UNIT III

SWITCHED RELUCTANCE MOTOR

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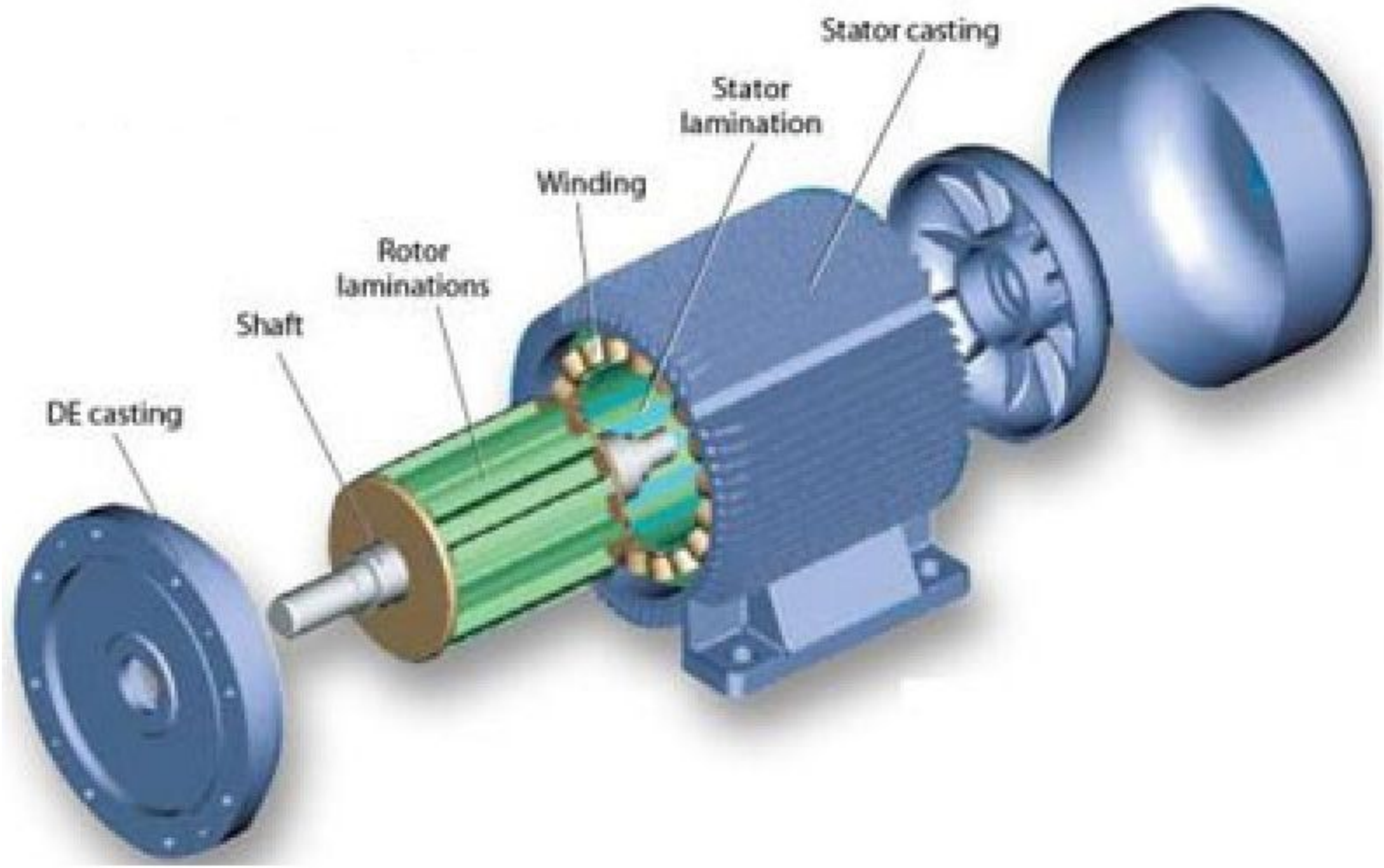
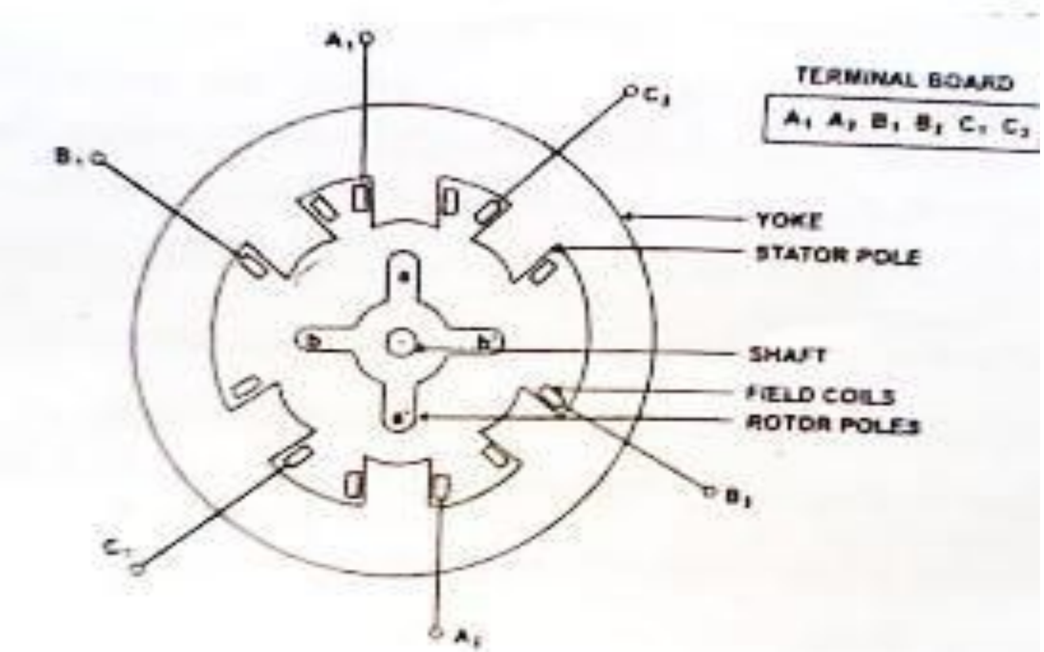
INTRODUCTION

- **SWITCHED RELUCTANCE MOTOR** -- Switched reluctance motor (**SRM**) is electromagnetic and electrodynamics equipment which converts the electrical energy into mechanical energy. The electromagnetic torque is produced on variable reluctance principle.

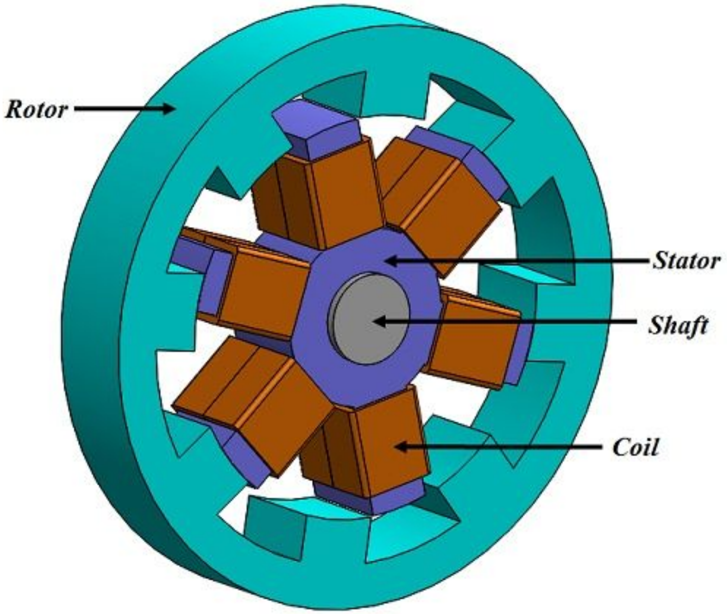
- construction is **simple and robust**
- It requires **less maintenance**
- Its **overall efficiency** is better
- It is flexible control driving motor as motoring mode generating mode of operations of the machine can be easily achieved


