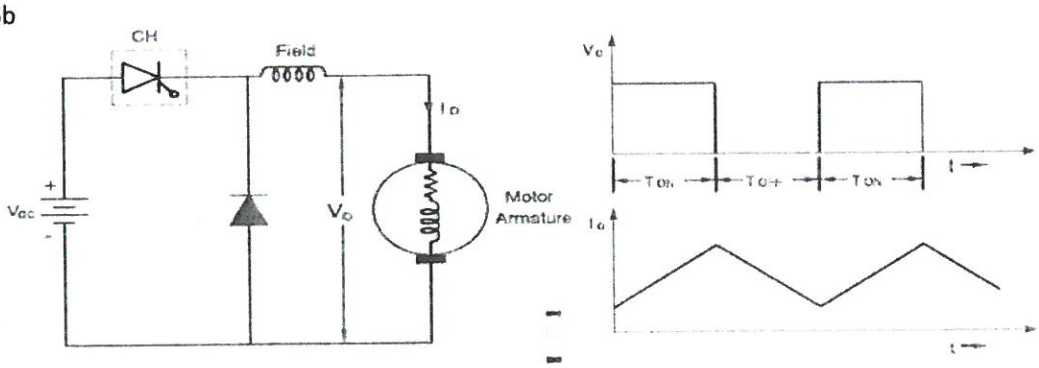


Fig. 5.47 Closed-loop speed control scheme for control below and above base speed

6b



When chopper CH is switched on, the DC motor gets input supply voltage V_{dc}. The DC motor does not get any voltage when chopper CH is switched off. The load current completes its path through freewheeling diode or we can say that stored energy of inductor dissipates in the freewheeling diode during chopper turn off time.

The average output voltage across load is

$$V_O = [\ T_{ON} / (\ T_{ON} + T_{OFF}\ )\ ]\ V_{dc}$$

$$= (\ T_{ON} / T\ ) V_{dc}$$

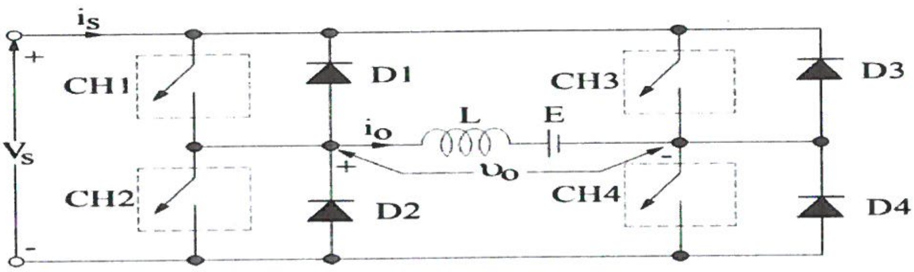
$$V_O = KV_{dc}$$

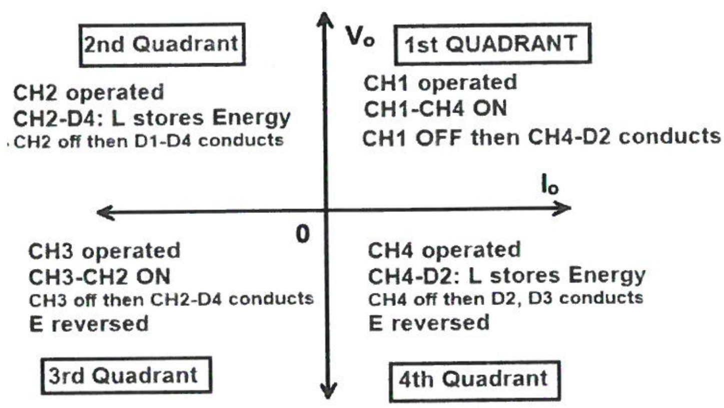
Where K = Duty Cycle

The voltage across load can be adjusted to any value by switching chopper with suitable time interval.

