UNIT-V

LINEAR INDUCTION MOTOR
&
LINEAR SYNCHRONOUS MOTOR

UNIT-V

Contents:

Linear Induction Motor (LIM)

- Construction
- Equivalent Circuit
- Steps in Design

Linear Synchronous Motor (LSM)

- Principle of Operation
- Types of LSM
- Control of LSM
- Applications

INTRODUCTION:

- Recently linear electric motors have gained considerable attention in applications requiring linear motion such as
  - robotic assembly systems
  - transportation systems and
  - laser cutting

- The electromagnetic thrust developed by the motor can be directly applied to the payloads without any mechanical transmission or conversion, that usually imposes mechanical limitations on linear velocity.

- Systems incorporating linear motors can be operated with higher velocity and acceleration.

- Linear motor drive systems have the additional advantages such as
  - less friction
  - no backlash
  - low mechanical maintenance and
  - long life.

INTRODUCTION: (Contd…)

- Basically, linear machines can be classified into three groups:

  power motors,
  energy motors and
  force motors

This classification is based on the applications for which they are used.

- In transportation systems like traction, cranes, conveyers and so on **power motors** are used. They are characterized by high power efficiency.

- In applications like aircraft, missile launchers and others, it is essential to have high acceleration from low to high speed in short time and short distance. The motors used for such applications are called **energy motors**. Their energy efficiency should be high.

INTRODUCTION: (Contd…)

- The applications like door closers, impact metal forming, stop valves and others require high force at rest or low speeds during short intervals. The motors used for providing thrust for these types of applications are called **force machines**.

- The **advantages** of linear motors compared to rotating motors are summarized as follows:
  - Simple construction
  - Low maintenance cost.
  - Overheating of stationary part is eliminated.
  - Unlimited maximum speed as the centrifugal force is absent.
  - Tractive effort is independent of speed.
  - Higher power to weight ratio.

- Linear motors have comparatively fewer **disadvantages** like,
  - high capital cost for reaction rail
  - less power factor and attractive force between primary and secondary.

Linear Induction Motor:

- Linear induction motor (LIM) is a special induction motor which gives linear motion instead of rotational motion provided by a conventional rotating induction motor.
- LIM has an open air gap with an entry end and an exit end.
- The magnetic field produced by the current–carrying conductors in an LIM is rectilinear and develops electromagnetic force along the direction of travelling magnetic field.

sample video to understand lim

Construction of Linear Induction Motors:

LIMs can be classified as **axial field motors** and **transverse field motors**.

Axial field motors

- Axial flux LIMs are directly derived from a traditional rotating squirrel cage induction motor.
- An elementary LIM can be obtained by cutting an ordinary induction motor axially and 'opening out' as shown in Fig. 8.1.
- This figure shows a typical flat linear induction motor.

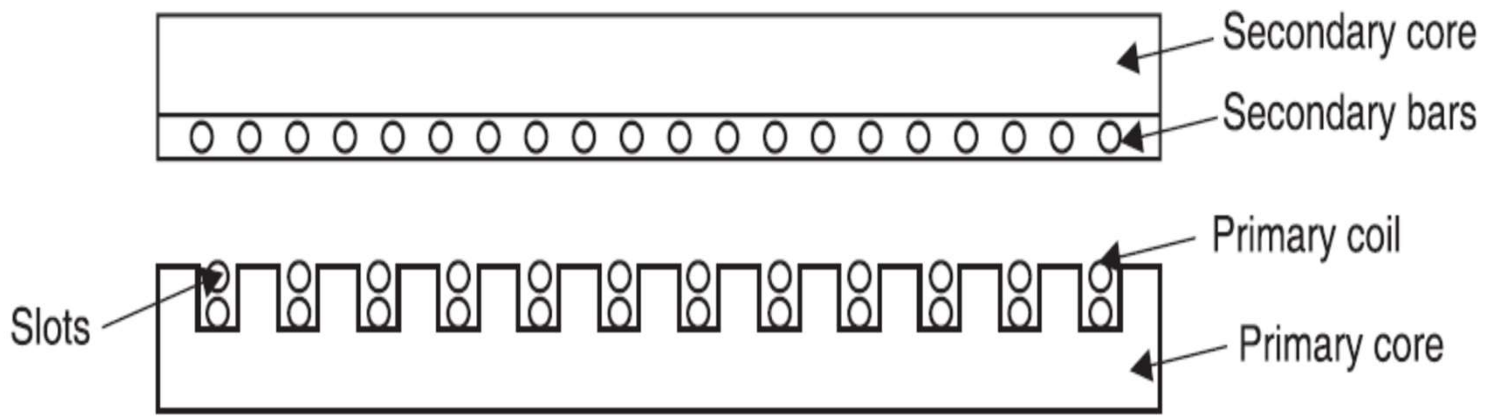


Fig. 8.1 Elementary linear induction motor

Construction of Linear Induction Motors: (Contd…)

Axial field motors (Contd…)

- In LIM,

  the part which carries windings and produces the magnetic field (corresponding to the stator of conventional motor) is called **primary**.

  and

  the part which carries current that interacts with flux to produce force (corresponding to the rotor of ordinary motor) in the axial direction is called **secondary**.

- The primary three-phase voltage develops a travelling wave flux.

- This flux induces emf in the secondary and a current flows through the secondary winding as it is closed.

- Due to the interaction of flux and current, a force is produced axially. The travelling flux, secondary current and force are mutually perpendicular to each other at all points, as shown in Fig. 8.2.

Construction of Linear Induction Motors: (Contd…)

***Axial field motors* (Contd…)**

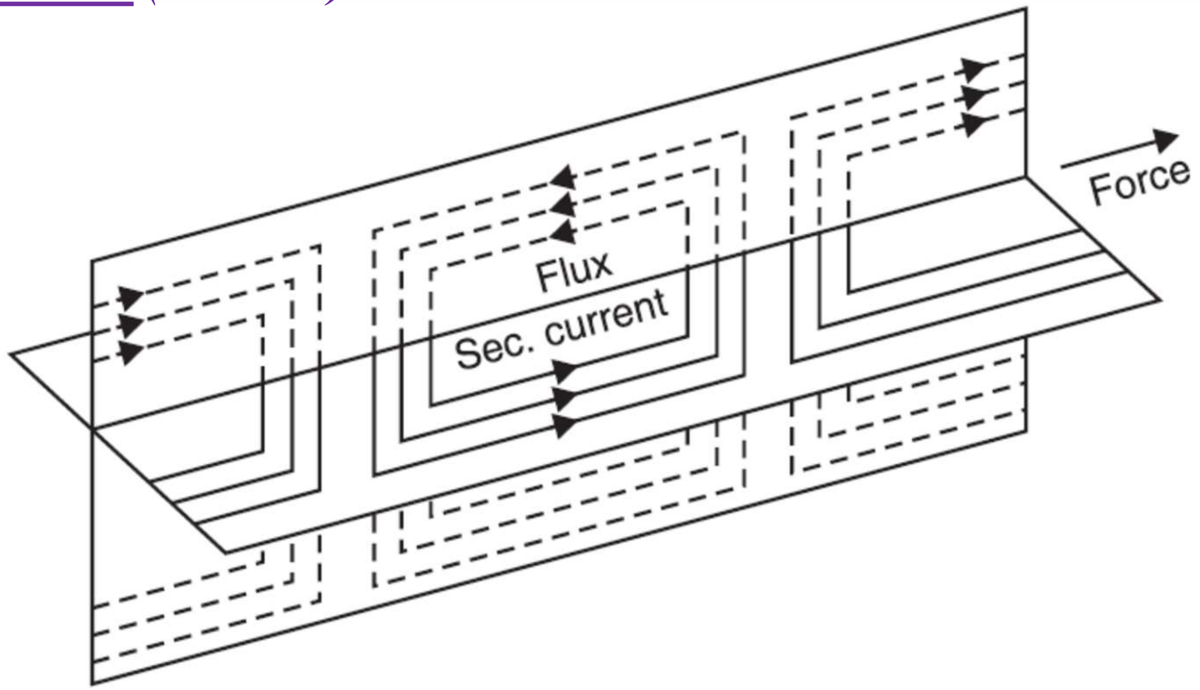


Fig. 8.2 Direction of secondary current, flux and force in axial field LIM

- Axial flux motor can be used only for low- and medium-speed applications.

Construction of Linear Induction Motors: (Contd…)

***Axial field motors** (Contd…)*

- Axial flux LIMs are of two types—
  flat LIM and
  tubular LIM.

- Flat linear induction motors are again classified into four types:
  short primary type
  short secondary type
  coreless secondary type and
  double primary type

- The constructional details of these types of LIMs are shown in Fig. 8.3.

Construction of Linear Induction Motors: (Contd…)

Axial field motors (Contd…)

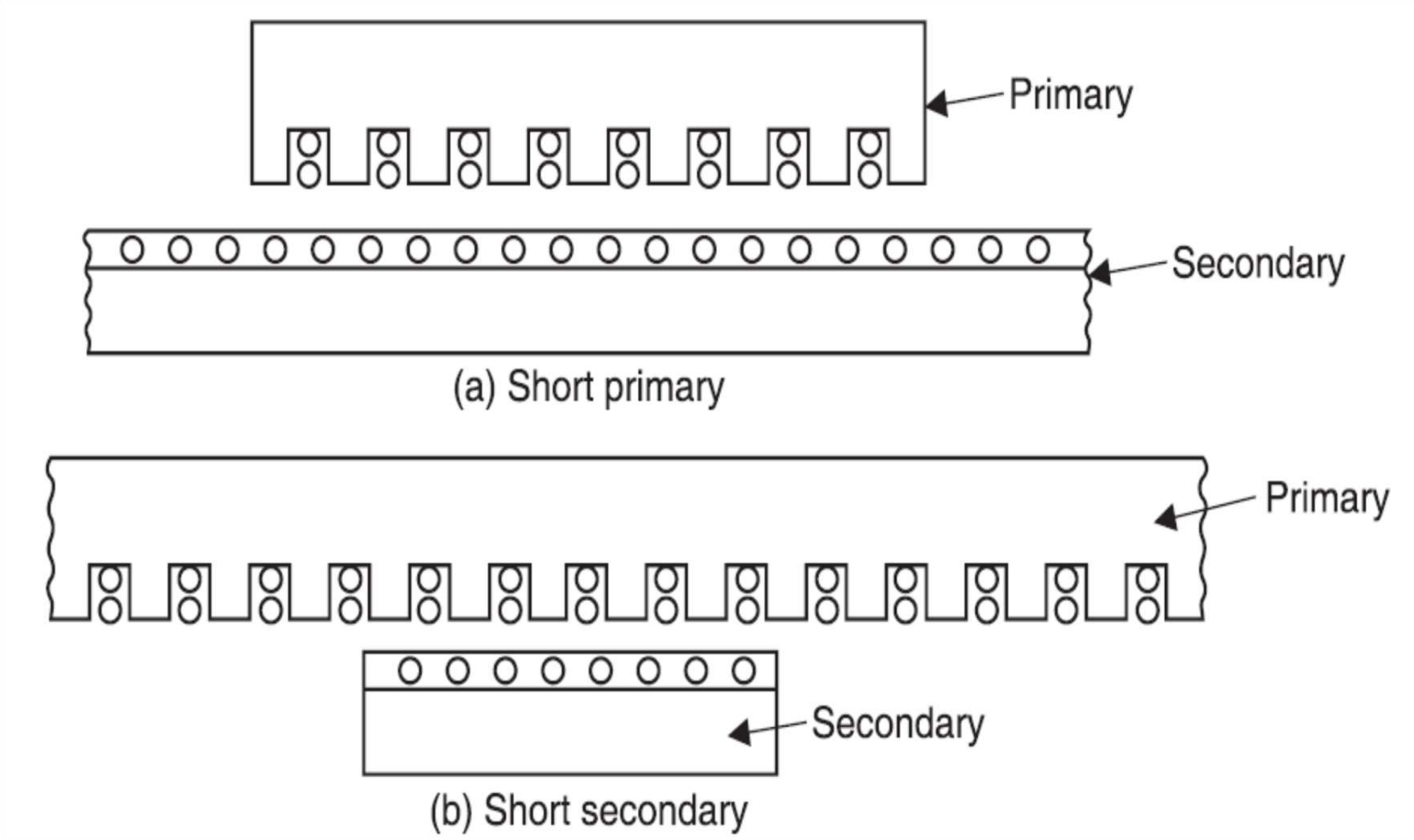


Fig. 8.3 Flat linear induction motors

Construction of Linear Induction Motors: (Contd…)

Axial field motors (Contd…)

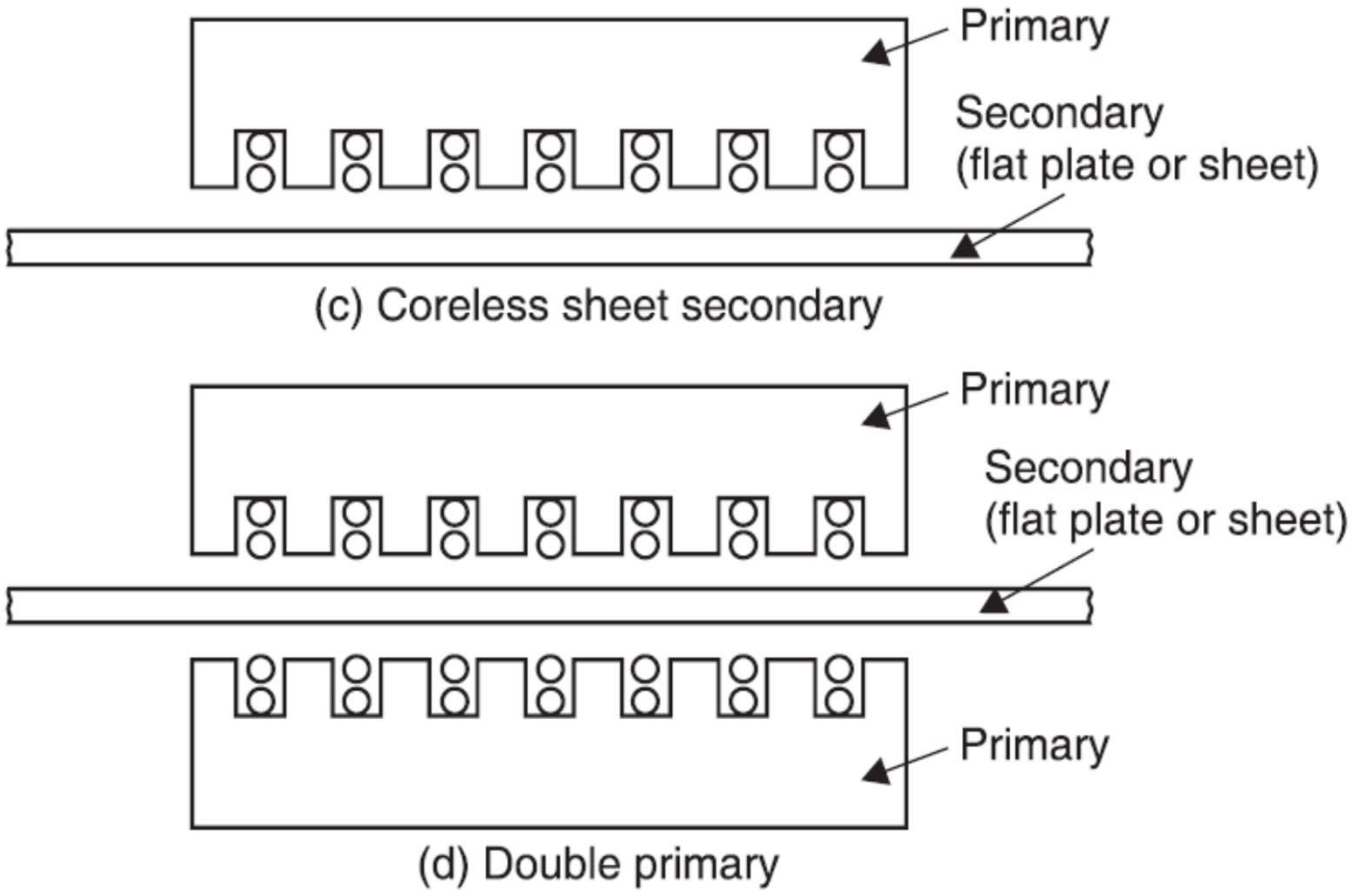


Fig. 8.3 Flat linear induction motors

Construction of Linear Induction Motors: (Contd…)

Axial field motors (Contd…)

- In another type of LIM, the primary is on one side and the secondary is placed on a laminated iron bed on the other side, as shown in Fig. 8.4.