Stator casting
Stator
lamination
Winding
Rotor
laminations
Shaft
DE casting

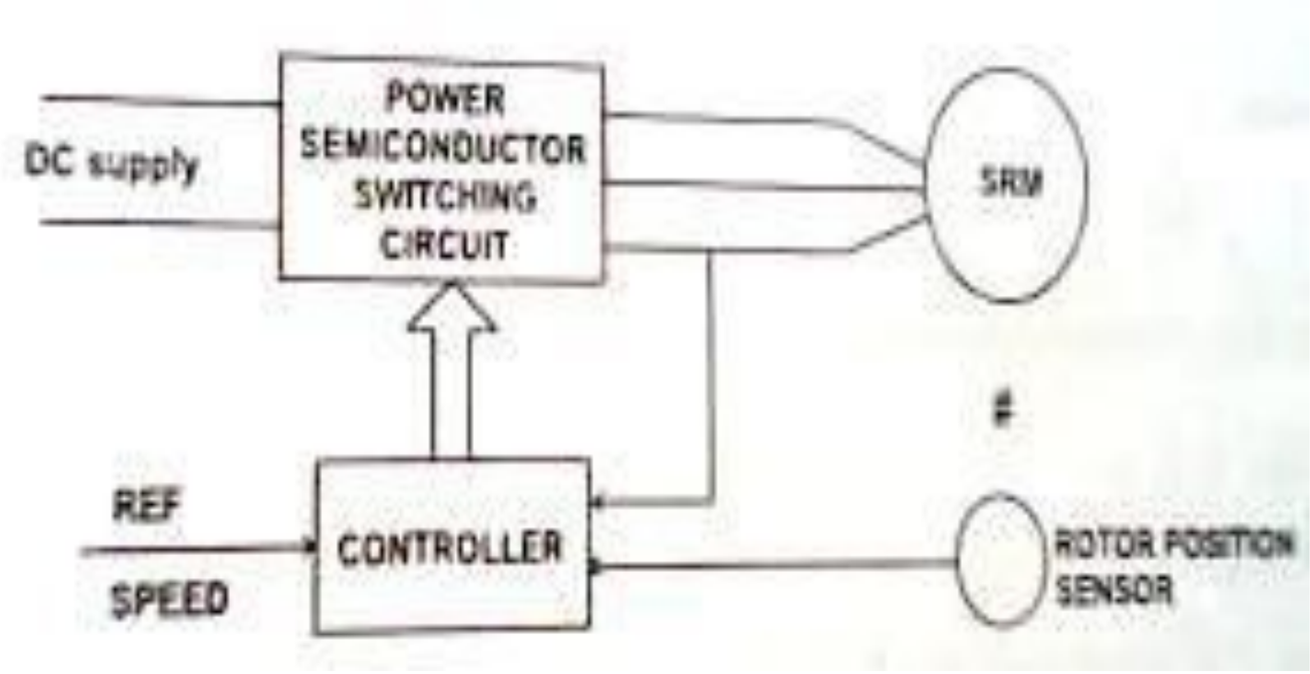
CONSTRUCTION OF SWITCHED RELUCTANCE MOTOR



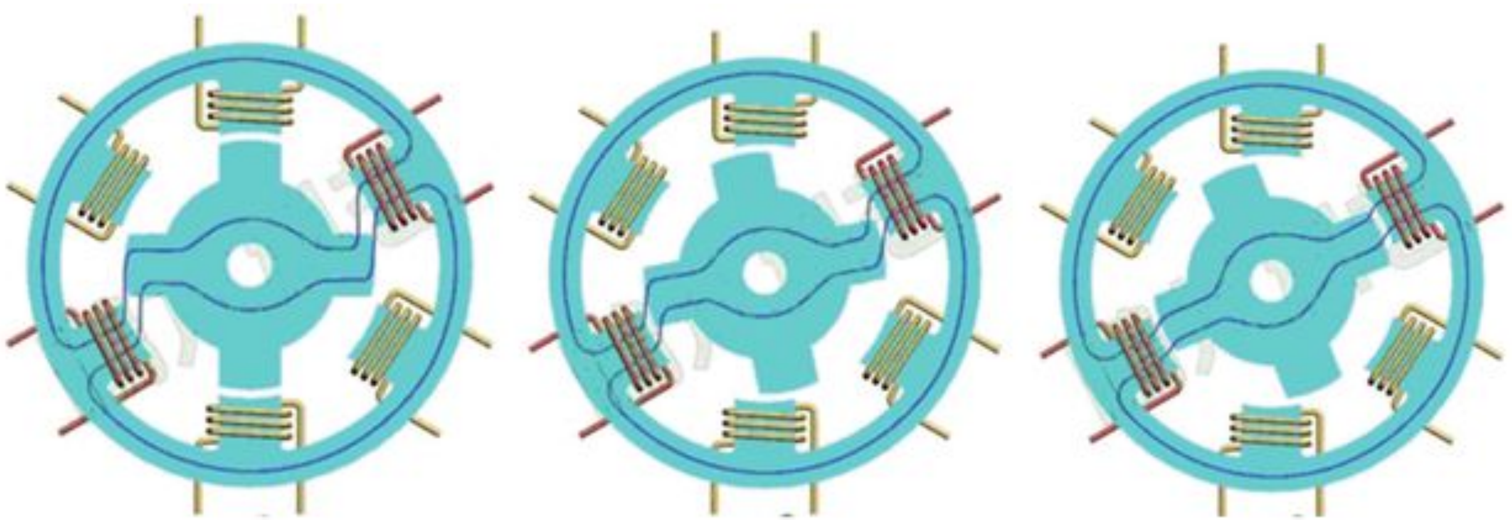
CONSTRUCTION OF SYNCHRONOUS RELUCTANCE MOTOR