OR

7





First Quadrant (Forward Motoring): CH1 and CH4 are operated. Both average output voltage (V_o) and current (I_o) are positive, feeding power to the load.

Second Quadrant (Forward Braking): CH2 and D4 are operated. V_o is positive, but I_o is negative, causing regenerative braking where energy is fed back to the source.

Third Quadrant (Reverse Motoring): CH3 and CH4 are operated. Both V_o and I_o are negative, driving the motor in the reverse direction.

Fourth Quadrant (Reverse Braking): CH4 and D2 are operated. V_o is negative and I_o is positive, allowing for regenerative braking in reverse. LinkedIn +5

UNIT-IV

8

$$V_{ph} = \frac{440}{\sqrt{3}} = 254\,V$$

$$S_{new} = 2 - S = 2 - 0.04 = 1.96$$

$$Z = \sqrt{0.353^2 + 1^2} = 1.06\,\Omega$$

$$I_1 = \frac{V_{ph}}{|Z|} = \frac{254}{1.06} = 239.6\,A$$

$$N_s = \frac{120 \times 50}{6} = 1000\,rpm$$

$$\omega_s = 104.7\,rad/sec$$

$$T = \frac{3}{\omega_s} \times \frac{V_{ph}^2}{\left(R_s + \frac{R_r}{S_{new}}\right)^2 + (X_s + X_r)^2} \times \frac{R_r}{S_{new}}$$

$$T = 251.7\,N\text{-}m.$$

OR

9

In a conventional rotor resistance controller, the slip power (power not converted to mechanical work) is dissipated in resistors, leading to low efficiency. SPRS instead converts this AC slip power—which varies in frequency ($f_{rotor} = s \times f_{supply}$)—back into the AC supply frequency for reuse.

- **Method:** A rotor-side converter rectifies the slip power to DC, which is then inverted by a grid-side converter back to AC, matching the grid frequency and voltage.
- **Advantages:** Significantly higher efficiency and the capability for speed control below synchronous speed (and above with specialized systems). YouTube · Read Electric Vehicle +2

Comparison: Static Kramer vs. Static Scherbius

Feature	**Static Kramer Drive**	**Static Scherbius Drive**
Speed Range	Primarily **below** synchronous speed ($N < N_s$)	**Below, above, and at** synchronous speed
Rotor Rectifier	Diode Bridge (Uncontrolled)	Thyristor Bridge (Controlled)
Feedback Mechanism	DC Converter to DC Motor or Inverter	Inverter to AC Supply
Power Flow	Unidirectional (Rotor to Supply)	Bidirectional (allows regeneration)
Converter Type	Simpler (diode rectifier)	Complex (requires thyristor inverter)
Main Application	Pumps, Fans, Centrifugal Loads	Rolling mills, Hoists (constant torque)

UNIT-V

10a

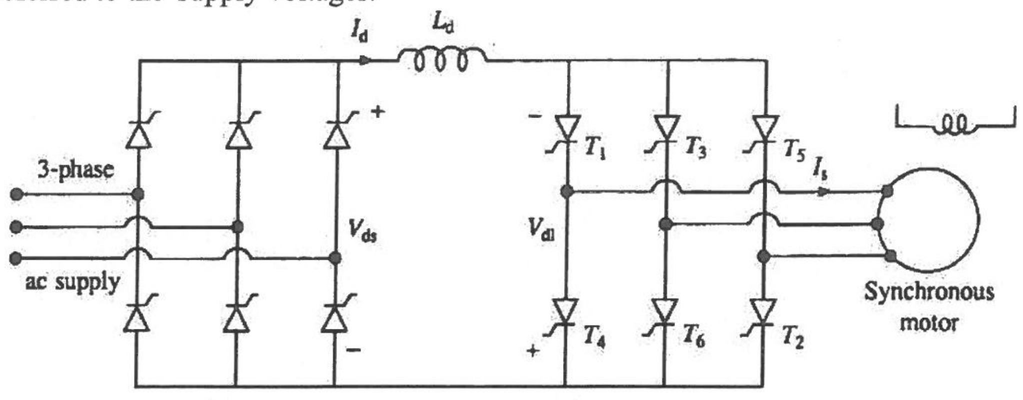
Self controlled mode:

In *Self controlled mode*, the stator supply frequency is changed in proportion to the rotor speed, so that the rotating magnetic field produced by the stator always moves at the same speed as the rotor (Or rotor field). This ensures that the rotor runs at synchronous speed at all operating points. (In all Load conditions)

The source side converter is a 3 phase 6 pulse line commutated fully controlled converter. When the firing angle range is **0° <** α_s **< 90°** the converter acts as a line commutated fully controlled rectifier. During this mode the output voltage V_{ds} and output current I_{ds} are both positive.

When the firing angle range is **90° < α_s < 180°** the converter acts as a line commutated fully controlled inverter. During this mode the output voltage V_{ds} is negative and output current I_{ds} is positive.

When the synchronous motor operates at a leading power factor, thyristors of the load side converter are commutated by the motor induced voltages just as the thyristors in a line commutated converter are commutated by the supply voltages. This is called Load commutation (here load is synchronous motor).Firing(triggering) angles are referred to the induced voltages just like the triggering angles in a line commutated inverter are referred to the supply voltages.



When the firing angle range is **0° < α_l < 90°** the **load side** converter acts as a line commutated fully controlled rectifier. During this mode the output voltage V_{dl} and output current I_d are both positive.

When the firing angle range is **90° < α_l < 180°** the **load side** converter acts as a line commutated fully controlled inverter. During this mode the output voltage V_{dl} is negative and current I_d is positive.

For **0° < α_s < 90° & 90° < α_l < 180°** and with $V_{ds} > V_{dl}$ the source side converter acts like a line commutated Rectifier and load side Converter acts like a line commutated Converter causing power to flow from the source to the motor thus giving motoring operation.

When the firing angles are changed such that **90° < α_s < 180° and 0° < α_l < 90°** the Load Side Converter acts like a line commutated Rectifier and Source Side Converter acts like a line commutated Inverter causing power to flow from the motor to the source thus giving regenerative braking operation.

The magnitude of Torque depends on **(V_{ds} -- V_{dl})**. The motor speed can be controlled by control of line side converter firing angles.

When working as an Inverter, the firing angle has to be less than 180° to take care of commutation overlap and turn off of thyristors. It is common to define a commutation lead angle for load side converter as

$$\beta_l = 180° - \alpha_l$$

If commutation overlap is ignored, the input AC current of the converter will lag behind the input AC voltage by an angle α_l. Since motor input current has an opposite phase to converter input current, the motor current will lead its terminal voltage by an angle β_l.

Therefore the motor operates at a leading power factor.Lower the value of β_l, higher the motor power factor and lower the Inverter rating.

In a simple control scheme ,the drive is operated at a fixed value of commutation lead angle β_{lc} for the load side converter working as an Inverter and at $\beta_l = 180°$(or

$\alpha_l = 0°$) when working as a rectifier. *When good power factor is required to minimize converter rating, the load side converter when working as an inverter is operated with* ***constant margin angle control.***