- For simplicity in construction, the laminated iron can be replaced by a solid iron plate as shown in Fig. 8.5.

- The current induced in the iron, in addition to the current induced in the aluminum or copper plate secondary, gives additional propulsive force.

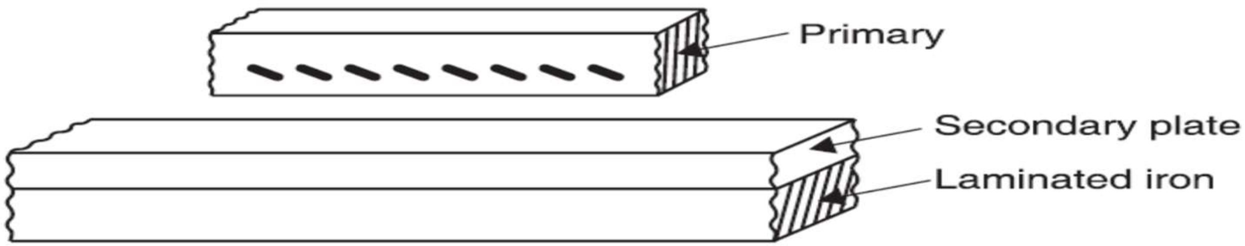


Fig. 8.4 LIM with secondary plate placed on laminated iron bed

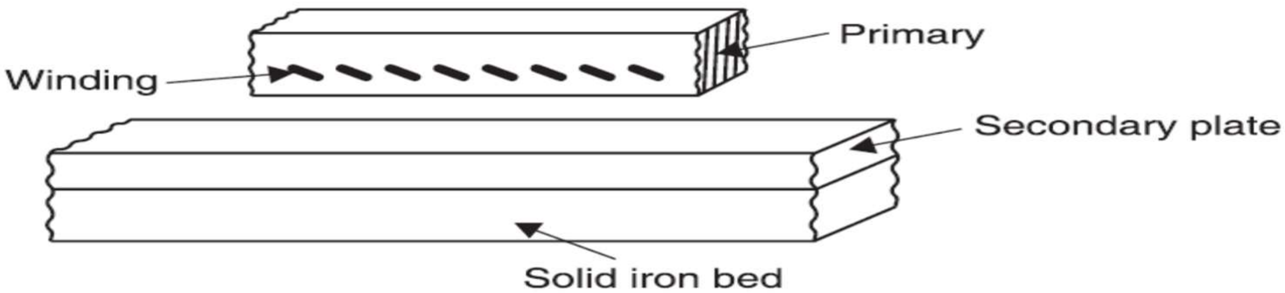


Fig. 8.5 LIM with laminated back iron replaced by solid iron

<u>Construction of Linear Induction Motors</u>: **(Contd…)**

<u>Axial field motors</u> (Contd…)

- By cutting a conventional rotating induction motor axially and re-rolling along a lengthwise axis, an elementary <u>tubular linear induction motor</u> can be realized.

- It is shown in Fig. 8.6. An axially travelling magnetic field is produced within the tube when the primary winding is energized by three-phase supply.

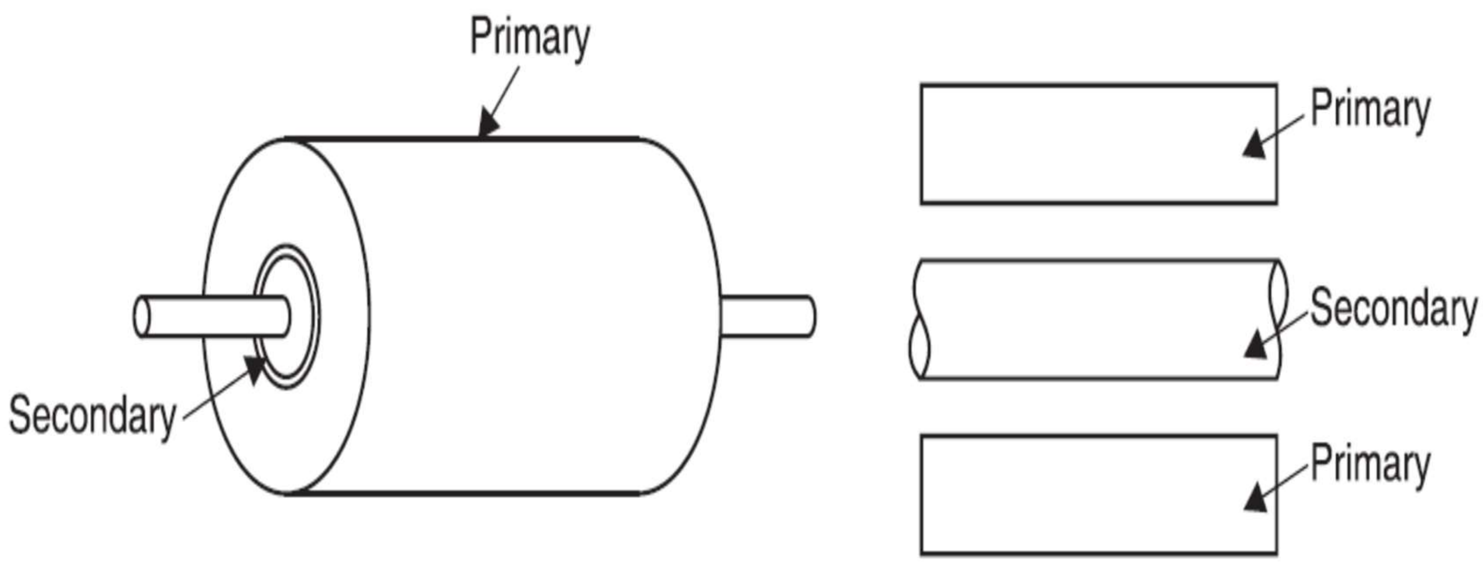


Fig. 8.6 Tubular LIM

Construction of Linear Induction Motors: (Contd…)

Transverse flux linear induction motor (TLIM) :

- Transverse field linear induction motors are used for high-speed applications.
- In axial flux motor, there is a limitation on pole pitch. But in TLIM, there is no restriction on pole pitch as no flux has to be conveyed axially, as shown in Fig. 8.7.

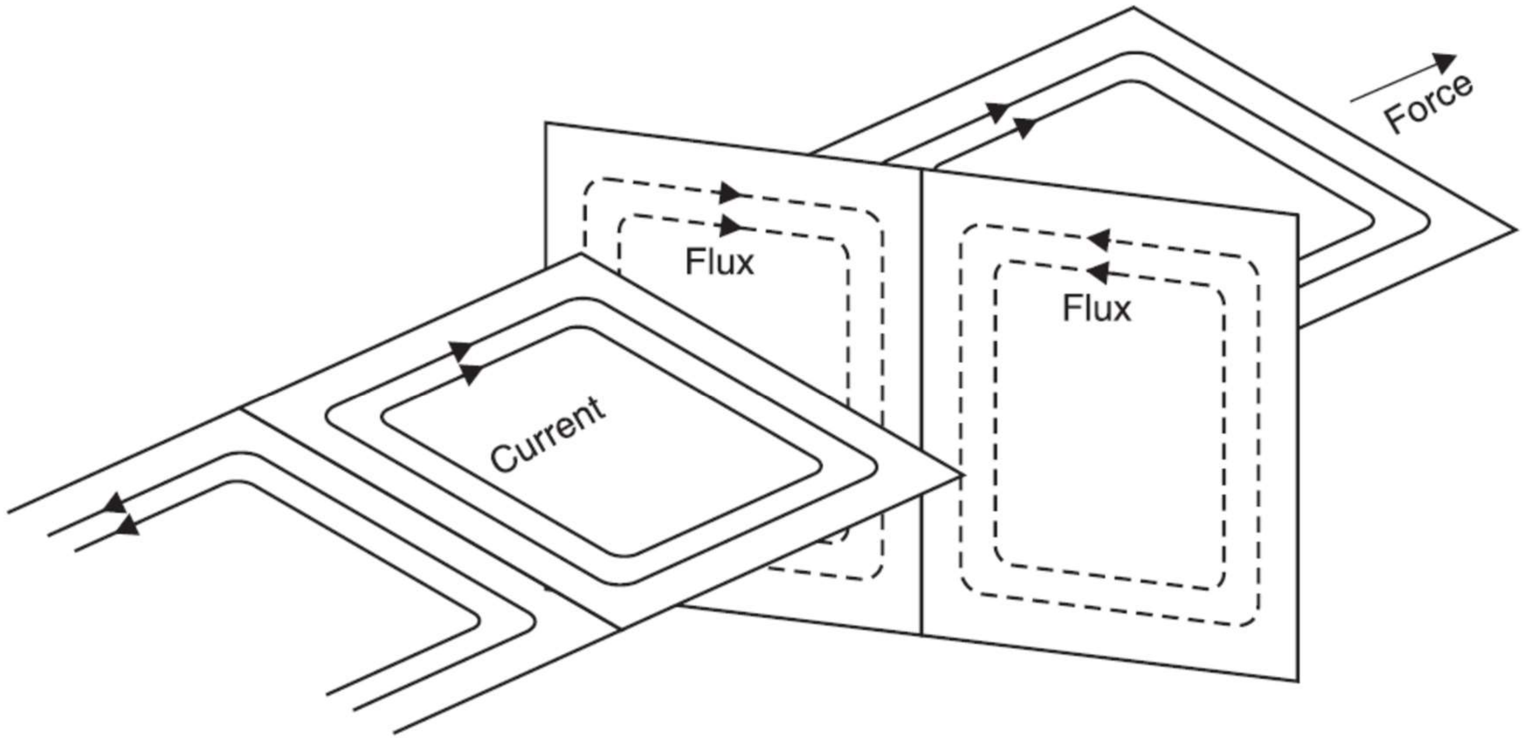


Fig. 8.7 Direction of current, flux and force in transverse LIM

Construction of Linear Induction Motors: (Contd…)

Transverse flux LIM : (Contd…)

The elementary realizations of TLIMs are shown in Fig. 8.8. Individual phase cores and windings are assembled in line.

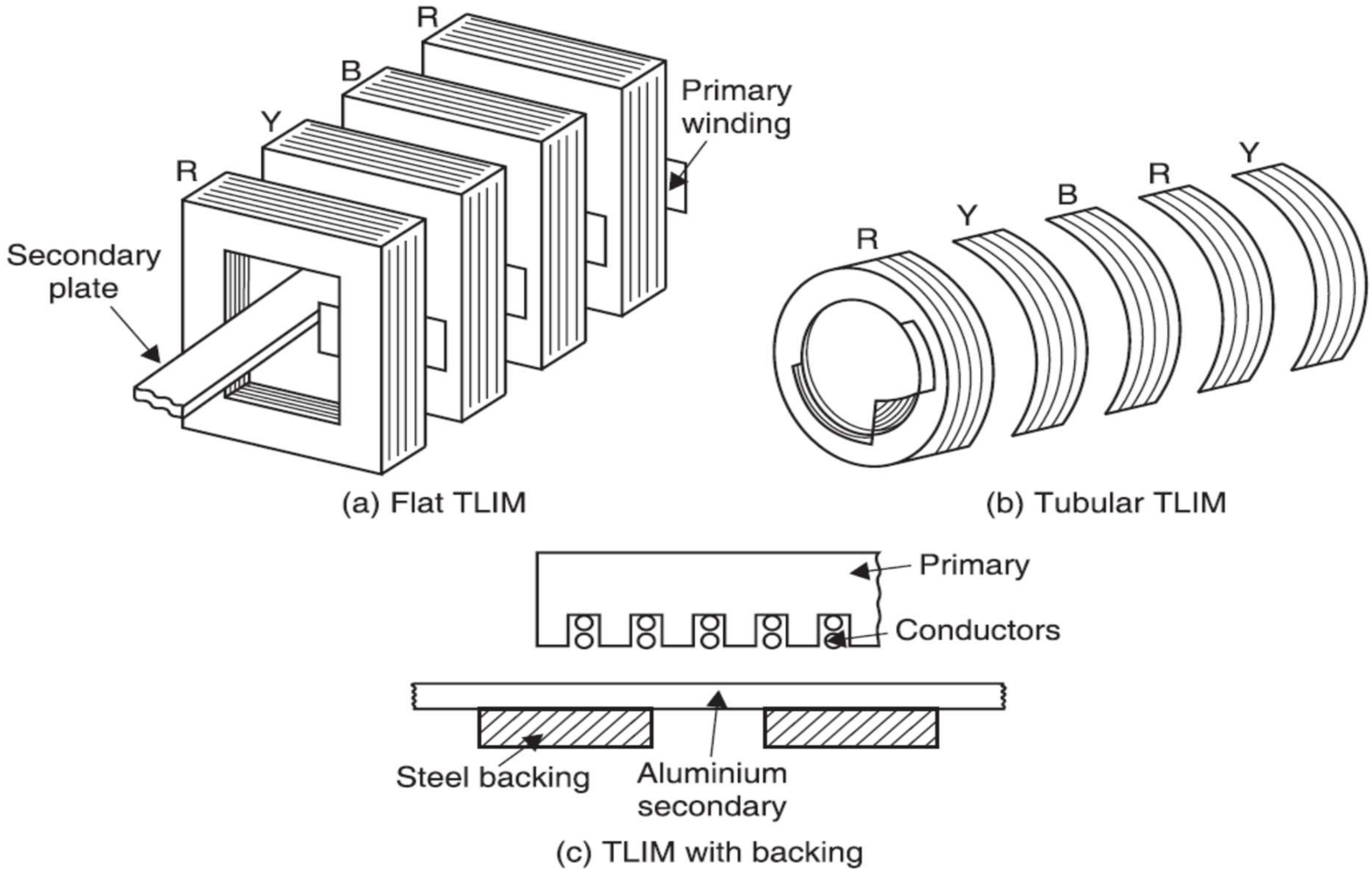


Fig. 8.8 Transverse flux LIMs

Construction of Linear Induction Motors: (Contd…)

Transverse flux LIM : (Contd…)

- The secondary is provided with steel backing to reduce the reluctance of the magnetic circuit.
- These arrangements have single slot per pole per phase and successive cores must be separated by a minimum distance to avoid the axial thrust produced by the strong axial flux distribution.
- Thus, the secondary current induced by one core interacts less effectively with the flux of the other.