BLOCK DIAGRAMOF SWITCHED RELUCTANCE MOTOR



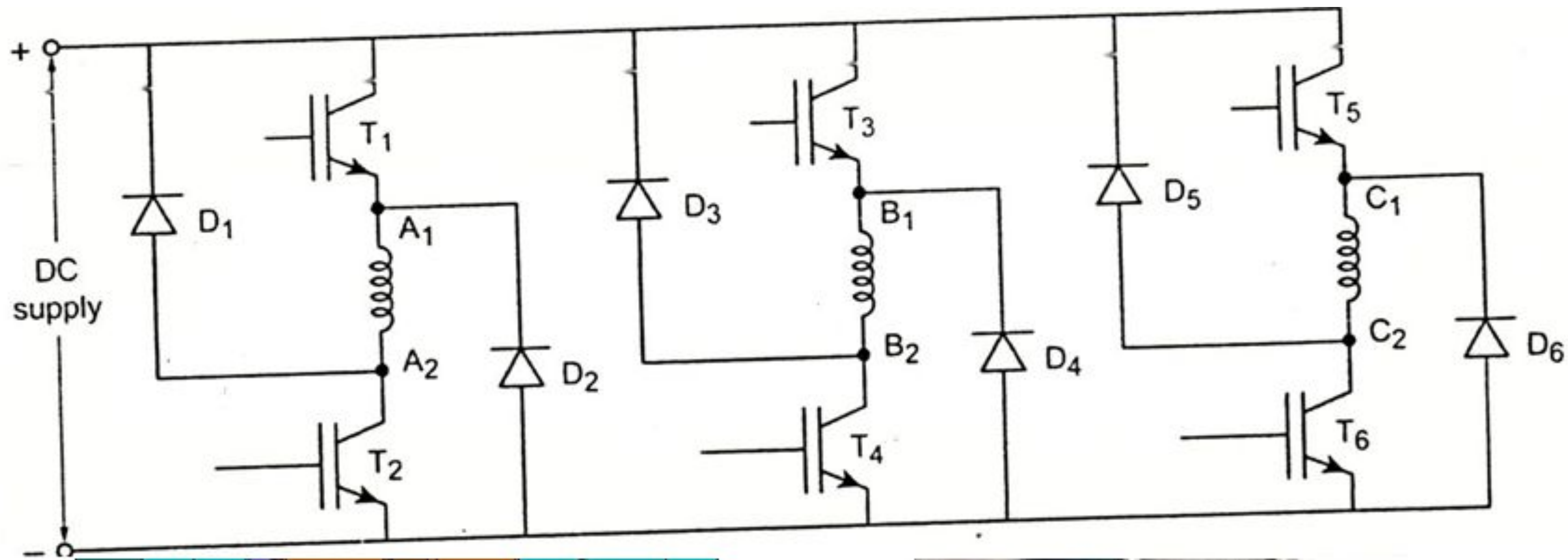
PRINCIPLE OF OPERATION



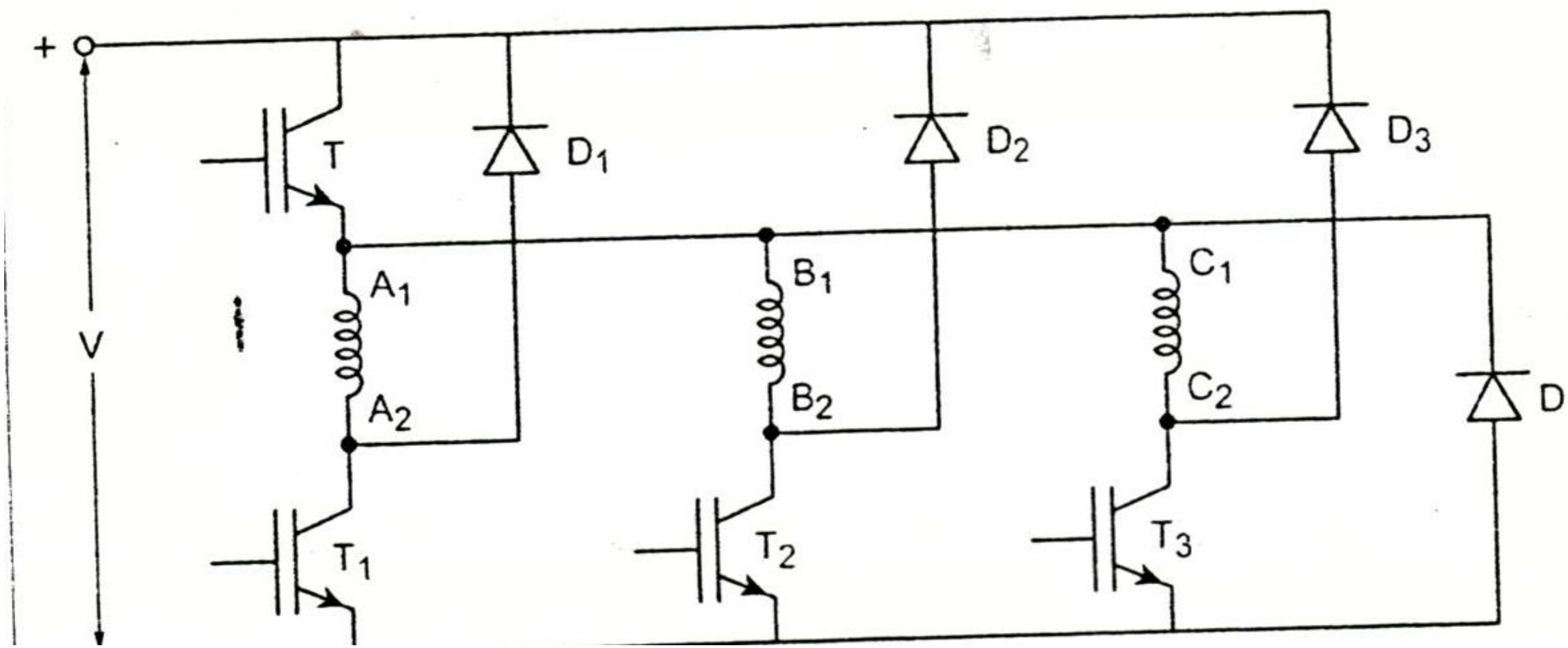
POWER SEMICONDUCTOR SWITCHING CIRCUITS FOR SRM (POWER CONTROLLERS)

- Two power semiconductor switching devices per phase and two diodes.
- (n+1) power semiconductor switching devices (n+1) diodes.
- Phase winding using bifilar wires.
- Split-link circuit used with even-phase number.
- C-dump circuit.

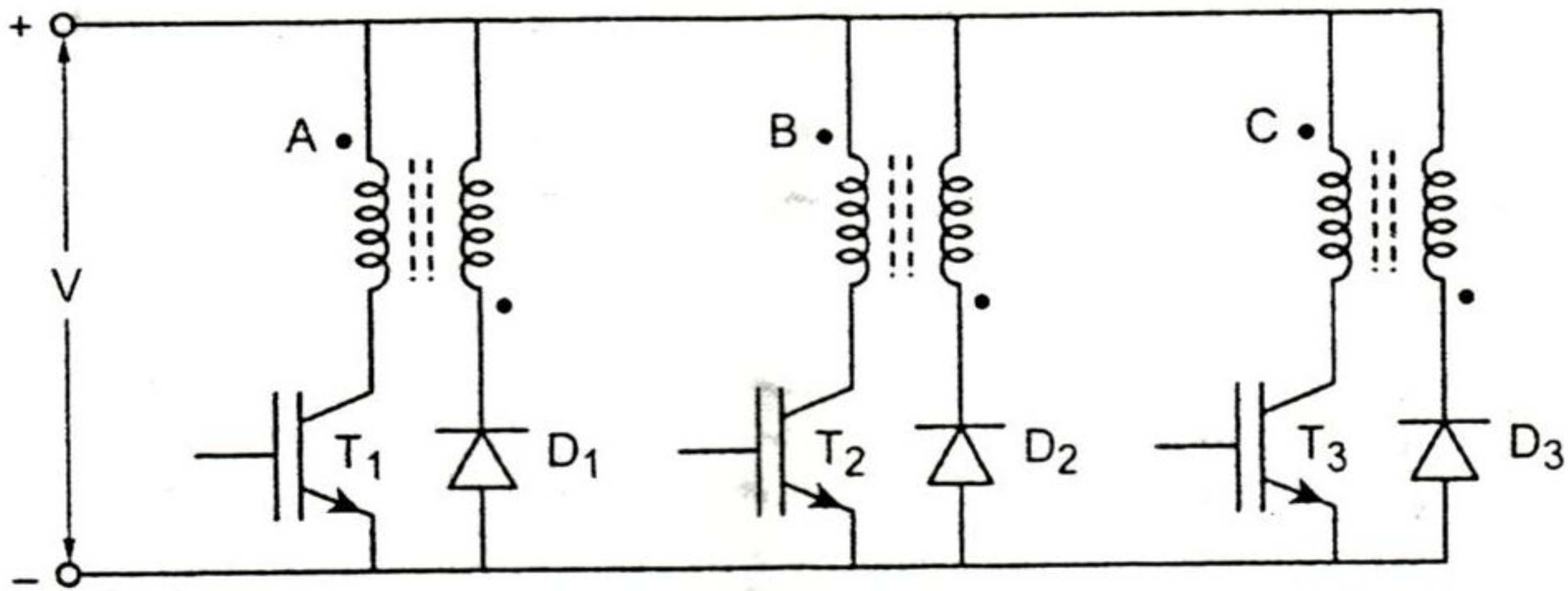
TWO POWER SEMICONDUCTOR SWITCHING DEVICES PER PHASE AND TWO DIODES



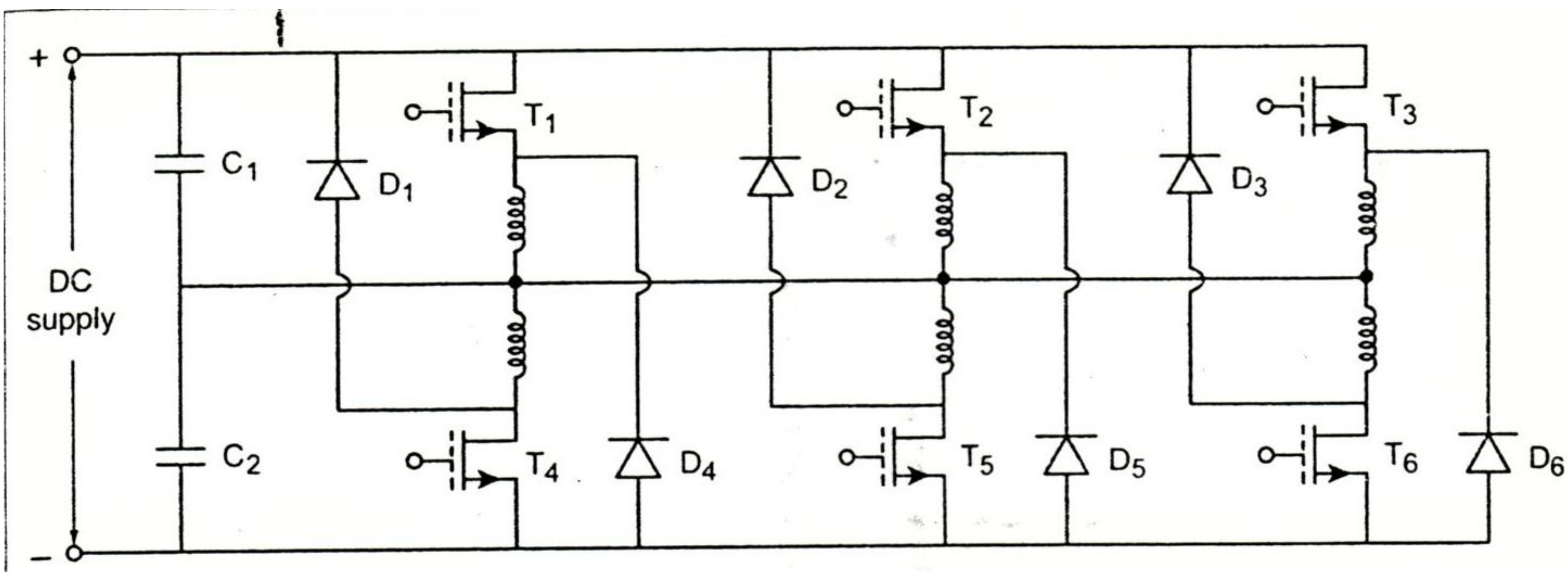
(N+1) POWER SEMICONDUCTOR SWITCHING DEVICES (N+1) DIODES