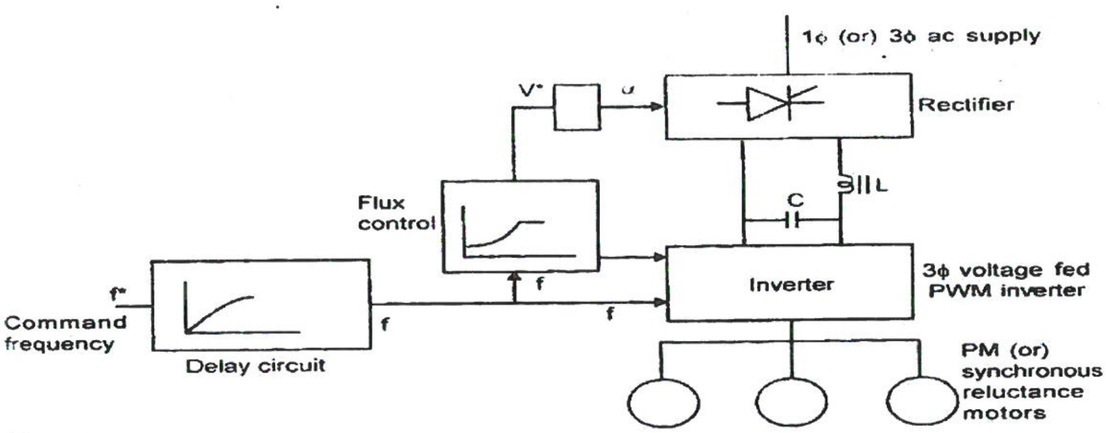
10b

Separate Control Mode:

This is an open loop control mode in which the stator supply frequency is controlled from an Independent oscillator. Hence the frequency is gradually increased from its initial value to the final desired value so that the difference between the synchronous and rotor speed is always very small. This enables the rotor to track the changes in synchronous speed and catch up without pulling out. When the desired synchronous speed is reached, the rotor pulls into step, after hunting oscillations. This method can be used for smooth starting and regenerative braking. This method is best suited for multiple synchronous, reluctance or Permanent magnet (PM) motor drives where close speed tracking is essential among a number of machines in applications such as fiber spinning mills, paper and textile mills where accurate speed tracking is required.

The block diagram of such an open loop control system using this separate control method for multiple synchronous motors is shown in the figure below.

Here all the machines are connected to the same Inverter and they move in response to the command frequency **f***at the input to the Ramp/delay circuit. The Input speed command is given through a ramp generator with a finite delay to ensure that the rotor gradually picks up speed and pulls into synchronism with the stator magnetic field and settles at the final synchronous speed.The frequency command **f*** after passing through the ramp/delay circuit generates the required **V** and **f** control signals just like in a VSI with a PWM Inverter as shown in the figure. The **V** control is applied to the DC converter through a flux control block so as to generate the required Voltage to generate a constant flux with varying frequency. The Rectifier output then gets applied to the PWM inverter through **L& C** filter as required for a VSI type drive. The frequency command is directly applied to the PWM inverter. The synchronous motor can be built with damper winding to prevent oscillations.