Construction of Linear Induction Motors: (Contd…)

Transverse flux LIM : (Contd…)

Another type of construction is shown in Fig. 8.9.

This type of TLIM has more lateral stability.

To increase the pole pitch and hence to reduce the harmonic content of air gap flux, successive cores are interlinked as shown in Fig. 8.9.

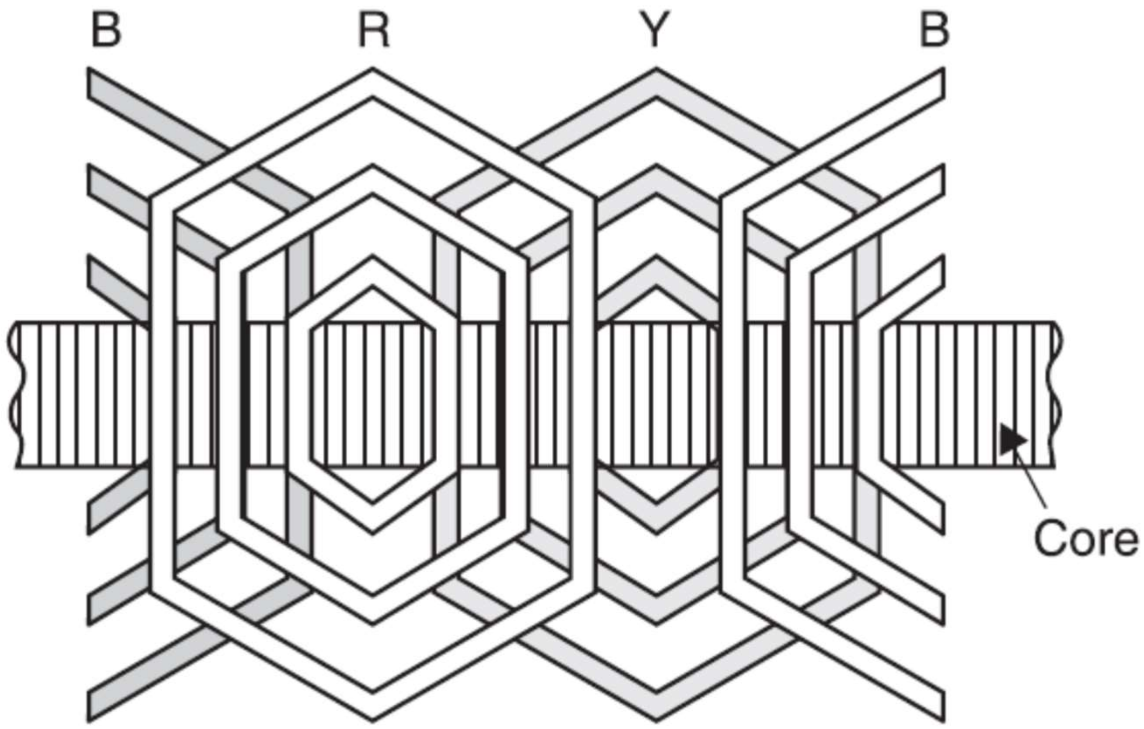


Fig. 8.9 TLIM with core interlinking

Thrust Equation of LIM:

Let

f = frequency of supply voltage, Hz

τ = pole pitch, m

V_s = synchronous speed, m/s

V = actual speed of runner, m/s

S = slip

E_1 = emf induced in the primary per phase, volts

I_1 = primary current, A (per phase)

P_g = gross power developed,

p_m = mechanical power developed

ϕ = power factor angle of primary

Φ_m = maximum flux density in the air gap, Wb

Thrust Equation of LIM: (Contd…)

T_{ph} = turns/phase

ac = specific electric loading

B_{av} = specific magnetic loading

L = length of the field system (primary core) along the direction of motion, m

P = number of poles

W = width of the field system, m

K_w = winding factor

The linear synchronous speed of the travelling wave,

$$V_s = 2\tau f \text{ m/s}$$

$$\text{Slip, } S = \frac{V_s - V}{V_s}$$

Thrust Equation of LIM: (Contd…)

Neglecting magnetic losses and primary copper loss, the gross power developed is

$$P_g = 3E_1 I_1 \cos\phi \tag{8.1}$$

The emf induced in the primary is given by

$$E_1 = \sqrt{2}\,\pi f K_w T_{\text{ph}} \Phi_m \tag{8.2}$$

Specific electric loading is given by

$$ac = \frac{3 \times 2T_{\text{ph}} \times I_1}{L}$$

$$\therefore \qquad I_1 = \frac{ac \times L}{3 \times 2 \times T_{\text{ph}}} \tag{8.3}$$

Also,

$$L = P\tau$$

Thrust Equation of LIM: (Contd…)

Specific magnetic loading,

$$B_{av} = \frac{P\phi_m}{L \times W}$$

$$\therefore \qquad P\Phi_m = B_{av} \times L \times W$$

Substituting the values of E_1 and I_1 from Eqs. (8.2) and (8.3) into Eq. (8.1), we get

$$P_g = 3(\sqrt{2}\pi\, K_w T_{ph}\, \Phi_m f) I_1 \cos\phi$$

$$P_g = 3\left(\sqrt{2}\pi\, K_w T_{ph} \frac{B_{av} LW}{P} \cdot \frac{V_s}{2\tau}\right)\left(\frac{acL}{6T_{ph}}\right)\cos\phi$$

$$\text{i.e.} \qquad P_g = \frac{\pi}{2\sqrt{2}} K_w LW\, V_s B_{av}\, ac \cos\phi \qquad (\because \quad L = P\tau) \qquad (8.4)$$

Thrust Equation of LIM: (Contd…)

The thrust of linear force developed is given by

$$F = \eta\left(\frac{P_g}{V_s}\right)$$

where η is efficiency.

$$\therefore \quad F = \eta\left(\frac{\pi}{2\sqrt{2}} LWK_w \frac{T_{ph} V_s B_{av}}{V_s} ac \cos\phi\right)$$

$$= \eta \frac{\pi}{2\sqrt{2}} LWK_w T_{ph} B_{av} ac \cos\phi$$

$$\therefore \quad \boxed{F = 1.11\, \eta\, LWK_w\, T_{ph}\, B_{av}\, ac \cos\phi} \qquad (8.5)$$

- In an LIM, there are two effects which are not seen in conventional induction motor, these effects increase the losses. They are ***transverse edge effect*** and ***end effect***.

- For explaining these two peculiar effects, consider the LIM shown in Fig. 8.10.

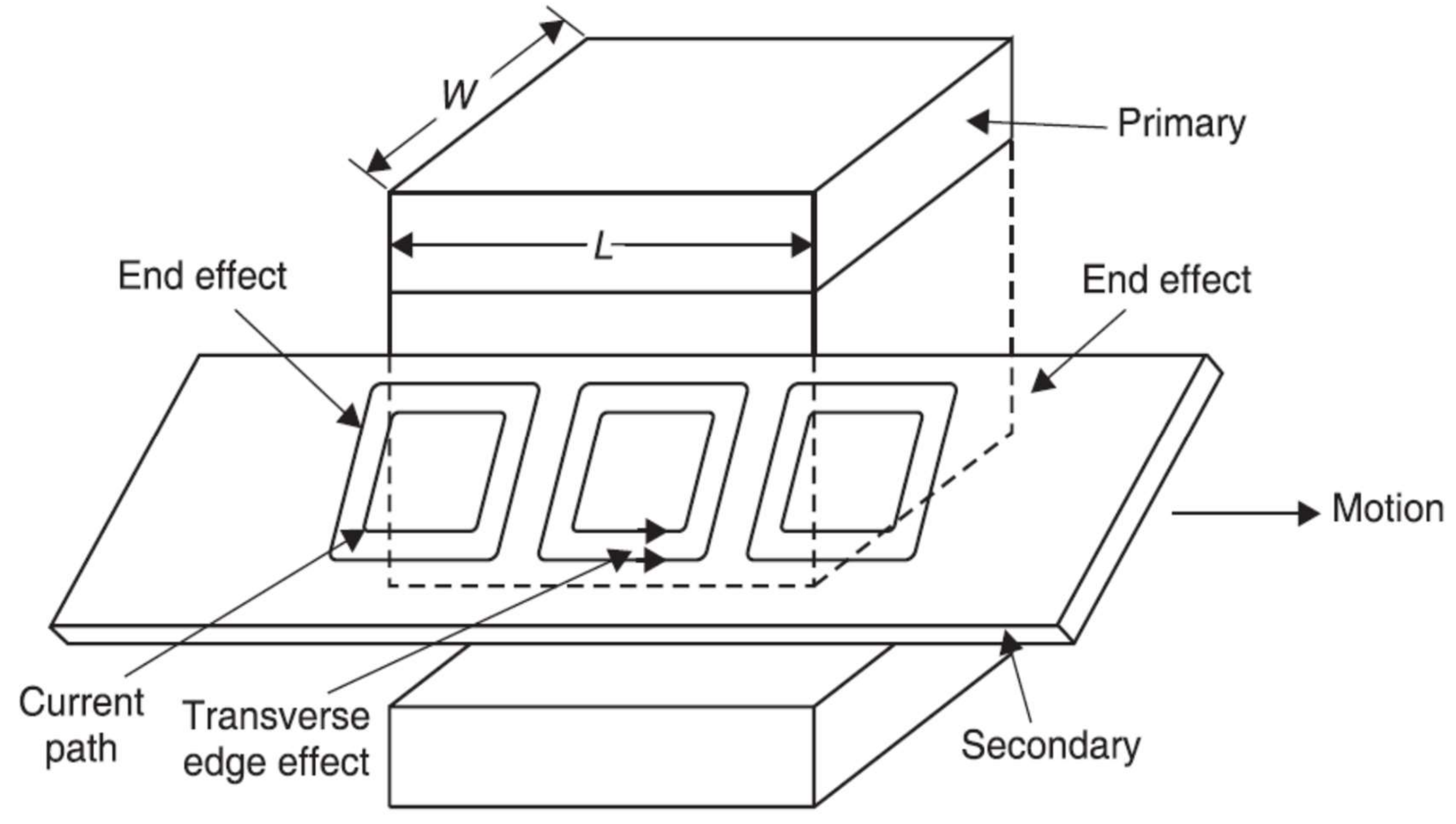


Fig. 8.10 Transverse edge and end effects

- The portion of the current (in the secondary) which has path parallel to the direction of motion makes no contribution towards the production of thrust. This current produces losses. This effect is called ***transverse edge effect***.

- For LIM with short primary, the current paths towards the end of field structure on the secondary go beyond the field structure of the primary and hence do not contribute to useful thrust. This current also increases the losses. This effect is called ***end effect***.

- The transverse edge effect results in reduction of effective thrust and increase in losses.

- Both transverse edge effects and end effects should be reduced.

- The end effects can be reduced by increasing the number of poles. But this has limitations.

The disadvantages of end effects are summarised as follows:

- The flux distribution becomes nonuniform.
- Secondary current due to end effects produces additional copper loss.
- The presence of flux outside the active zone results in production of retarding force.
- A considerable amount of reactive VA is produced which lowers the power factor.

Goodness Factor:

Goodness factor is a criterion for nonconventional machines.

It expresses the capability of a machine to convert air gap power between the secondary and primary in electrical form and mechanical form at a speed related to primary field speed.

The goodness factor for a double primary three phase LIM is given by

$$G = \left(\frac{\mu_0}{\rho}\right)\left(\frac{d}{l_g}\right)\left(\frac{V_s^2}{2\pi f}\right)$$

The goodness factor can be used for predicting the performance of LIM.

If G>1 then the LIM is more efficient.

Equivalent Circuit of LIM:

The simple resistance cannot represent the machine when it moves. The resistance should represent the power input to the secondary given by *R2*/*S*, which depends on slip.

This resistance may be divided into two:

one representing secondary copper loss (*R2*) and
the other the output of the motor, [*R2*(1 – *S*)/*S*].

This condition is shown in Fig. 8.13a.

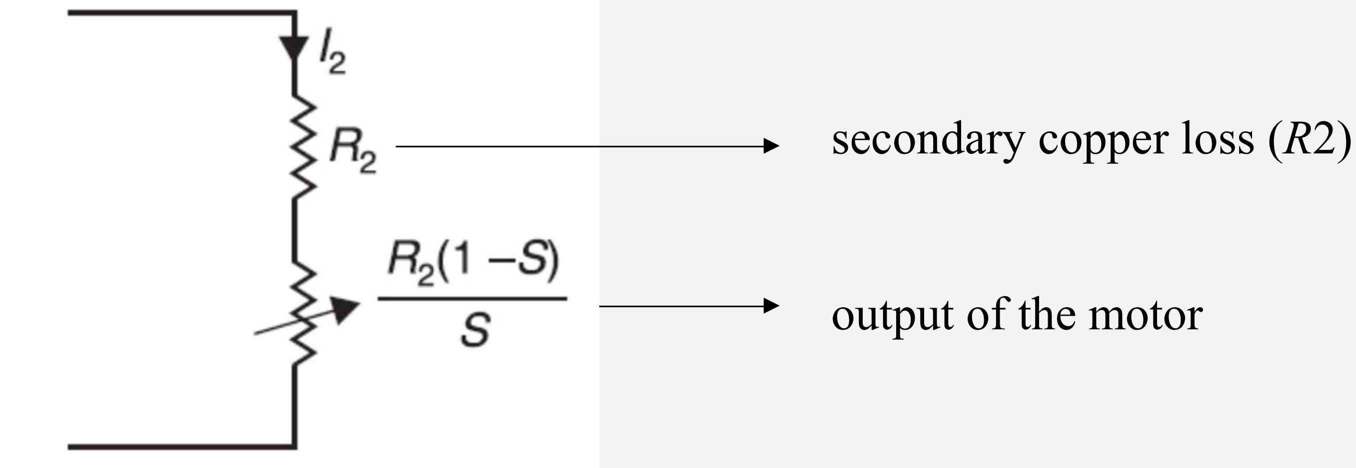


Fig 8.13 (a)

Equivalent Circuit of LIM: (Contd…)

To this circuit, the secondary leakage reactance *X*2 is added as shown in Fig. 8.13b.