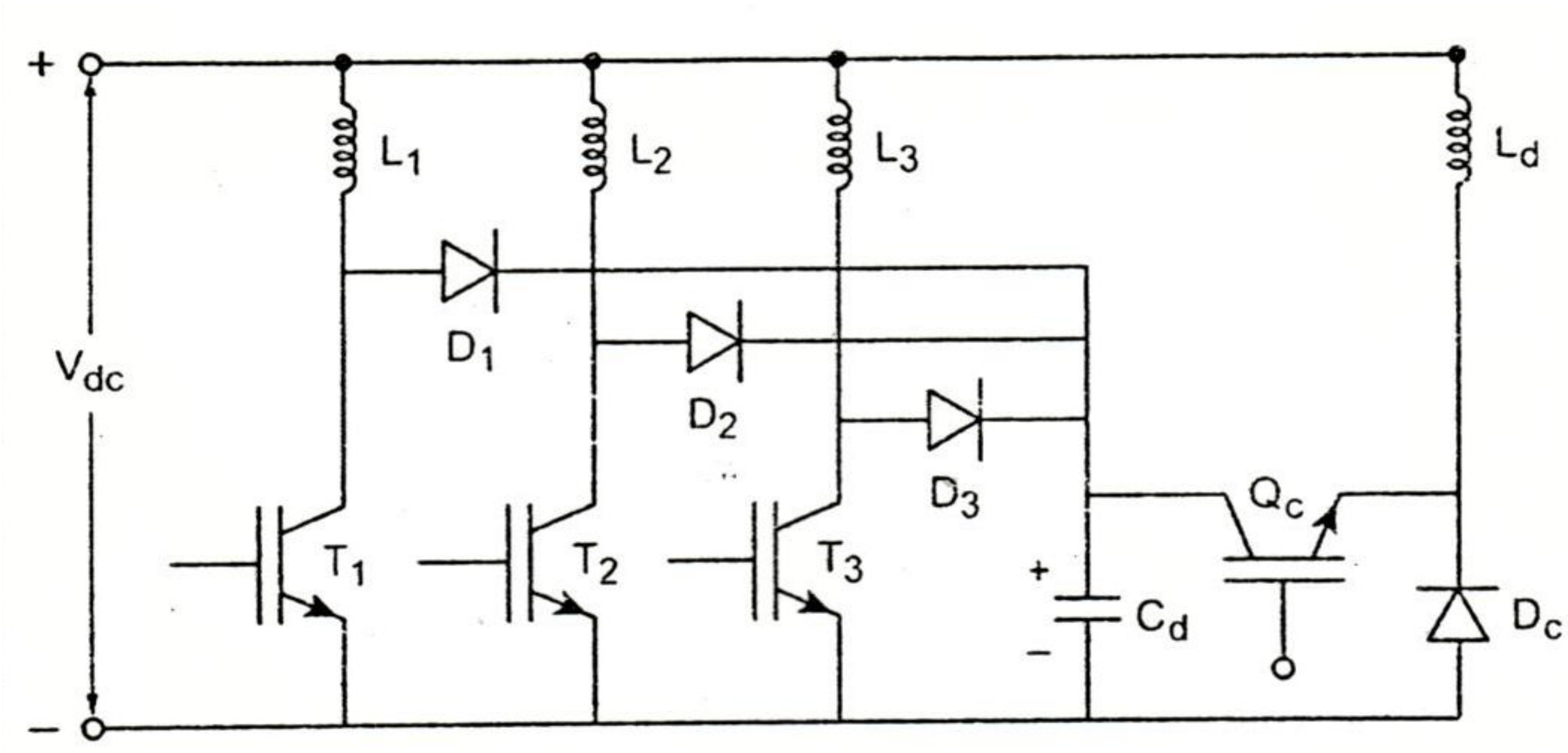
PHASE WINDING USING BIFILAR WIRES



SPLIT-LINK CIRCUIT USED WITH EVEN-PHASE NUMBER



C-DUMP CIRCUIT



TORQUE EQUATION

TORQUE PRODUCTION IN SWITCHED RELUCTANCE MOTORS:

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→ Torque is produced due to Variable reluctance principle.

The flux linkage (λ) due to excitation of winding:

$$\lambda = Li \longrightarrow (1)$$

According to Faraday's law of electromagnetic induction, emf (e) due to change in flux linkage,

$$\therefore e = (-)\frac{d\lambda}{dt} \longrightarrow (2)$$

Substituting λ from eqn (1) in (2),

$$(2) \Rightarrow \quad e = (-)\frac{\partial(Li)}{\partial t} = -L\frac{\partial i}{\partial t} - i\frac{\partial L}{\partial t}$$

Multiply (x) & Divide (÷) by $\partial\theta$ on the second term,

$$e = (-)L\frac{\partial i}{\partial t} - i\frac{\partial L}{\partial \theta} \times \left(\frac{\partial\theta}{\partial t}\right)$$

$$= -L\frac{\partial i}{\partial t} - i\frac{\partial L}{\partial\theta}(\omega) \qquad \left[\because \theta = \omega t;\ \therefore \omega = \frac{\partial\theta}{\partial t}\right]$$

$$e = (-)\left[L\frac{\partial i}{\partial t} + i\frac{\partial L}{\partial\theta}(\omega)\right] \longrightarrow (3)$$

Considering only magnitude,

$$\therefore e = L\frac{\partial i}{\partial t} + i\frac{\partial L}{\partial\theta}(\omega) \longrightarrow (4)$$

TORQUE EQUATION (CONTD…)

Energy stored in the magnetic field,

$$W_e = \frac{1}{2} L i^2 \longrightarrow (5)$$

Mechanical Power developed = Power input to motor (−) Power due to variation in stored energy

Power input to the motor $= e\,i \longrightarrow (6)$

$$= \left[L \frac{\partial i}{\partial t} + i(\omega) \frac{\partial L}{\partial \theta} \right] i$$

$$= L i \frac{\partial i}{\partial t} + i^2 \omega \frac{\partial L}{\partial \theta} \longrightarrow (7)$$

Power due to variation in stored energy $= \frac{dW_e}{dt}$

$$= \frac{d}{dt}\left[\frac{1}{2} L i^2\right]$$

$$= \frac{1}{2}\left[2 L i \frac{\partial i}{\partial t} + i^2 \frac{\partial L}{\partial t}\right]$$

$$= \frac{1}{2}\left[2 L i \frac{\partial i}{\partial t}\right] + \frac{1}{2}\left[i^2 \frac{\partial L}{\partial t}\right]$$

$$= L i \frac{\partial i}{\partial t} + \frac{i^2}{2} \frac{\partial L}{\partial t}$$

TORQUE EQUATION (CONTD…)

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$$= Li\frac{\partial i}{\partial t} + \frac{i^2}{2}\frac{\partial L}{\partial \theta}\left(\frac{\partial \theta}{\partial t}\right)$$

$$= Li\frac{\partial i}{\partial t} + \frac{i^2}{2}(\omega)\frac{\partial L}{\partial \theta} \longrightarrow (8)$$

Subtracting (8) from (7),

(7) − (8) ⇒

Mechanical Power developed $= P_m = \cancel{Li\frac{\partial i}{\partial t}} + i^2\omega\frac{\partial L}{\partial \theta}$

$$- \cancel{Li\frac{\partial i}{\partial t}} - \frac{i^2}{2}(\omega)\frac{\partial L}{\partial \theta}$$

$$\therefore P_m = \frac{1}{2}\left[i^2\omega\frac{\partial L}{\partial \theta}\right] \longrightarrow (9)$$

In general,

$$P_m = \frac{2\pi NT}{60} = \left[\frac{2\pi N}{60}\right]T = \omega T$$

$$\therefore P_m = \omega T \longrightarrow (10)$$

where,
$\omega \rightarrow$ angular velocity,
$T \rightarrow$ Electromagnetic torque developed.