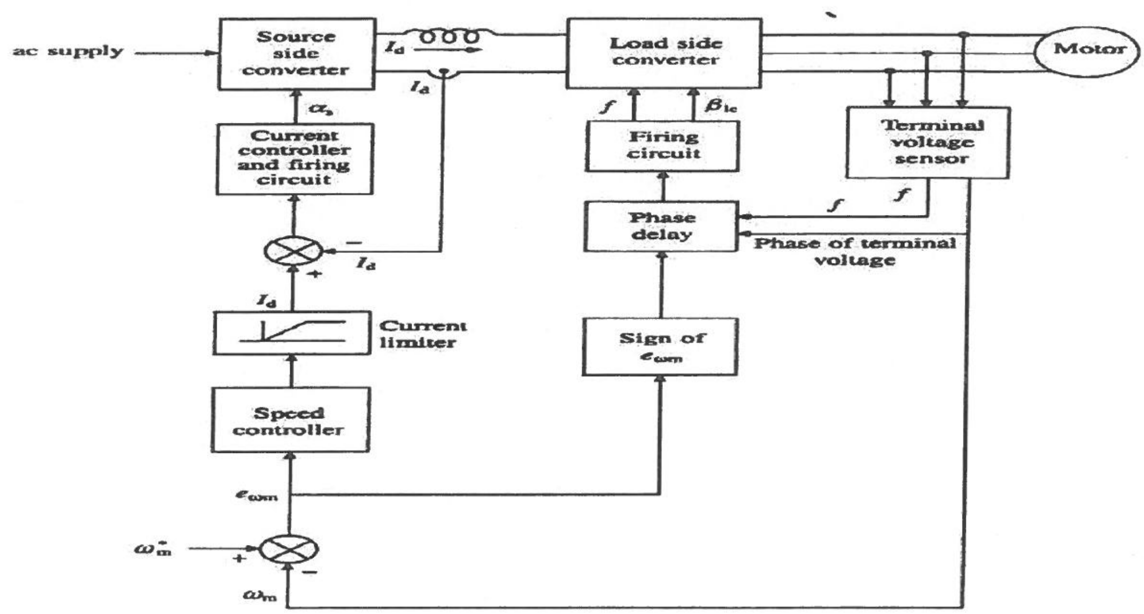


11 a

Closed loop operation of Synchronous drives:

A closed loop speed control scheme of a Load Commutated Inverter (LCI) Synchronous Drive is shown in the figure below.

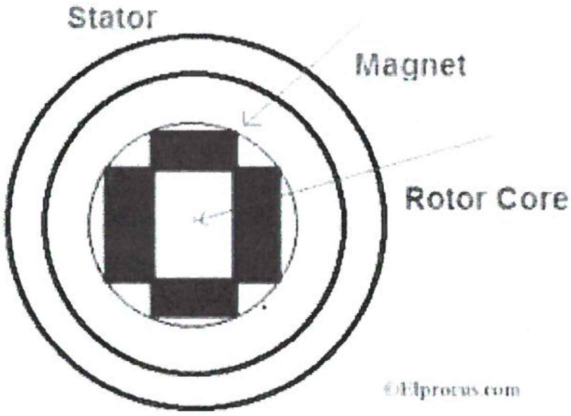
- It employs outer speed control loop and inner current control loop with a limiter just as in a DC motor speed control system.
- The phase controlled Thyristor rectifier on the supply side of the DC link has a constant current regulating loop and operates as a controlled current source.
- The regulated DC current is delivered through the DC link inductor to the Thyristors in the LCI (Load Commutated Inverter) (shown in the figure as Load side Inverter) which supplies square-wave line currents to the synchronous motor.
- The terminal voltage sensors generate reference pulses of same frequency as the motor-induced voltages. The phase delay circuit shifts the reference pulses suitably to obtain control at a constant commutation lead angle β_{lc}.
- Depending on the sign of speed error, β_{lc} is set to provide motoring or braking operation. Speed ω_m can be sensed either from the terminal voltage sensor or from a separate tachometer.



11b

An increase in reference speed ω_m produces a positive speed error. β_{lc} value is then set for motoring operation. The speed controller and the current limiter set the DC link current reference at the maximum permissible value. The motor accelerates fast. When close to the desired speed the current limiter desaturates and the drive settles at the desired speed and at a DC link current which balances motor and load torques .

Similarly a reduction in reference speed produces a negative speed error. This sets β_{lc} for regenerative braking operation (i.e. 180 °) and the motor decelerates. When speed error changes sign β_{lc} value is set for motoring operation and the drive settles at the desired speed.



The working of the permanent magnet synchronous motor is very simple, fast, and effective when compared to conventional motors. The working of PMSM depends on the rotating magnetic field of the stator and the constant magnetic field of the rotor. The permanent magnets are used as the rotor to create constant magnetic flux, operates and locks at synchronous speed. These types of motors are similar to brushless DC motors.

The phasor groups are formed by joining the windings of the stator with one another. These phasor groups are joined together to form different connections like a star, Delta, double and single phases. To reduce harmonic voltages, the windings should be wound shortly with each other.

When the 3-phase AC supply is given to the stator, it creates a rotating magnetic field and the constant magnetic field is induced due to the permanent magnet of the rotor. This rotor operates in synchronism with the synchronous speed. The whole working of the PMSM depends on the air gap between the stator and rotor with no load.