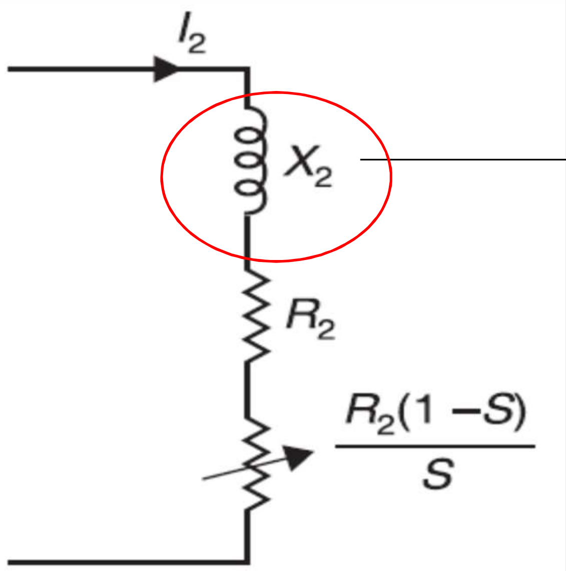


Fig 8.13 (b)

secondary leakage reactance *X*2

Equivalent Circuit of LIM: (Contd…)

Now let us assume that the magnetic circuit has a finite reluctance and hence some mmf and current is required to set up the flux. This can be represented by reactance X_m.

Power loss in the "iron part of the motor" is represented by resistance R_i, as shown in Fig. 8.13c.

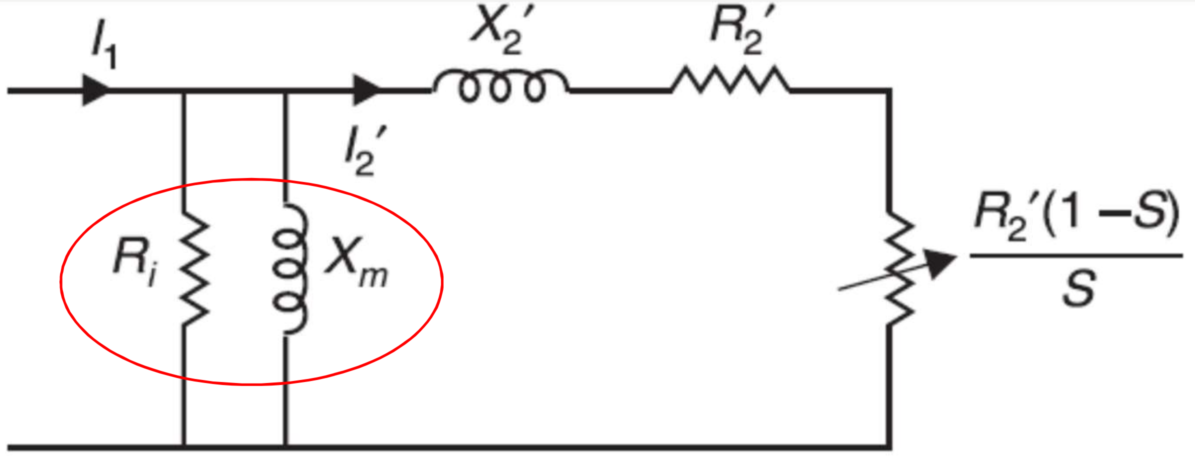


Fig 8.13 (c)

Equivalent Circuit of LIM: (Contd…)

Finally, the primary leakage reactance $X1$ and resistance $R1$ are included to get the equivalent circuit of the practical LIM, as shown in Fig. 8.13d.

In the figure R_2', X_2' are the secondary resistance and the leakage reactance referred to the primary.

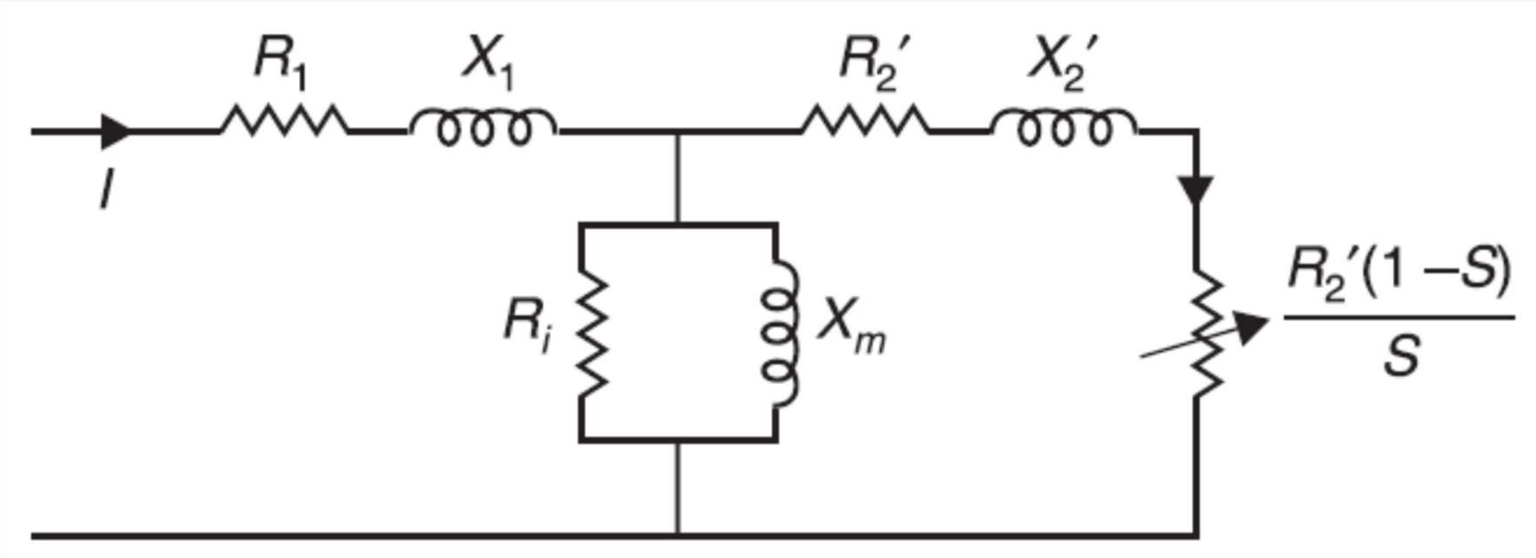


Fig 8.13 (d) Final Equivalent circuit of Linear Induction Motor

Characteristics of LIM:

- The performance of LIM depends on air gap, pole pitch, number of poles, thickness of secondary, resistivity of secondary and tooth width of primary.

- A large air gap length increases the magnetizing current end exit and losses and decreases the goodness factor, thrust and efficiency.

- Higher pole pitch increases goodness factor and reduces the number of poles required.

- Higher number of poles decreases the end effects and increases the leakage reactance of the secondary.

- Increased secondary thickness results in large goodness factor and high starting current. Secondary resistivity reduces goodness factor.

- Tooth width affects the thrust.

Characteristics of LIM: (Contd…)

The various characteristics of a typical LIM are shown in Fig. 8.14.

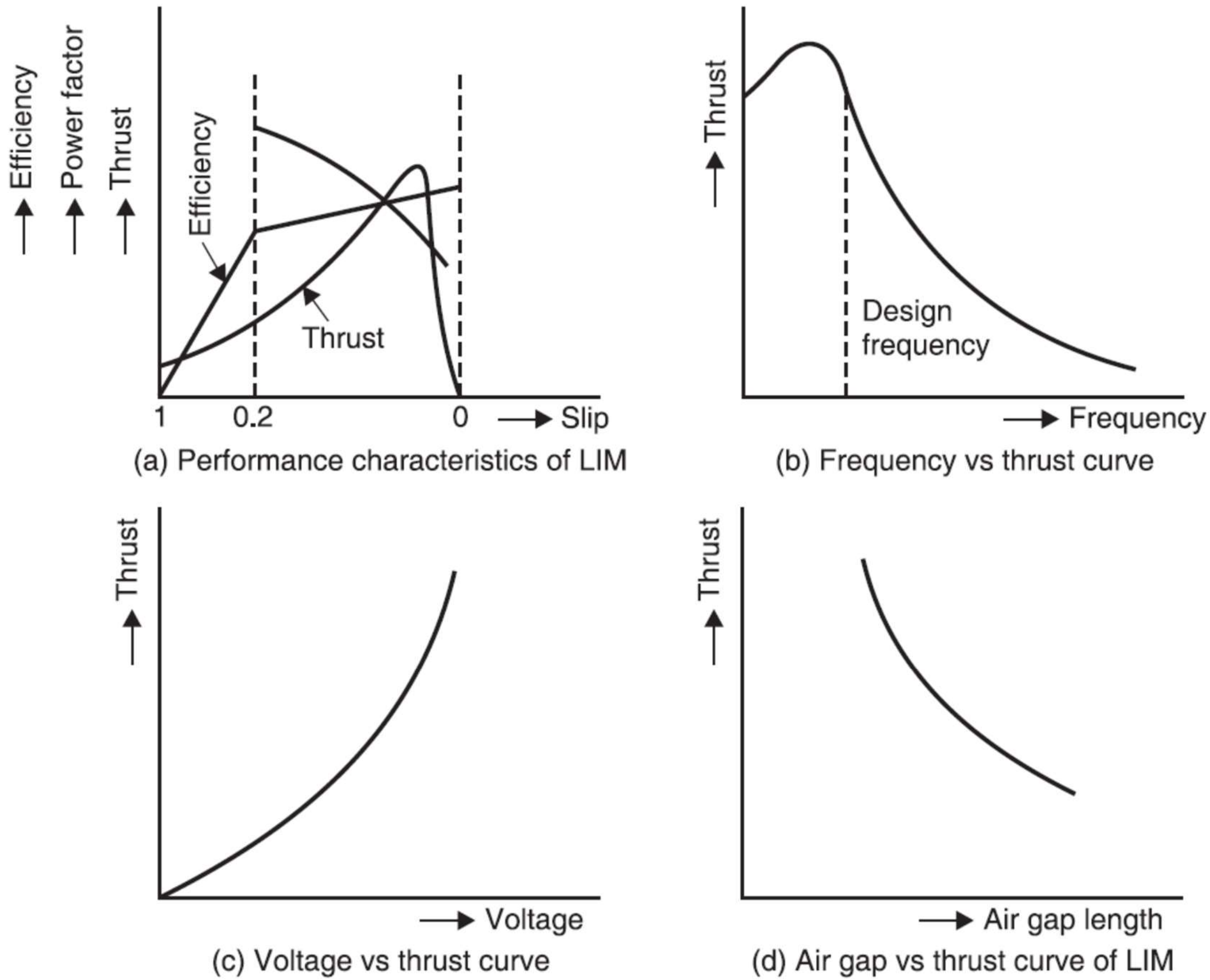


Fig. 8.14 Characteristics of LIM.

Certain Design Aspects of LIM:

The design is based on the output Eq. (8.5),

$$F = 1.11\, \eta\, LW\, K_w\, T_{ph}\, B_{av}\, ac \cos\Phi$$

Choice of specific magnetic loading (B_{av})

The specific magnetic loading is chosen by considering the following factors:

(a) Power factor: As with rotating induction motor, the magnetizing current makes the power factor low for an LIM. The magnetizing current is proportional to the mmf required to force the flux through the air gap and iron parts of LIM. The specific magnetic loading should be so selected that there is no saturation in any part of the magnetic circuit.

(b) **Iron loss:** The iron loss depends on flux density. A high value of specific magnetic loading causes increased iron loss and decreased efficiency.

(c) **Overload capacity:** A high value of flux density reduces the number of turns per phase for a given voltage rating. The reduction in number of turns results in less leakage reactance and higher overload capacity. Generally, the specific magnetic loading lies between 0.3 Wb/m^2 and 0.6 Wb/m^2.

Certain Design Aspects of LIM: (Contd…)

Choice of specific electric loading (ac)

The factors to be considered for the choice of specific electric loading are:

(a) Permissible temperature rise:

The limiting value of specific electric loading is fixed by maximum allowable temperature rise and cooling coefficient.

A large value of specific electric loading requires more number of conductors and the primary resistance becomes higher. This results in large copper loss and high temperature rise.

The maximum temperature rise allowed depends on the type of insulating materials used.

Use of better quality insulating materials permits the use of higher specific electric loading.

The cooling coefficient depends on ventilation provided in the machine.

A higher value of specific electric loading can be chosen for LIM with higher cooling coefficient.

Certain Design Aspects of LIM: (Contd…)

Choice of specific electric loading (ac) (Contd…)

(b) **Size of machine:** The large machines have large slot depth and hence higher value of *ac* can be chosen.

(c) **Current density:** Motors having lower current density can be designed with a higher *ac*.

(d) **Voltage:** For high voltage motors, the space required for insulation is large. So, the value of *ac* should be small.

(e) **Overload capacity:** Higher value of *ac* requires more turns/phase and results in increase of leakage reactance. Higher leakage reactance makes the overload capacity lower. The usual value of *ac* lies between 5000 and 40,000 ampere conductors/metre.

Certain Design Aspects of LIM: (Contd…)

Design of primary

(a) **Shape of the slots:** Semi-enclosed slots are generally used for LIMs operating below 600 V. These types of slots give good performance and higher efficiency in the use of material. Slot opening should be as small as possible. Use of semi-closed slots reduces tooth pulsation and leads to a quieter operation.

(b) **Choice of number of slots:** Following factors are considered while selecting the number of slots:

(i) *Tooth pulsation losses*. Use of large number of slots minimizes the variations on the air gap reluctance and reduces the tooth pulsation losses and noise.

(ii) *Leakage reactance*. The leakage reactance can be reduced by using large number of slots.

Certain Design Aspects of LIM: (Contd…)

Design of primary (Contd…)

(iii) *Mechanical difficulties*. Use of large number of slots reduces the width of tooth. If the width of the teeth is less, they become mechanically weak and supports should be provided. The supports affect ventilation. It is better to select less number of slots for mechanical strength.

(iv) *Magnetizing current and iron losses*. Use of large number of slots causes excessive flux density in the teeth and hence high magnetizing current and iron losses. It is better to select large number of slots. The number of slots/pole/phase should not be less than two. Integral number of slots/pole/phase is normally employed.