From (10) ⇒

$$T = \frac{P_m}{\omega} \longrightarrow (11)$$

Substituting (9) in (11),

$$T = \frac{\frac{1}{2}\left(i^2\cancel{\omega}\frac{\partial L}{\partial \theta}\right)}{\cancel{\omega}}$$

$$\therefore \boxed{T = \frac{1}{2}\left[i^2\frac{\partial L}{\partial \theta}\right]} \longrightarrow (12)$$

TORQUE EQUATION (CONTD…)

Torque corresponds to motoring,

when $\frac{\partial L}{\partial \theta}$ is +ve.

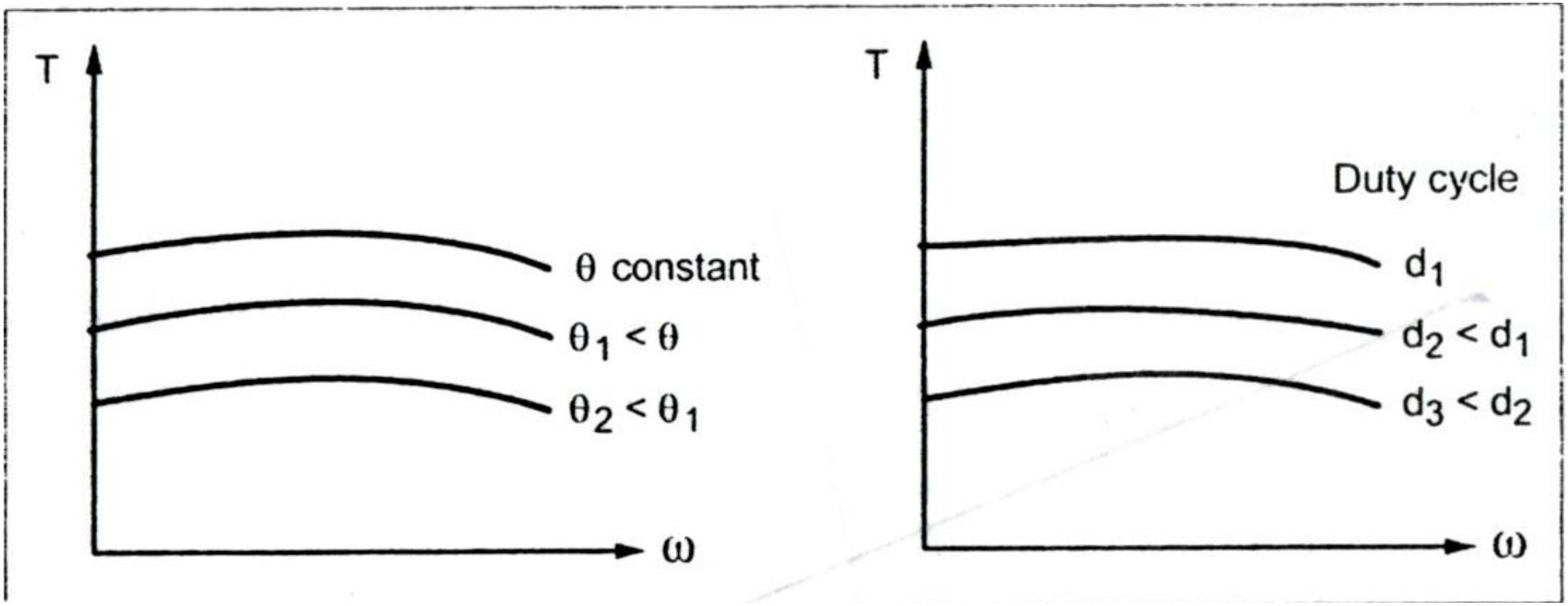
Torque corresponds to generating

when $\frac{\partial L}{\partial \theta}$ is −ve.

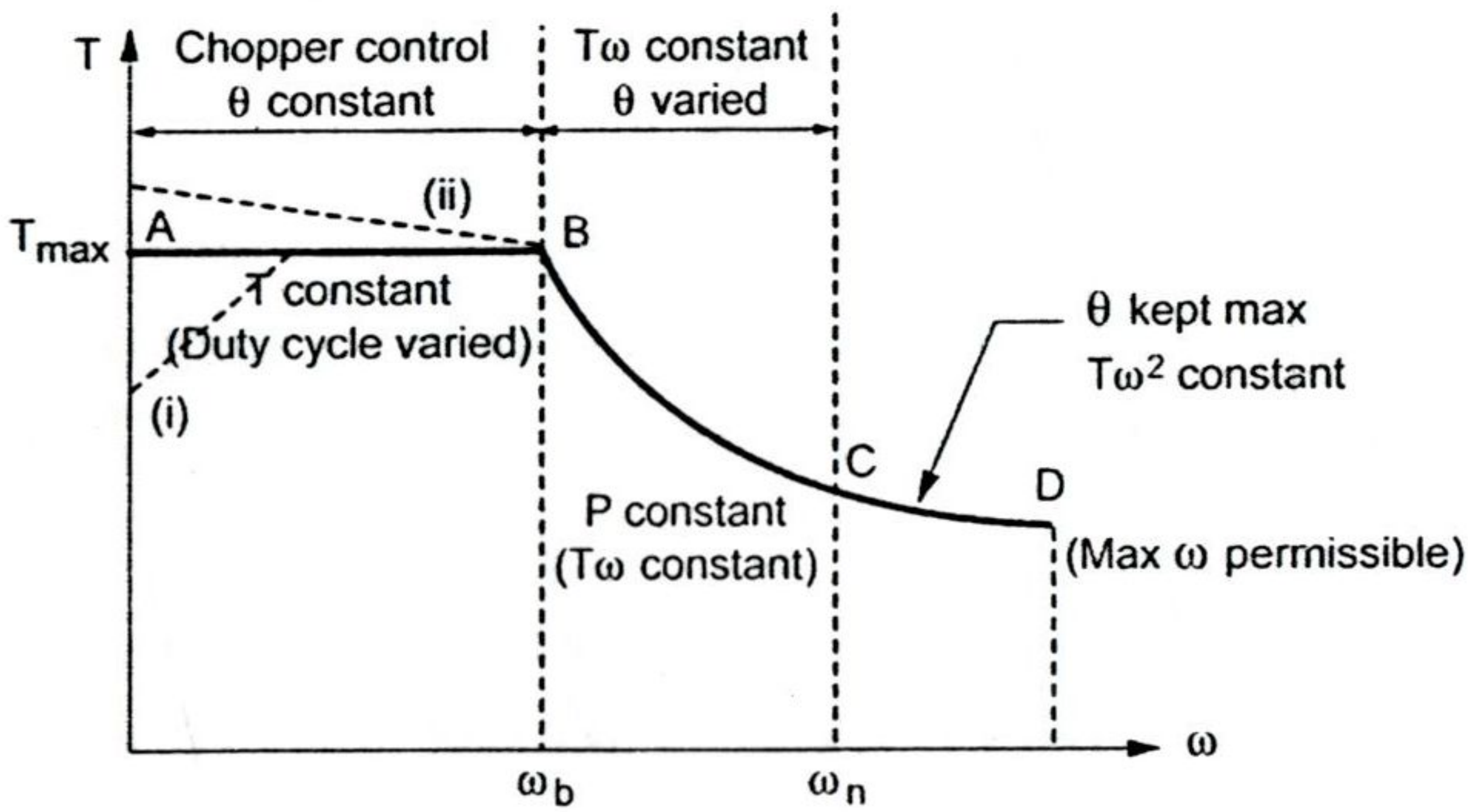
As, $\underline{\underline{T \propto i^2}}$, it is independent of direction of current.