(c) **Primary winding:** For motors of rating up to 100 HP and 600 V, mesh winding is used. The coils are wound on a mold and then placed in the slots.

Certain Design Aspects of LIM: (Contd…)

Design of primary (Contd…)

(d) **Length of air gap:** The length of the air gap is decided by considering the following factors:

(i) *Cooling*. A large air gap provides better cooling of the primary and secondary surfaces.

(ii) *Magnetic pull*. A large air gap avoids any noticeable unbalanced magnetic pull due to small eccentricity.

(iii) *Pulsation loss and noise*. The variation in reluctance due to slots is small when the air gap is large. So pulsation losses and noise get reduced if large air gap is provided.

(iv) *Power factor*. For good power factor, air gap length should be small.

(v) *Overload capacity*. Overload capacity increases with increase in air gap length.

Control of LIM:

The speed of an LIM depends on the supply frequency and pole pitch of winding.

The pole pitch is set by the arrangement of winding.

A certain limited number of speeds can be obtained by changing the connections of stator coils in different ways by means of external switches.

This technique is known as pole-changing technique.

The complexity of the switching circuit increases with the increase in the number of speeds required.

Linear Synchronous Motor (LSM):

- Linear synchronous motor is a linear counterpart of conventional rotating synchronous motor.

- In LSM, the mechanical motion is in synchronism with magnetic field, i.e. the mechanical speed is the same as the speed of the travelling magnetic speed.

- The thrust is provided by the action of the travelling magnetic field produced by a three-phase winding and a group of magnetic poles N, S, N, S, …, N, S or a variable reluctance ferromagnetic rail.

- LSMs have better energy conversion levels than that of LIMs, but with higher cost.

- They can produce much higher thrust density compared to LIMs for the same thrust. This makes them suitable for applications in vehicles and propulsion.

Types and Construction of LSMs:

- Many types of LSMs have been developed and are in use.

- Depending upon the speed of operation, LSMs are classified as
  - transportation LSMs (for medium and high speeds) and
  - low-speed LSMs. (Ex: Linear motion synchronous stepper motor)

- Transportation LSMs can be classified into
  - heteropolar LSM
  - homopolar LSM
  - permanent magnet LSM
  - superconductor field LSM
  - transverse flux LSM
  - longitudinal flux LSM

- The constructional details of various types of LSMs are described in this section.

Types and Construction of LSMs: (Contd…)

LSM with electromagnetic excitation (longitudinal flux LSM *)*

The electromagnetic excitation system of an LSM is similar to that of a conventional salient pole synchronous motor.

There are two types of LSM: flat single-sided LSM and
flat double-sided LSM.

They have salient ferromagnetic poles and DC field winding.

The poles and pole shoes are made up of solid steel, laminated steel or sintered powder.

If the excitation system is integrated with the moving part, the DC excitation should be provided with the help of brushes and contact bars.

Types and Construction of LSMs: (Contd…)

LSM with electromagnetic excitation (Contd…)

The constructional details are shown in Fig. 8.15.

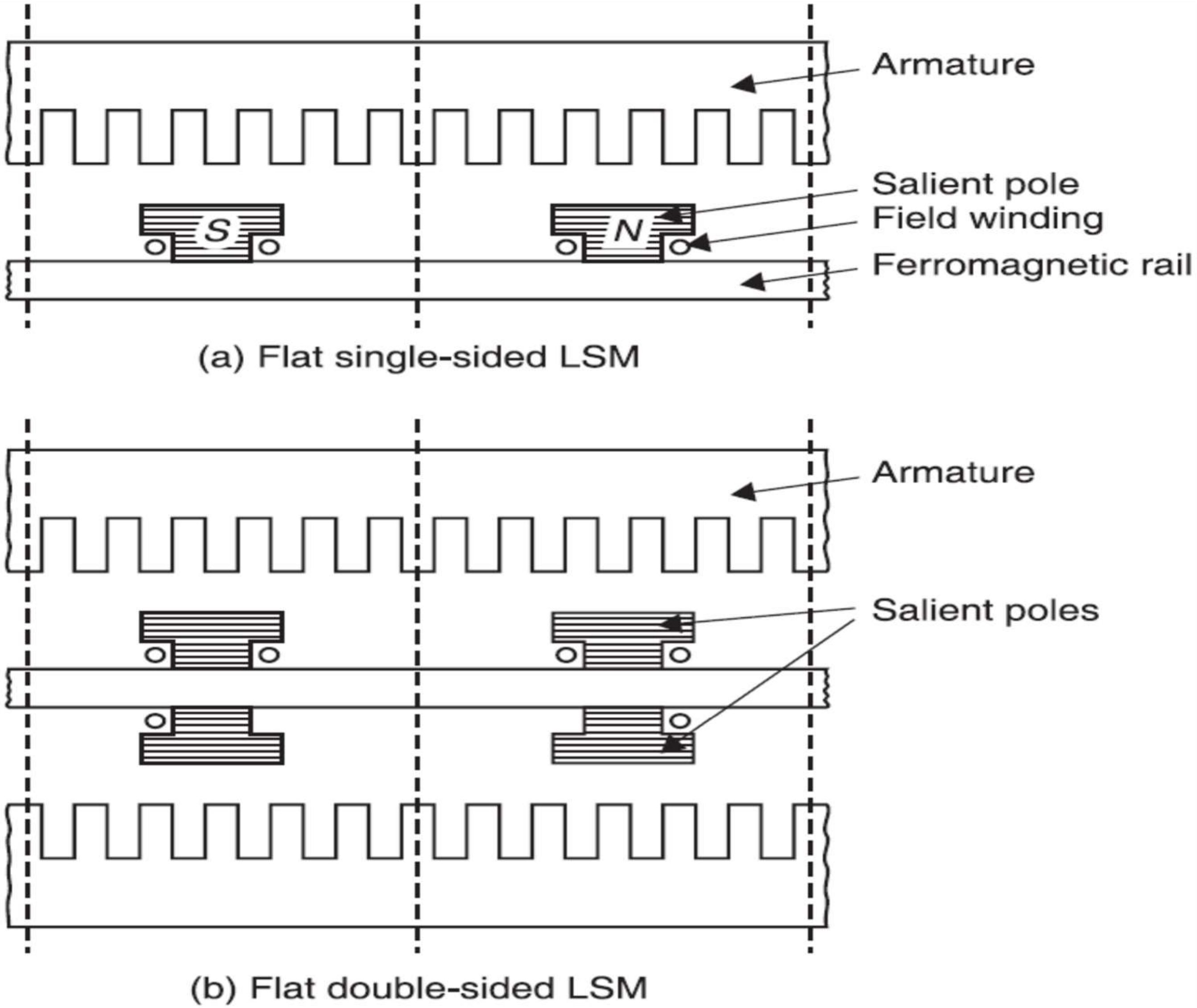


Fig. 8.15 LSM with electromagnetic excitation systems

Types and Construction of LSMs: (Contd…)

LSM with superconducting excitation system

This type of LSM is used for large-power applications.

The ferromagnetic core that produces magnetic field is replaced by coreless superconducting electromagnets.

The magnetic flux produced by superconducting electromagnets is much greater than the saturation flux of the best laminated alloys (e.g. cobalt alloy).

LSM using superconducting excitation system is a fully air-cored motor.

Types and Construction of LSMs: (Contd…)

LSM with superconducting excitation system (Contd…)

The structure is shown in Fig. 8.16.

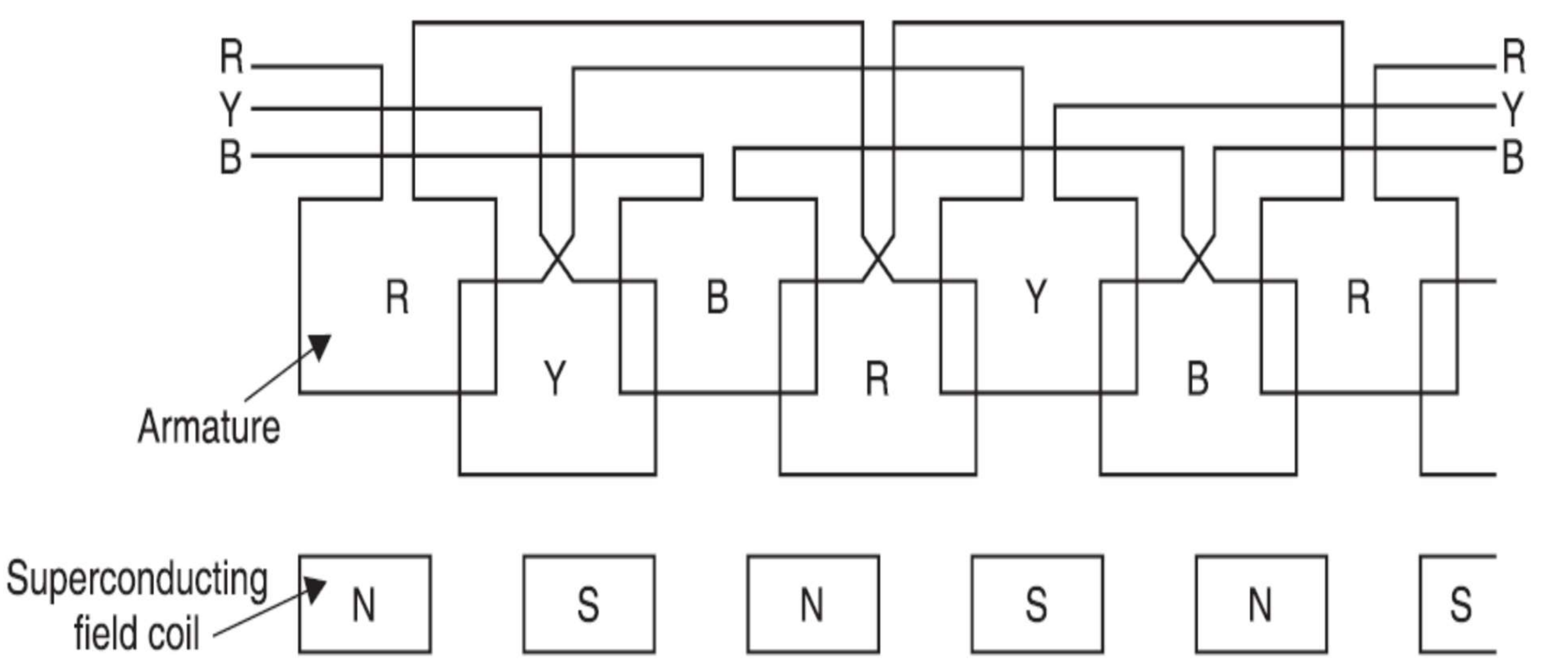


Fig. 8.16 LSM with superconducting excitation systems

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail (*heteropolar LSM *):

The details of single-sided flat LSMs with surface permanent magnets and embedded-permanent magnets are shown in Fig. 8.17.

In surface PM type, the yoke (back iron) of the reaction rail is made up of ferromagnetic material and the PMs are magnetized in perpendicular direction to the active surface.

Whereas magnetization is done in the direction of travelling magnetic field in embedded PM type.

In this type, the yoke is non-ferromagnetic (e.g. aluminum). This is to reduce the bottom leakage flux.

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

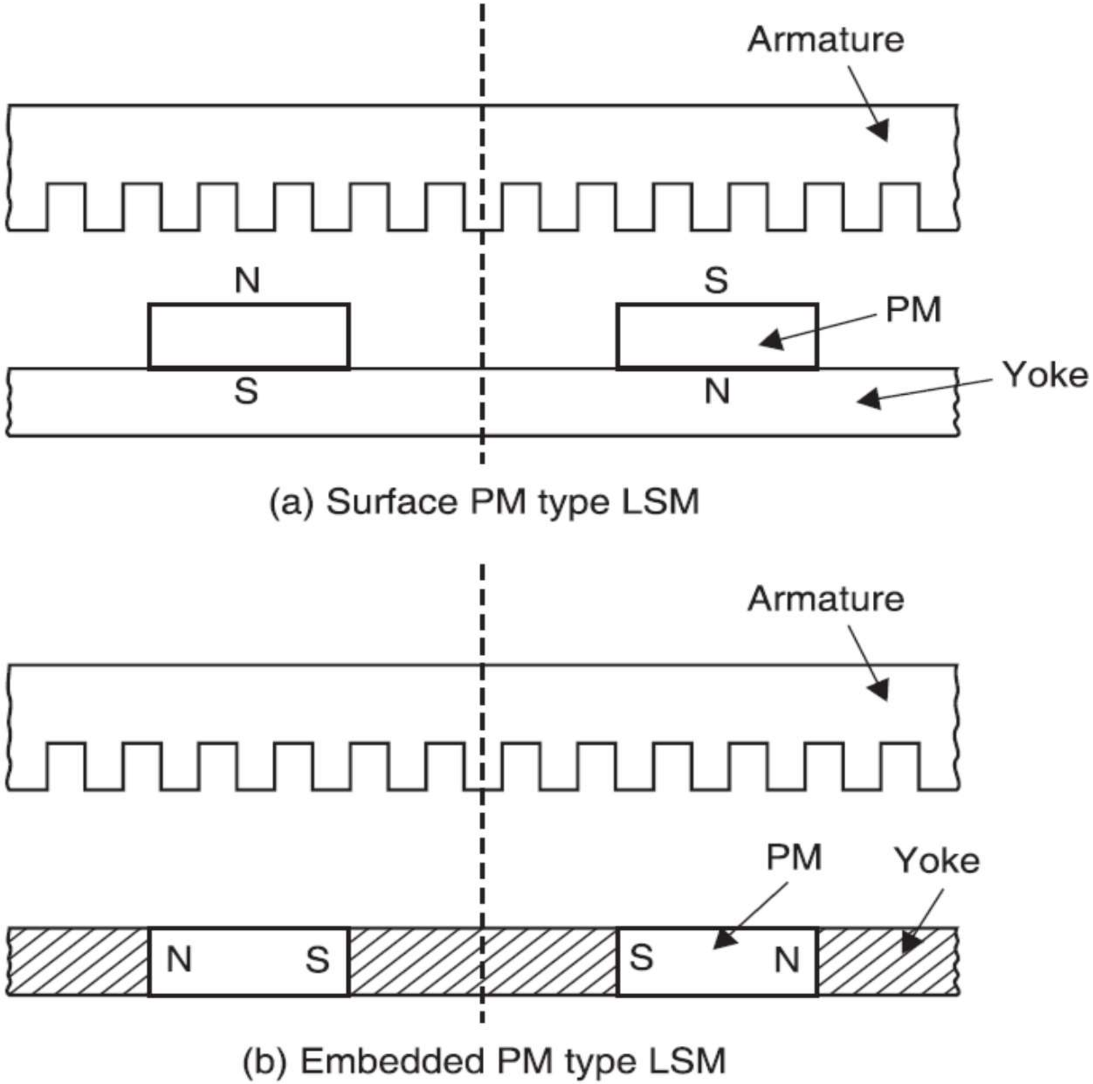


Fig. 8.17 Single-sided PM LSMs

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

The detent force, higher-order space harmonics and force ripples can be reduced by skewing the PMs as shown in Fig. 8.18.

The detent force is the attractive force between the PMs and the armature ferromagnetic teeth.

The skewed PMs can be arranged in one row, two rows or even more.

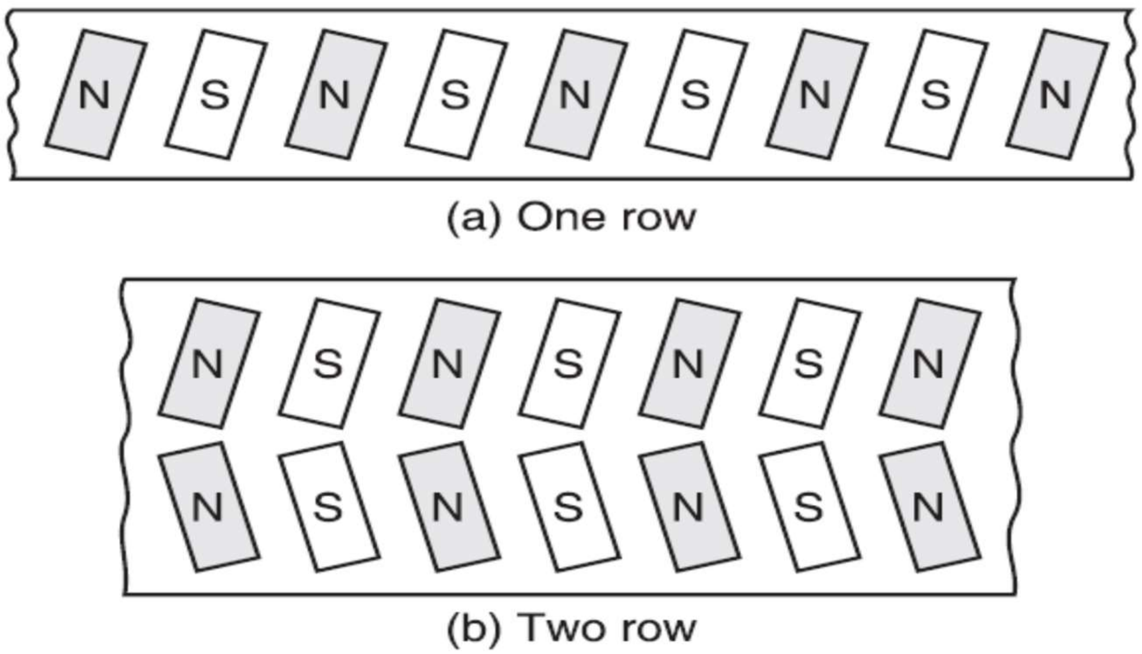


Fig. 8.18 Skewed PMs in flat LSMs

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

Generally, PM LSMs are provided with dampers.

When the speeds are different (speeds of travelling wave and rail), electric currents are induced in damper circuits.

The interaction of armature magnetic field and damper currents helps in starting, damps oscillations and brings in synchronism when the speed increases or decreases.

These dampers also provide protection to PMs from mechanical damage.

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

The damper of PM LSMs are aluminum cover, as shown in Fig. 8.19 or solid steel poles shoes, as shown in Fig. 8.20

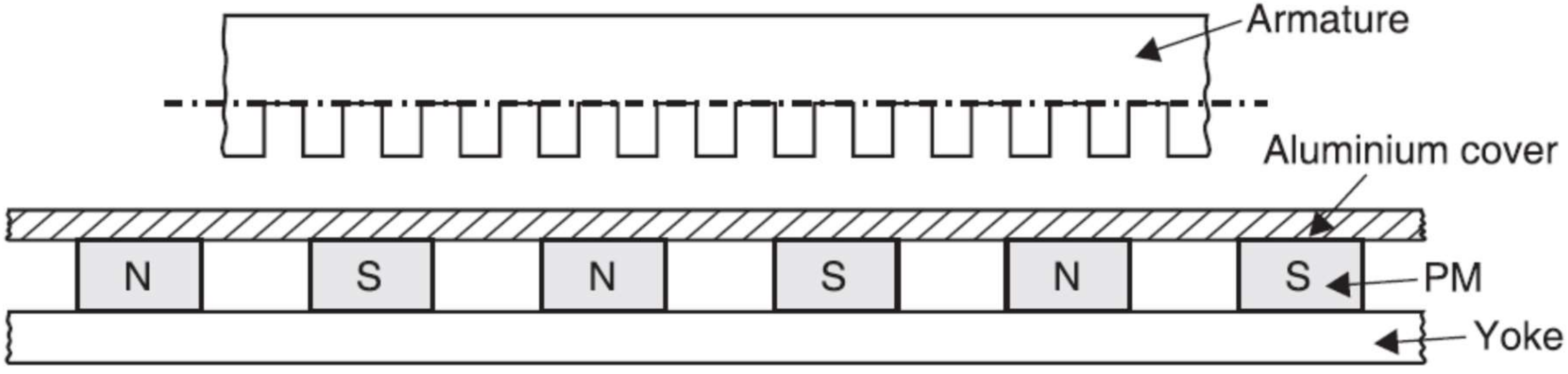


Fig. 8.19 Damper of surface type LSM aluminium core

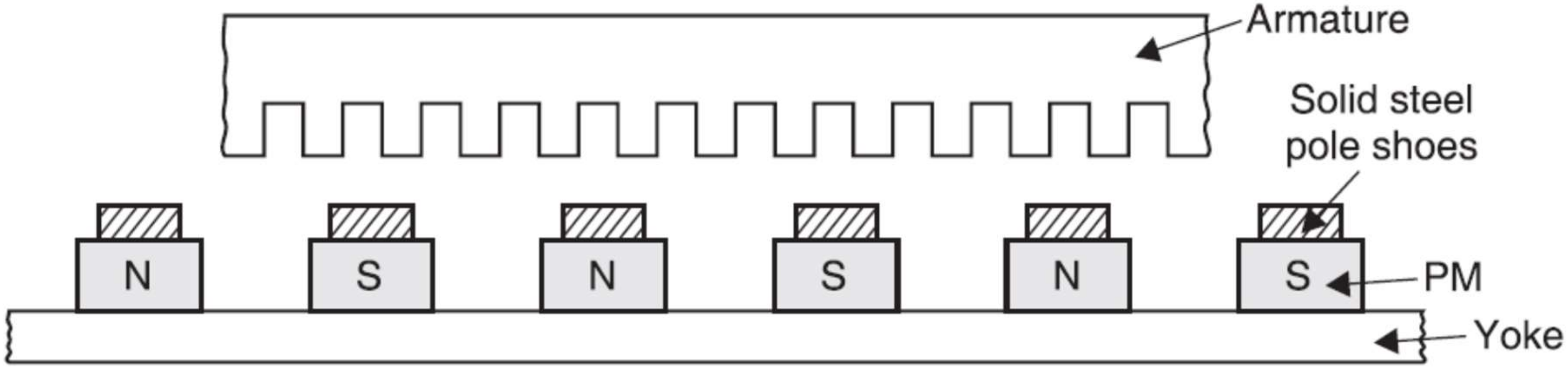


Fig. 8.20 Dampers of surface type LSM solid steel pole shoe

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

Double-sided flat PM LSM can also be built with one internal armature system and two excitation systems as shown in Fig. 8.21.

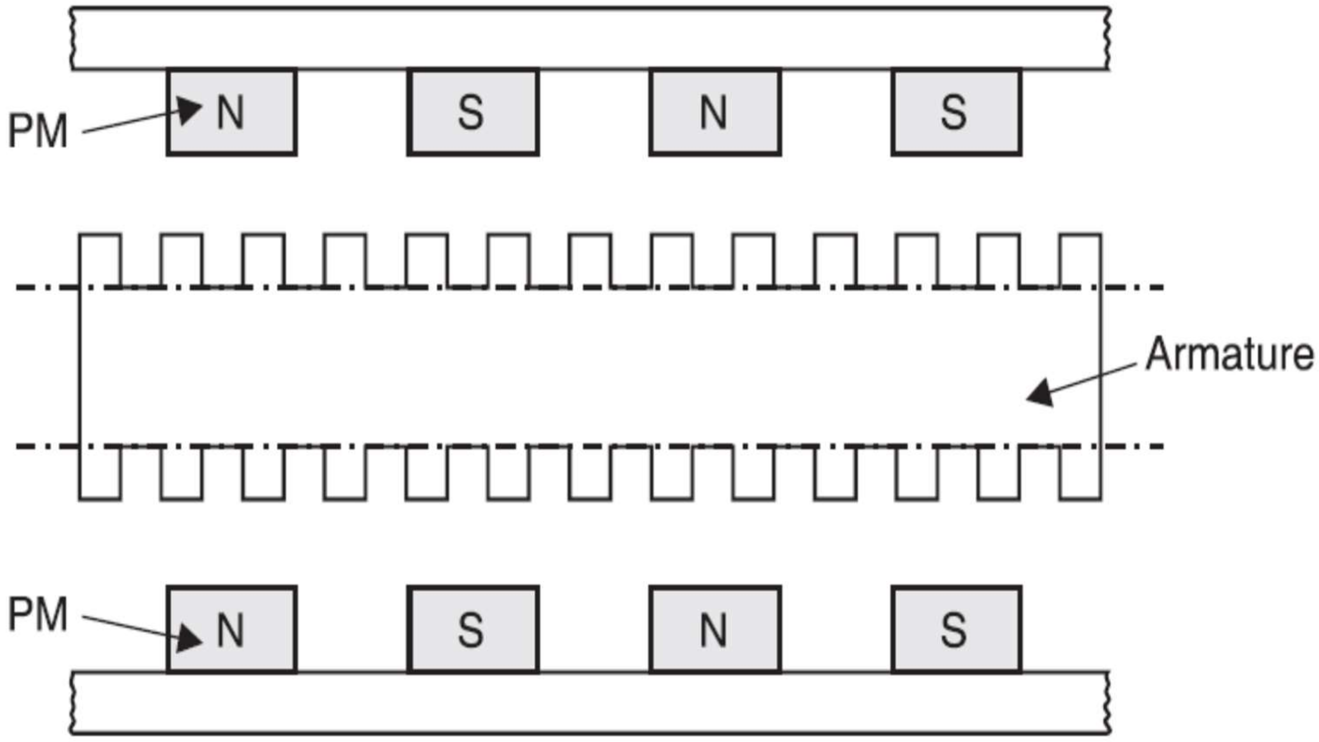


Fig. 8.21 Double-sided flat PM LSM

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

Another type of PM LSM is slot less motor. In this type, the primary winding is uniformly distributed on a smooth armature core or without a core.

Slot less PM LSMs are characterized by detent force, free operation and higher input frequency than that of slotted LSM.

They require more PM material due to larger non-ferromagnetic air gap.

The absence of teeth leads to very low value for direct and quadrature axes synchronous reactance, which results in higher input current.

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

Figures 8.22(a) and 8.22 (b) show the constructional details of slot less LSMs.

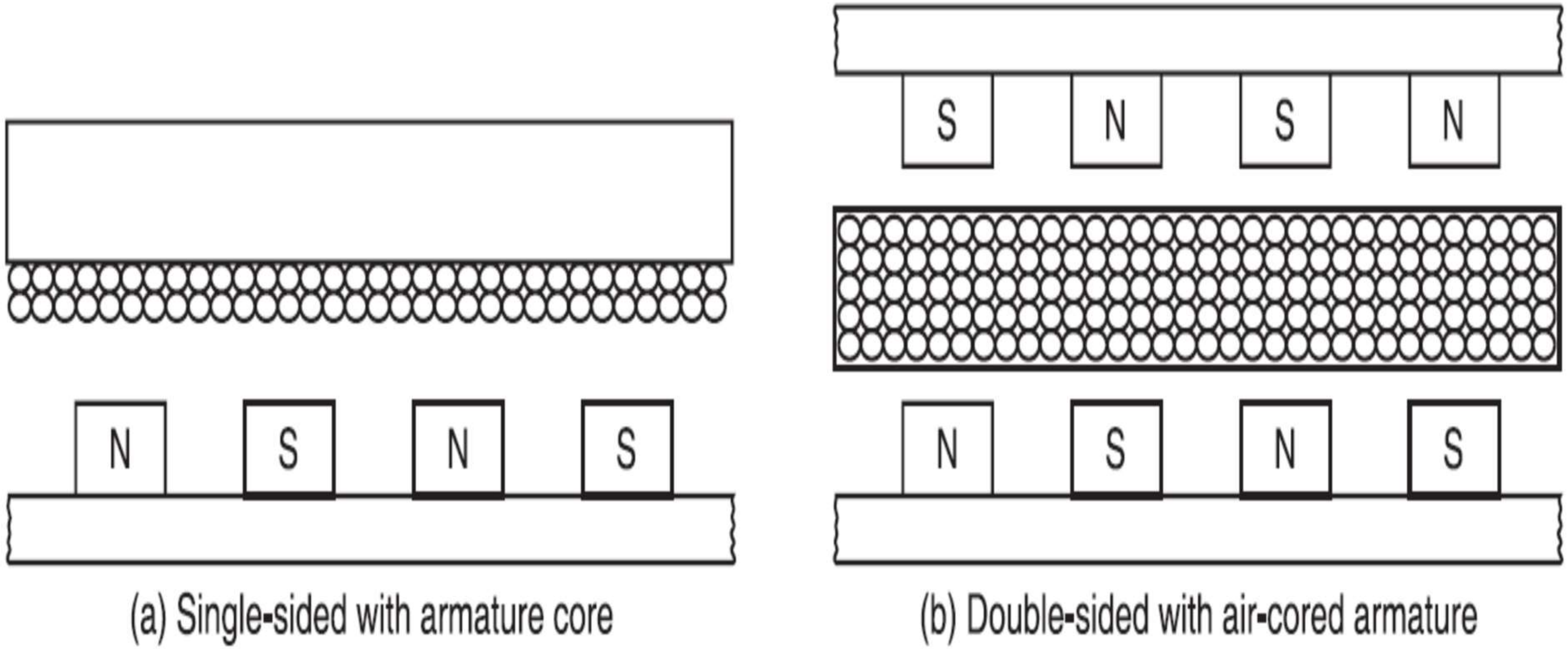


Fig. 8.22 Flat slotless PM LSMs

Types and Construction of LSMs: (Contd…)

Permanent magnet LSM with active reaction rail: (Contd…)

The advantages (and disadvantages of other) of slotless and slotted LSMs are given in Table 8.1.