* If there is magnetic saturation equation (12) is invalid & the torque should be derived as the derivative of co-energy or field stored energy.

TORQUE-SPEED CHARACTERISTICS



TORQUE SPEED CAPABILITY CURVE



ROTOR POSITION SENSING

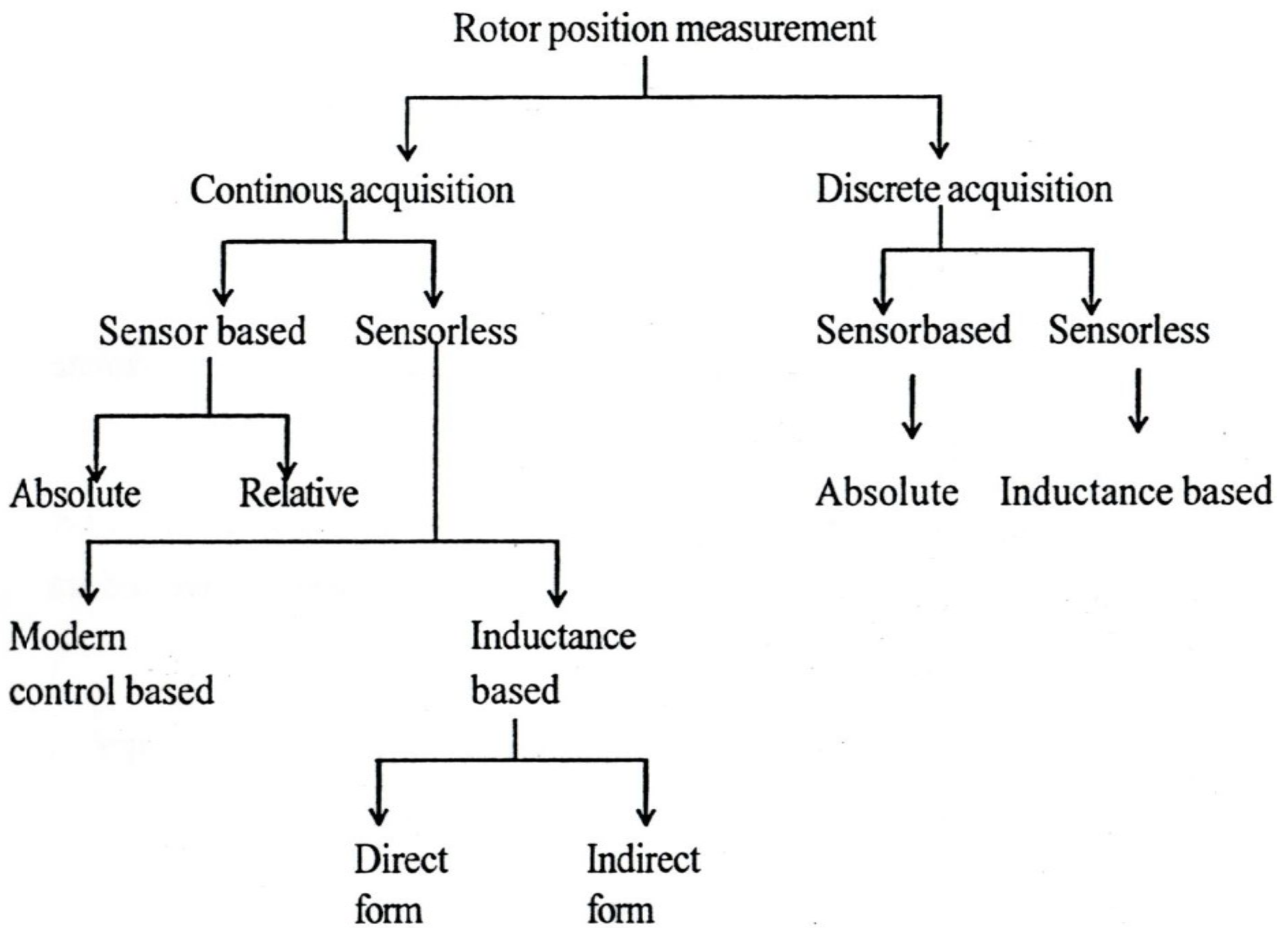
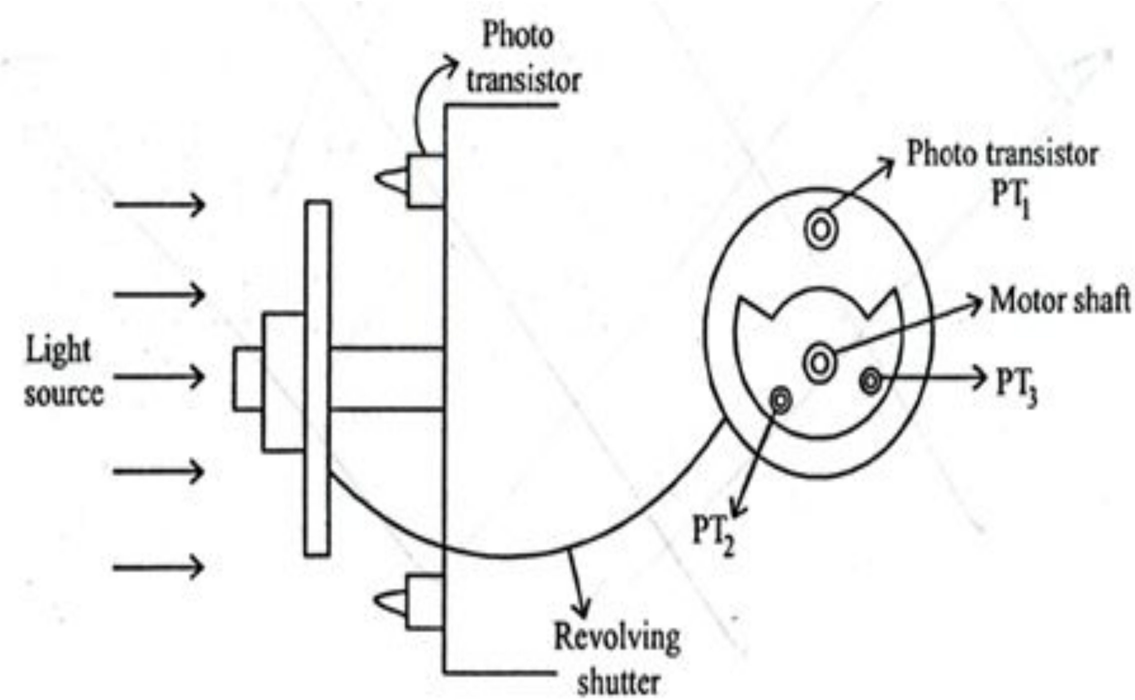
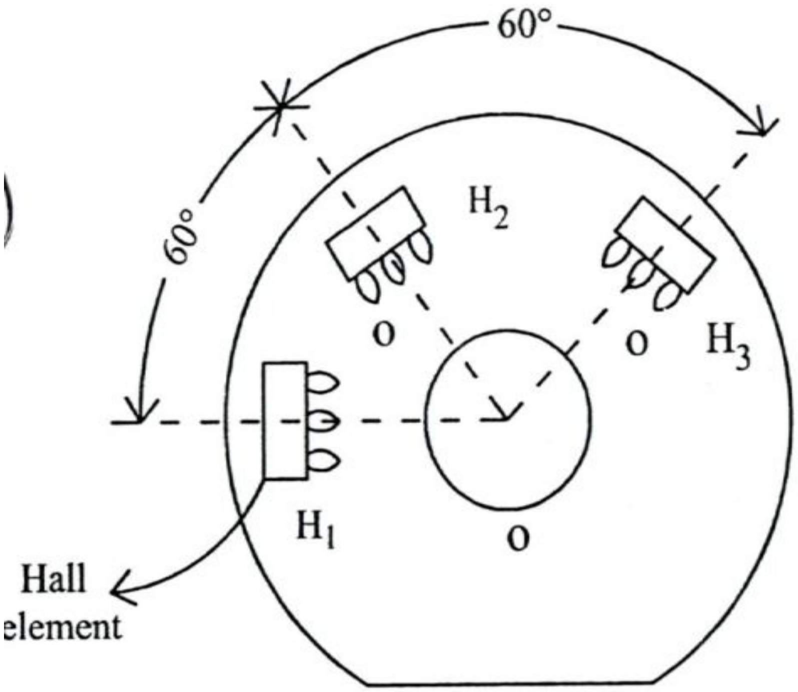