Table 8.1 Comparison of slotless and slotted LSMs

Slotless LSM	Slotted LSM
Higher efficiency in the higher speed range	Higher efficiency in lower speed range
Lower winding cost	Higher thrust density
Lower thrust pulsation	Lower input current
Lower acoustic noise	Less number of permanent magnets

Types and Construction of LSMs: (Contd…)

Transverse magnetic flux LSMs

The flux in these motors are in the direction parallel to the direction of motion. In transverse flux LSMs, the lines of magnetic flux are in a plane perpendicular to the direction of travelling magnetic field.

The constructional details of single-sided and double-sided configurations of LSMs are shown in Fig. 8.24.

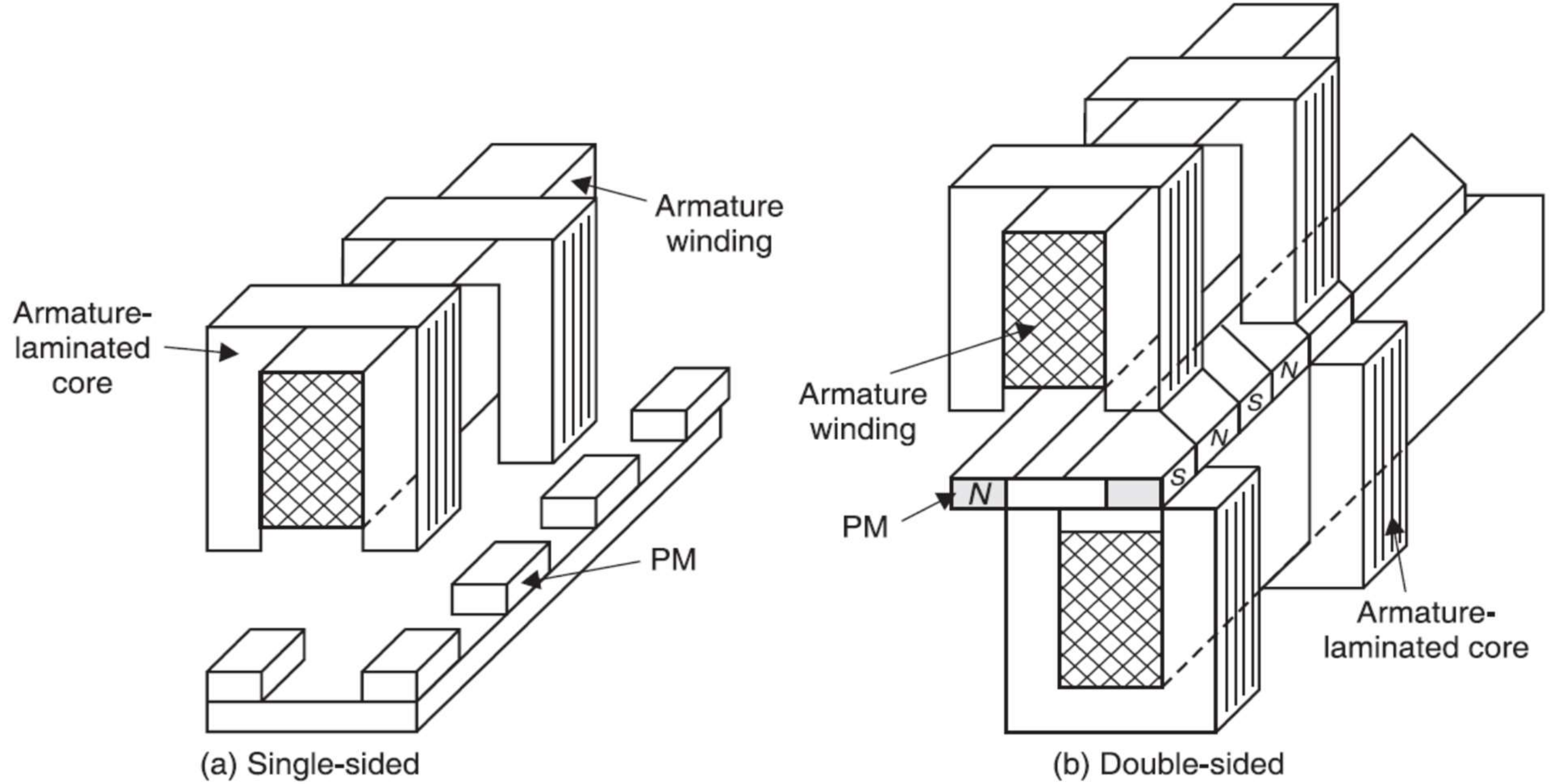


Fig. 8.24 Transverse flux PM LSM

Types and Construction of LSMs: (Contd…)

PM LSM with passive reaction rail (homopolar)

The LSMs discussed so far are heteropolar LSMs in which the armature winding and field system are in separate parts. Another type of LSM is homopolar.

In homopolar LSMs, the armature winding and field system are in same part and the reaction rail is of passive nature.

A double-sided homopolar LSM is shown in Fig. 8.25.

It has two polyphase armature windings. Both armature systems are magnetically and mechanically coupled by a ferromagnetic *U* type yoke.

Each armature has a slotted stack with polyphase winding and permanent magnets are placed between the stack and the yoke.

Types and Construction of LSMs: (Contd…)

PM LSM with passive reaction rail (Contd…)

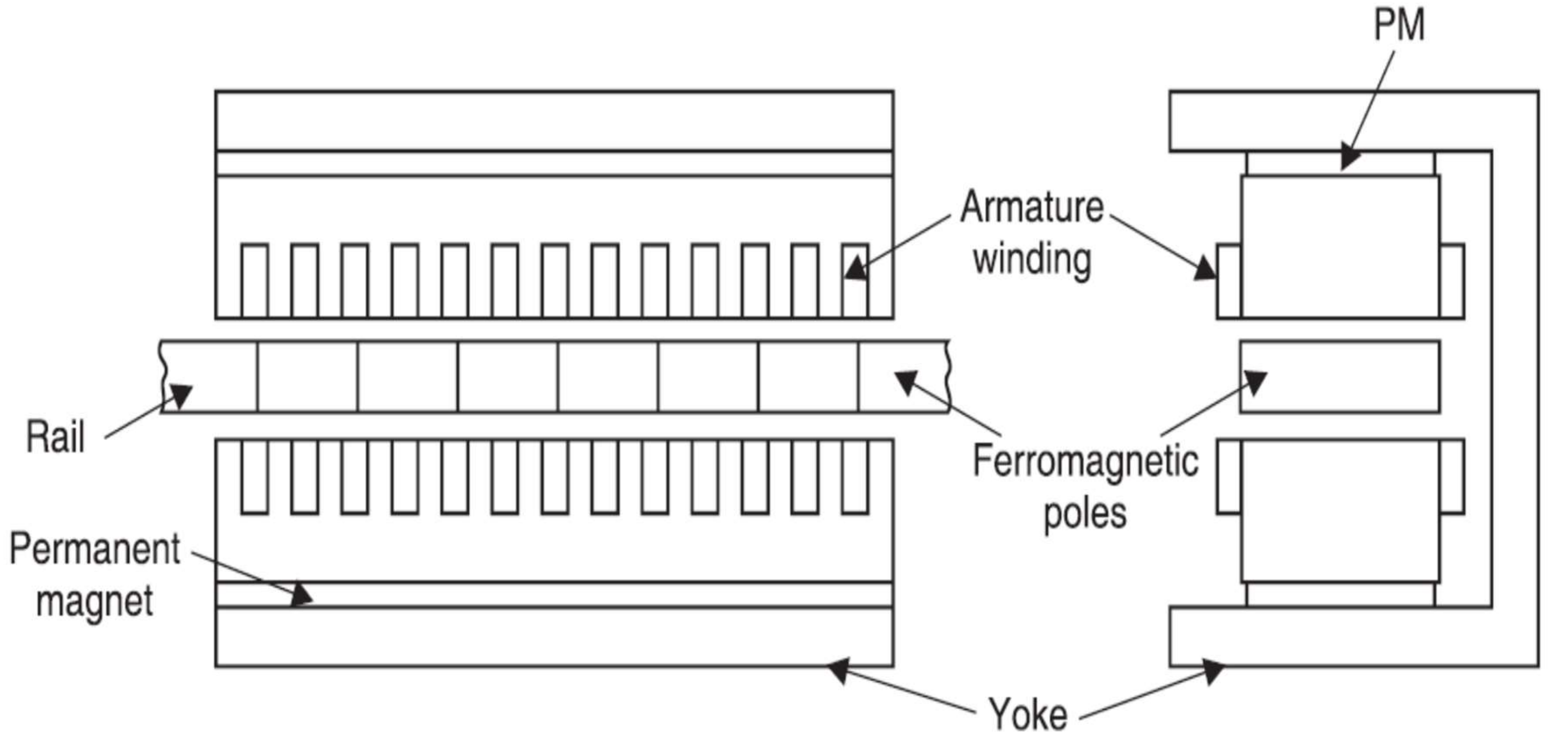


Fig. 8.25 Double-sided homopolar LSM

Types and Construction of LSMs: (Contd…)

PM LSM with passive reaction rail (Contd…)

As both armature and excitation systems are combined together, the stack is oversized compared to steel–cored LSM.

The PMs may be replaced by electromagnets. The reaction rail is of passive nature and salient.

The saliency is obtained by using solid or laminated ferromagnetic cubes separated by non-ferro magnetic material.

The reaction rail poles are magnetized by the armature PMs through the air gap.

The interaction between the travelling magnetic field produced by armature winding and the magnetized poles of reaction rail produces the thrust.

A single-sided homopolar LSM is shown in Fig. 8.26.

Types and Construction of LSMs: (Contd…)

PM LSM with passive reaction rail (Contd…)

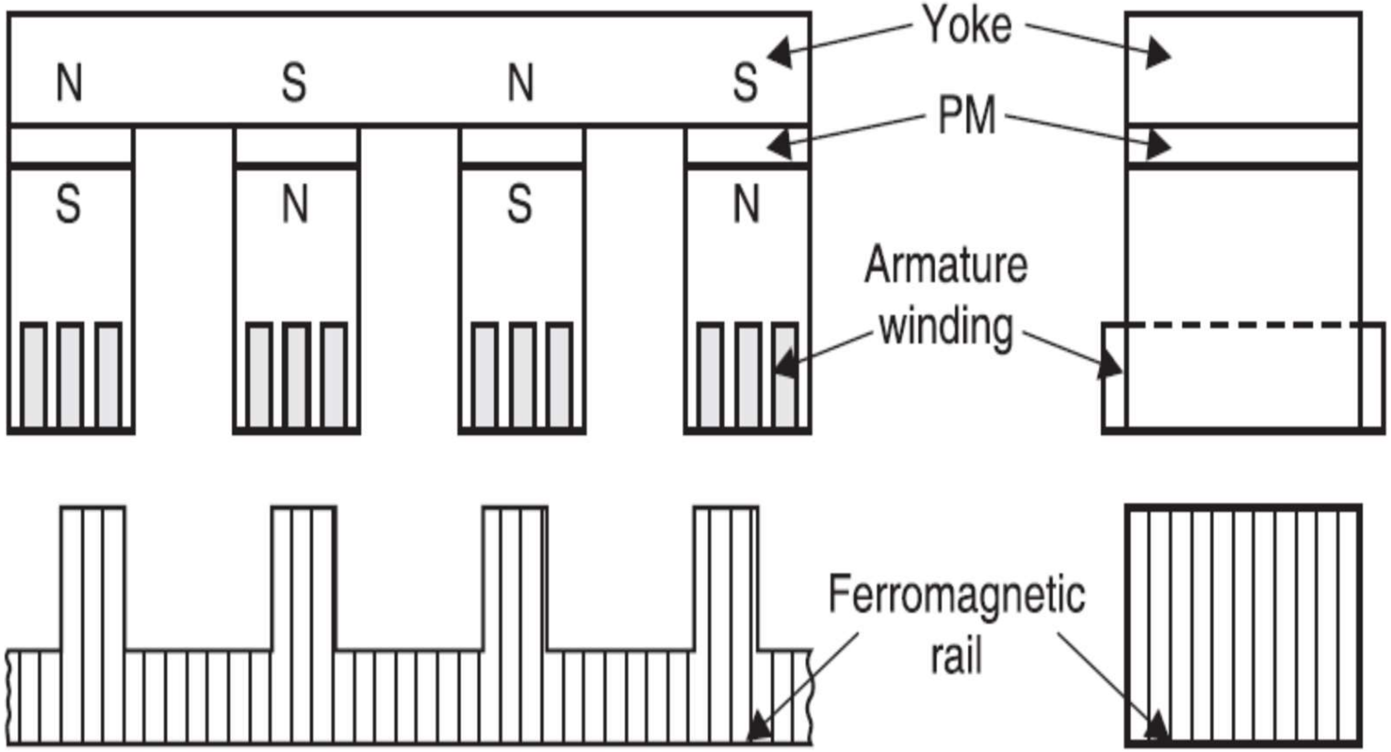


Fig. 8.26 Single-sided homopolar LSM

Control of LSM:

A control scheme for an LSM is shown in Fig. 8.29.

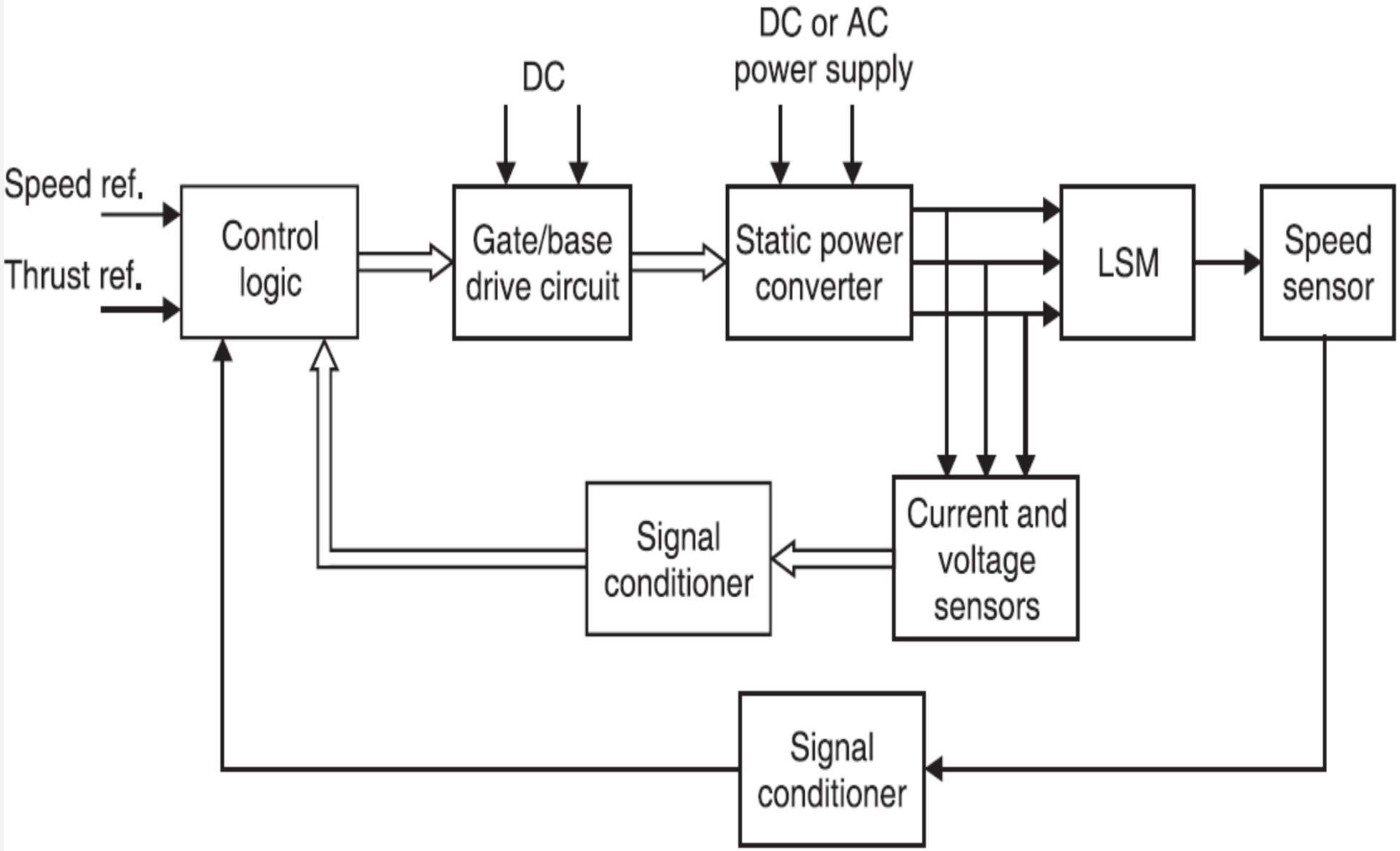


Fig. 8.29 Control schemes for LSM

Control of LSM: (Contd…)

The logic controller outputs the necessary signals for switching ON the semiconductor power switches.

Depending on the power supply, suitable power converter configuration is used. Commonly used power converter circuits are shown in Fig. 8.30.

If the supply is DC, a voltage inverter circuit as shown in Fig. 8.30(a) or a chopper and current inverter circuit shown in Fig. 8.30(b) can be used.

Control of LSM: (Contd…)

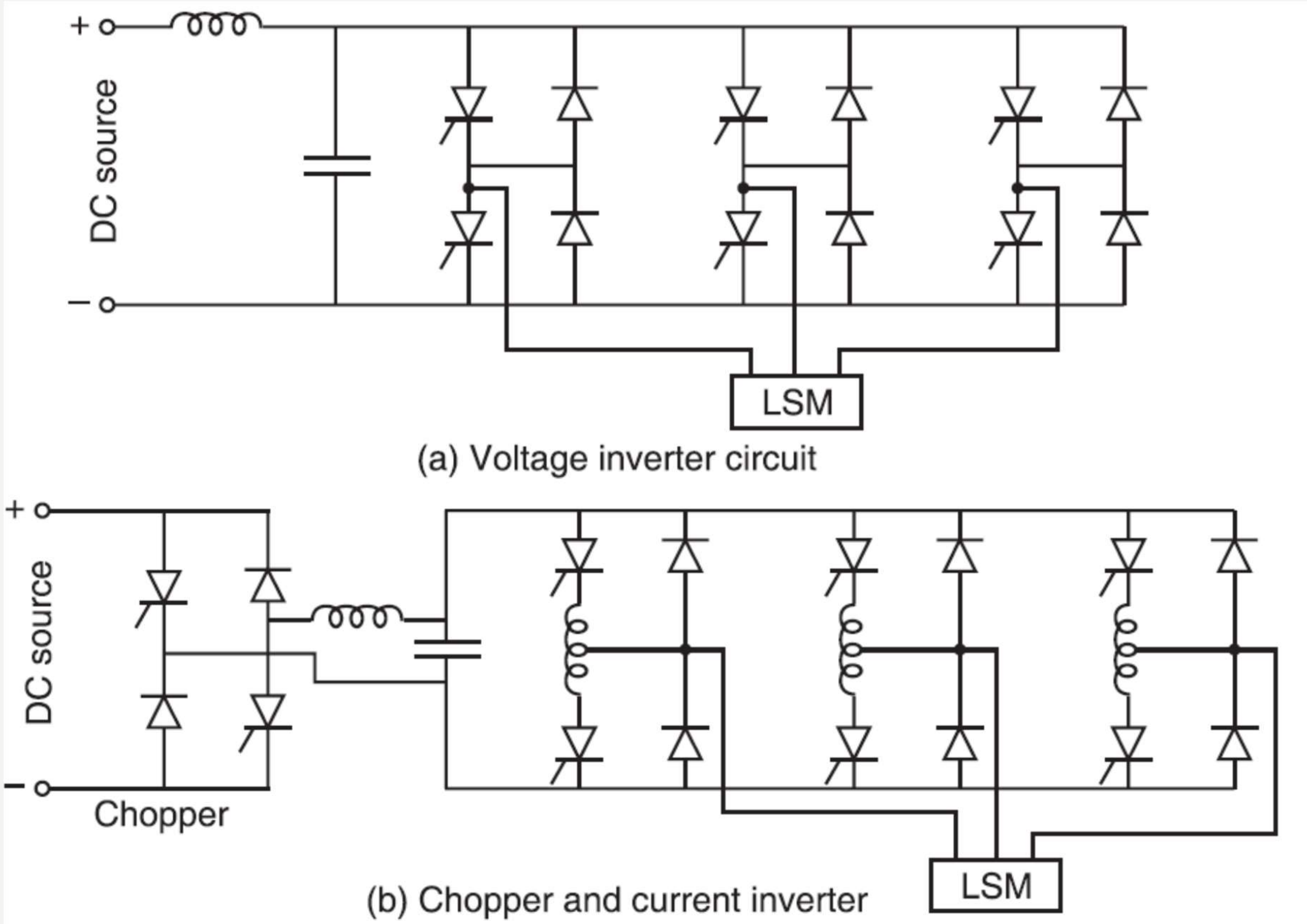


Fig. 8.30 Inverter circuit for LSM.

Control of LSM: (Contd…)

AC-fed converter circuits are the commonly used circuits.

In industrial drives, three-phase inverters are used.

For traction purpose, single-phase inverter circuits are used.

Typical power converter circuits for single-phase and three-phase are shown in Fig. 8.31(a), (b) & (c).

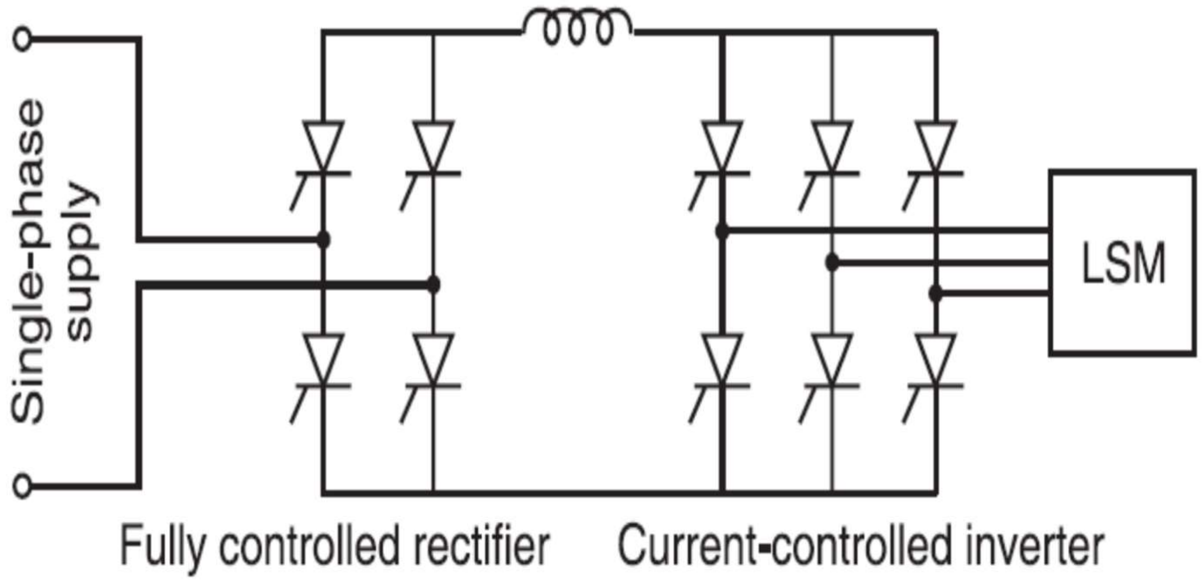
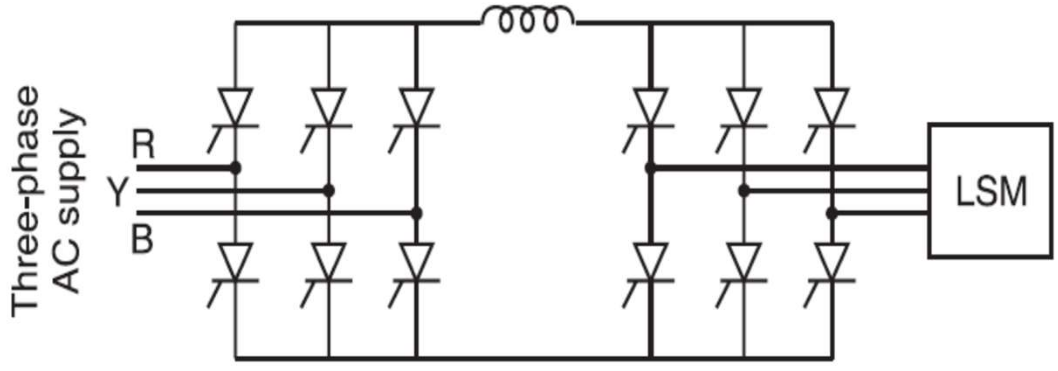
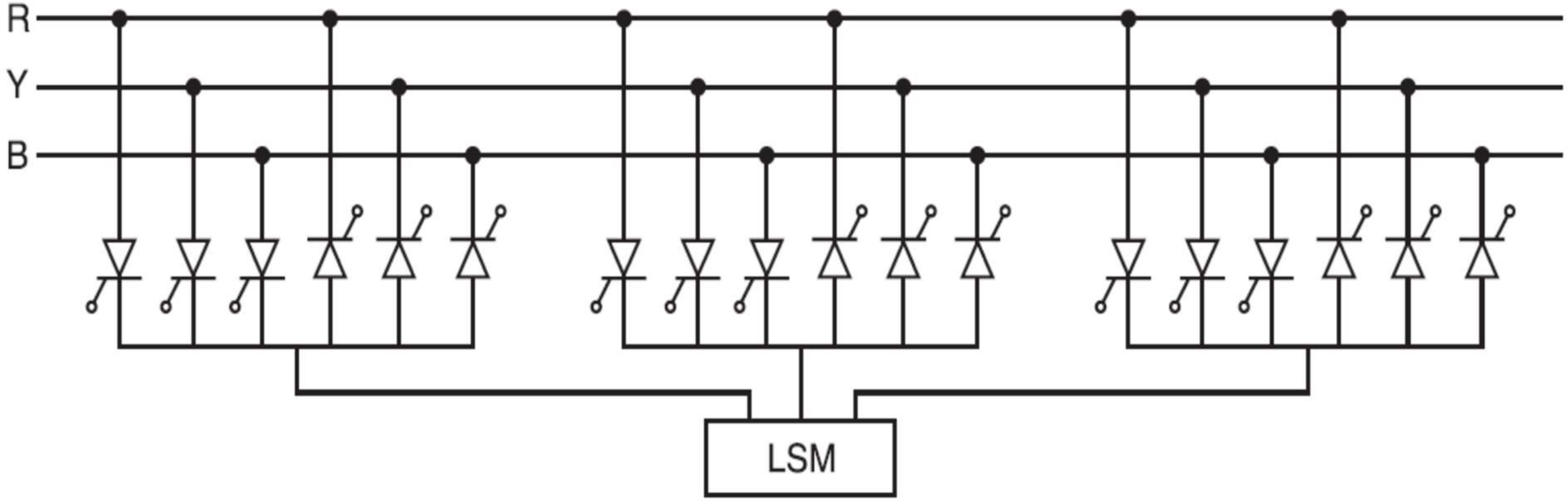


Fig. 8.31 (a) Single-phase fully controlled rectifier and current-controlled three-phase inverter

Control of LSM: (Contd…)



(b) Three-phase fully controlled rectifier and current controlled inverter



(c) Cyclo converter

Fig. 8.31 Power converter circuit for LSM.

Applications of LSM:

LSMs have the following advantages that make them suitable for many applications:

- LSMs are highly reliable. They have two components that may be subjected to wearing.
- The acceleration and braking are independent of friction.
- They have improved performance like high speed, acceleration and efficiency. Very precise control of position is possible.
- They can be used for movement along any slope including vertical direction without friction.
- The vehicle can be free from any active elements of the motor.
- Signals for control need not be sent to the vehicle.

Applications of LSM: (Contd…)

The features of LSMs like lower maintenance, fewer moving parts, reduced input/output and ease of installation enable them to be used in

- factory automation
- packaging
- material handling.

LSMs find applications in

- passenger elevators for tall buildings
- military elevators for weapons and aircraft.

Lighter than conventional elevators and less space requirement, multiple cabs in single shaft, higher speed and fewer hoist ways are the advantages of LSMs.

LSM is a better solution for many industrial problems.

- The movement along vertical and diagonal directions is possible
- LSM is cost effective.
- There is no need of cables and counter weights.
- Better control is also possible.

Applications of LSM: (Contd…)

In transportation systems, LSMs find wide applications. They are used in propel-wheeled and maglev vehicles.

They have more effective and efficient electromagnetic suspension. LSMs allow the use of small vehicles with short headway and decreased waiting time.

LSMs find applications in Military and Navy for shipboard elevators, automated material handling and aircraft and vehicle launch and current.

LSM can replace hydraulic actuators with same space requirement with added advantages of less wearing and higher reliability.

LSMs can be used for horizontal, vertical or inclined movements for loading and unloading ships and hazardous cargo.

ASSIGNMNET (UNIT – V)

1. Derive the Thrust equation of LIM?
2. Explain the Constructional details of any three types of LSM with neat diagram?

Note: (1) Submit the soft copy of assignment on before 09/05/2020
ravikiraneed@mjcollege.ac.in

(2) Online QUIZ form (UNIT – V) will send to your mail IDs on 08/05//2020.