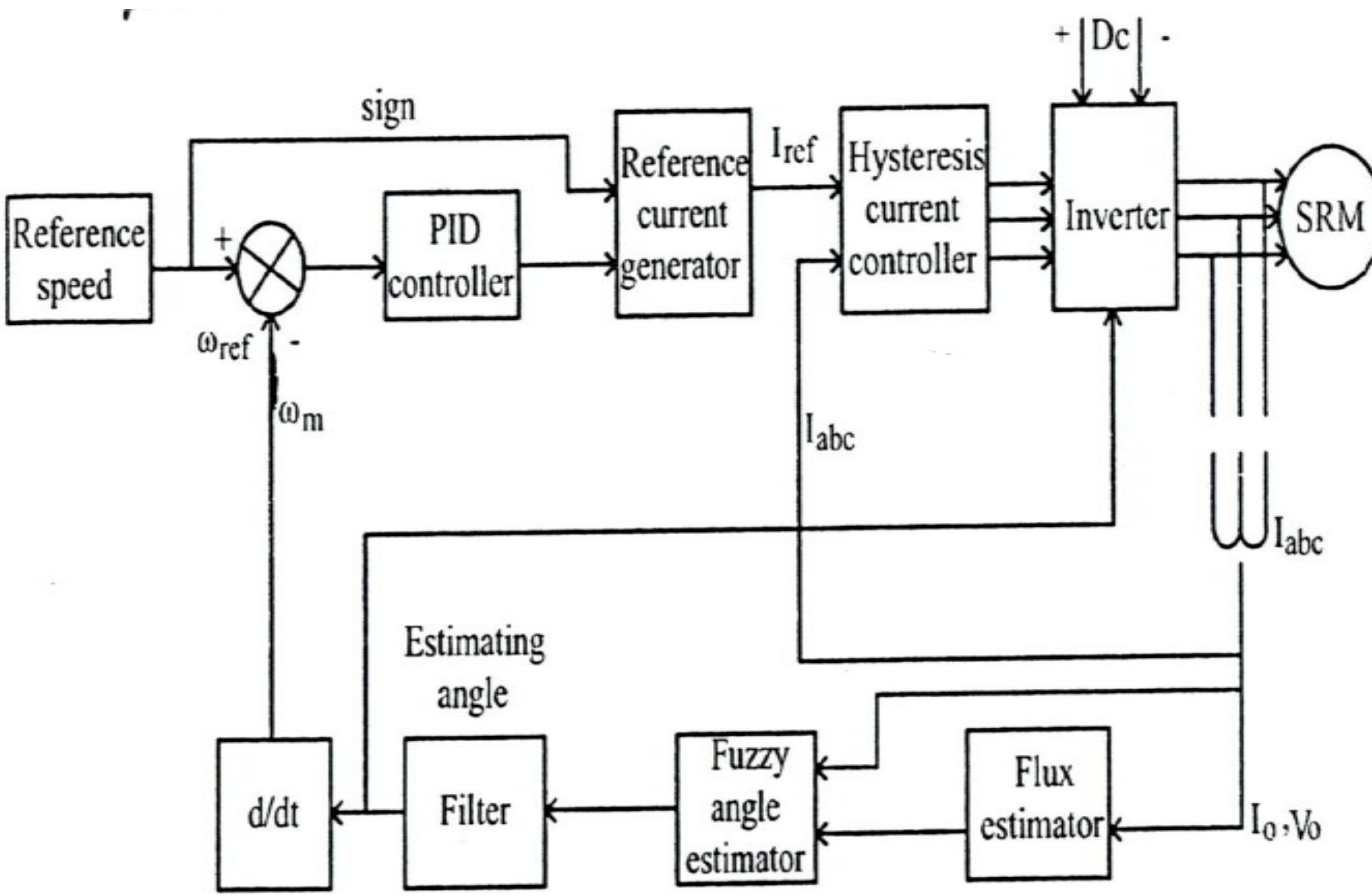
PHOTO TRANSISTOR SENSOR



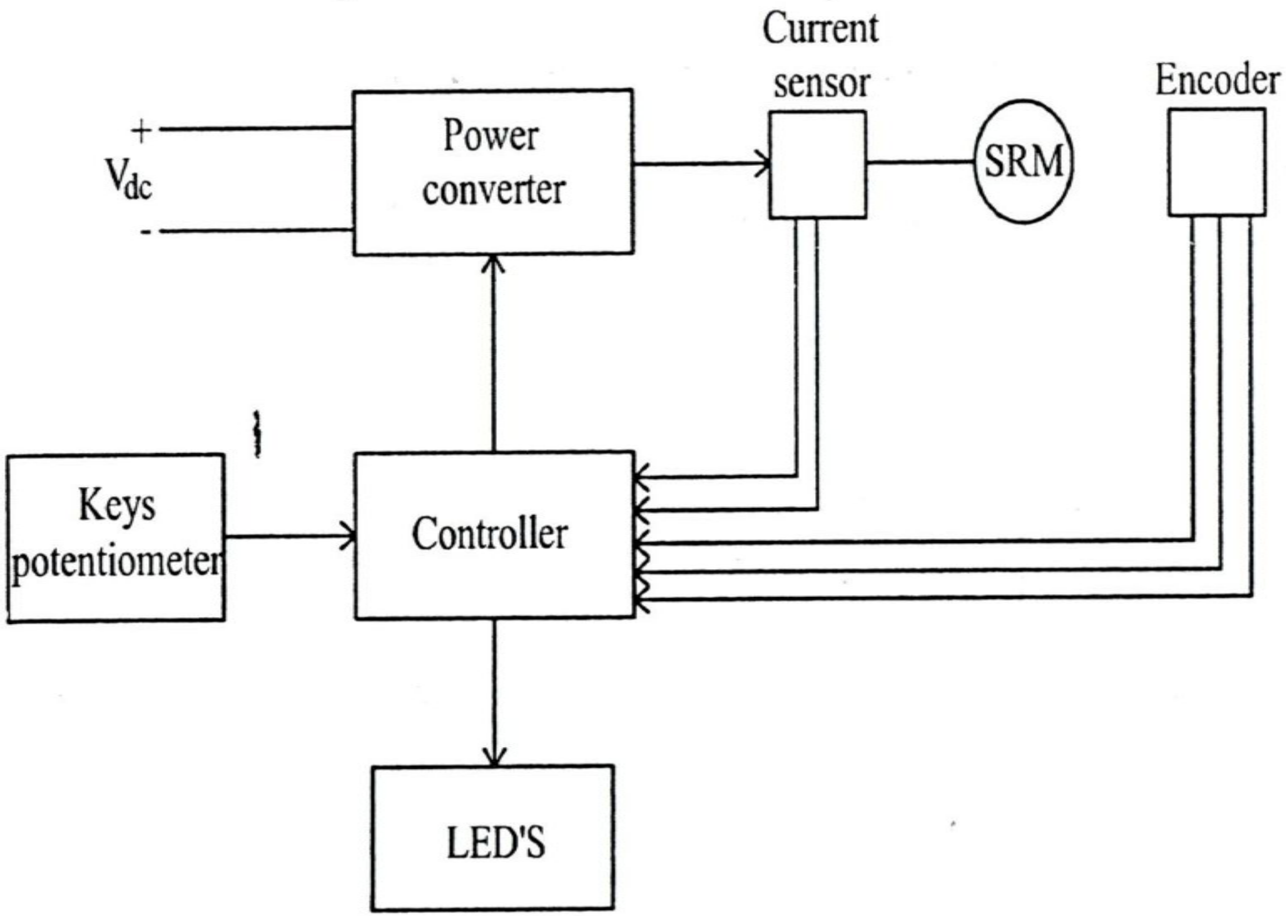
HAL EFFECT SENSOR



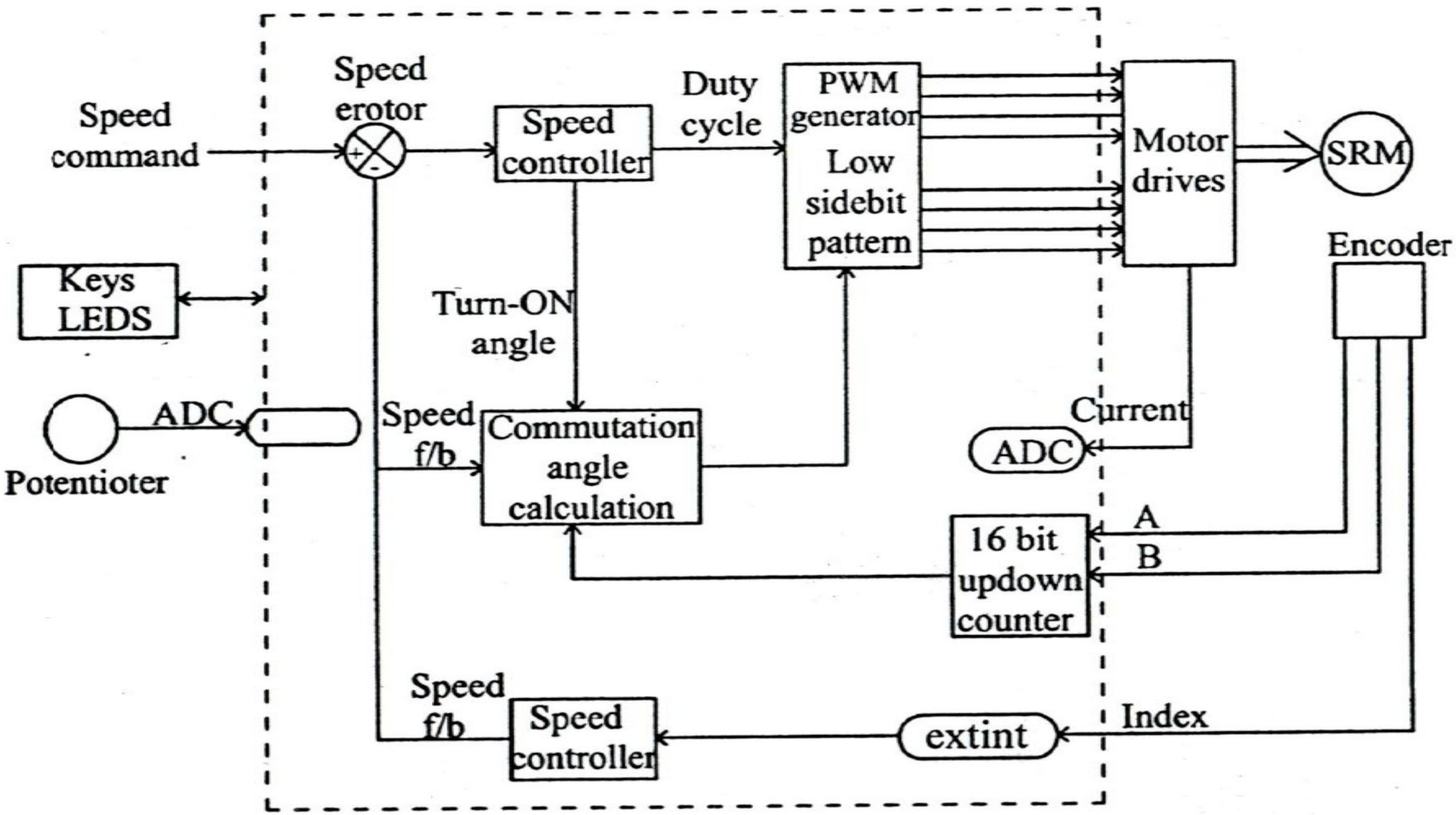
SENSORLESS CONTROL



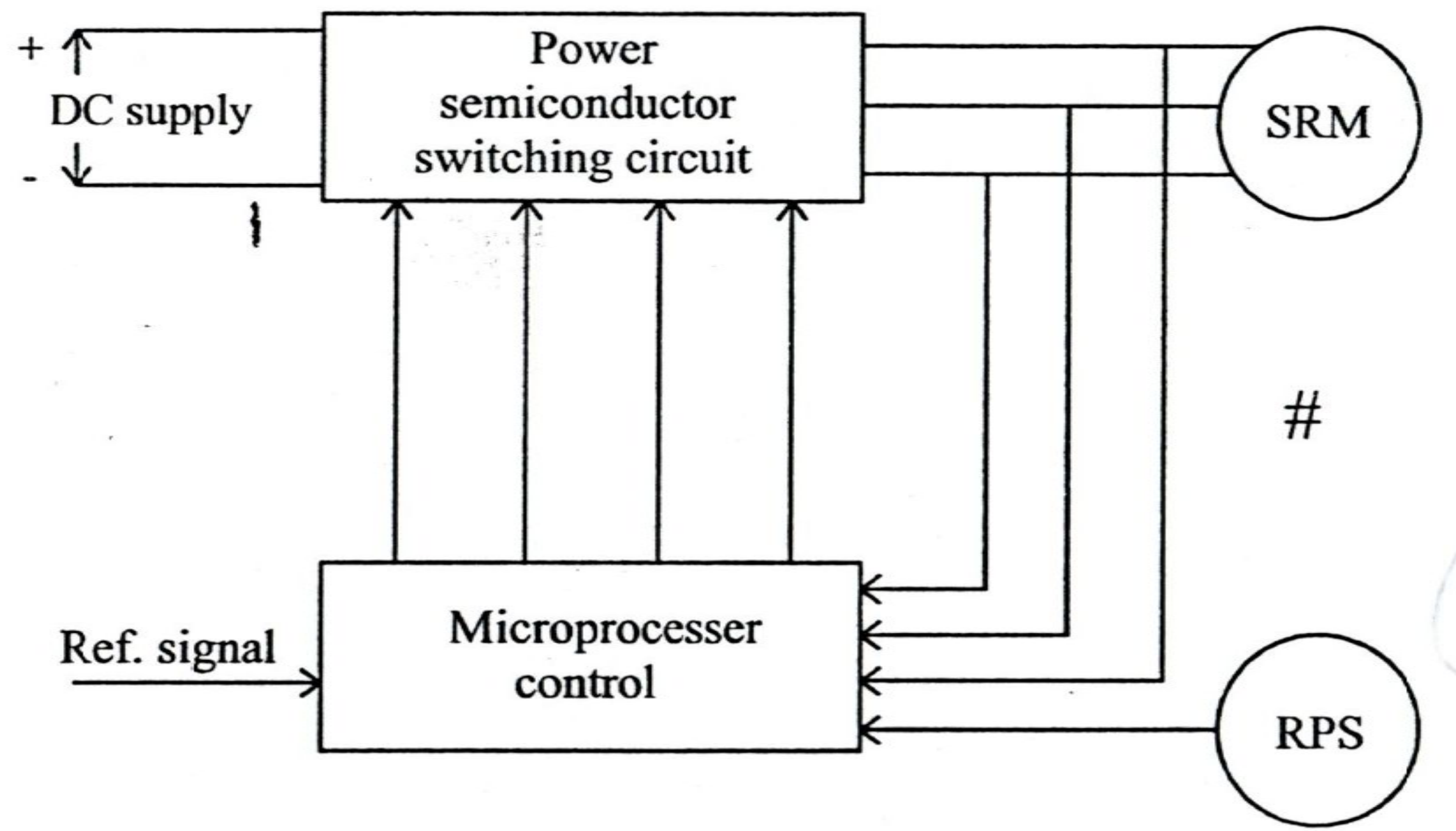
CLOSED LOOP CONTROL



CLOSED LOOP CONTROL



MICROPROCESSOR CONTROL



MERITS OF SRM

- Construction is simple and robust, as there is no brush.
- Rotor carries no windings, no slip rings and brush-less maintenance.
- No permanent magnet, neither in the stator nor in the rotor.
- Ventilating system is simpler as losses takes place mostly in stator.
- Power semiconductor switching circuitry is simpler.
- No shoot-through fault is likely to happen in power semiconductor circuits.
- Torque developed does not depend upon the polarity of the current

DE-MERITS OF SRM

- Stator phase winding should be capable of carrying the magnetizing current also, for setting up the flux in the air gap.
- For high speed operations, the developed torque has undesirable ripples. As a result it develops undesirable acoustic losses (noise).
- For high speeds, current waveform also has undesirable harmonics. To suppress this effect
- large size capacitor is to be connected.
- The air gap at the aligned axis should be very small while the air gap at the inter-polar axis should be very large. It is difficult to achieve. No standardized practice is available.
- The size of the motor is comparable with the size of variable speed induction motor drive.

APPLICATIONS OF SRM

- Washing machines
- Vacuum cleaners
- Fans
- Future automobile applications
- Robotic control applications