Energy conversion I

Lecture 22:

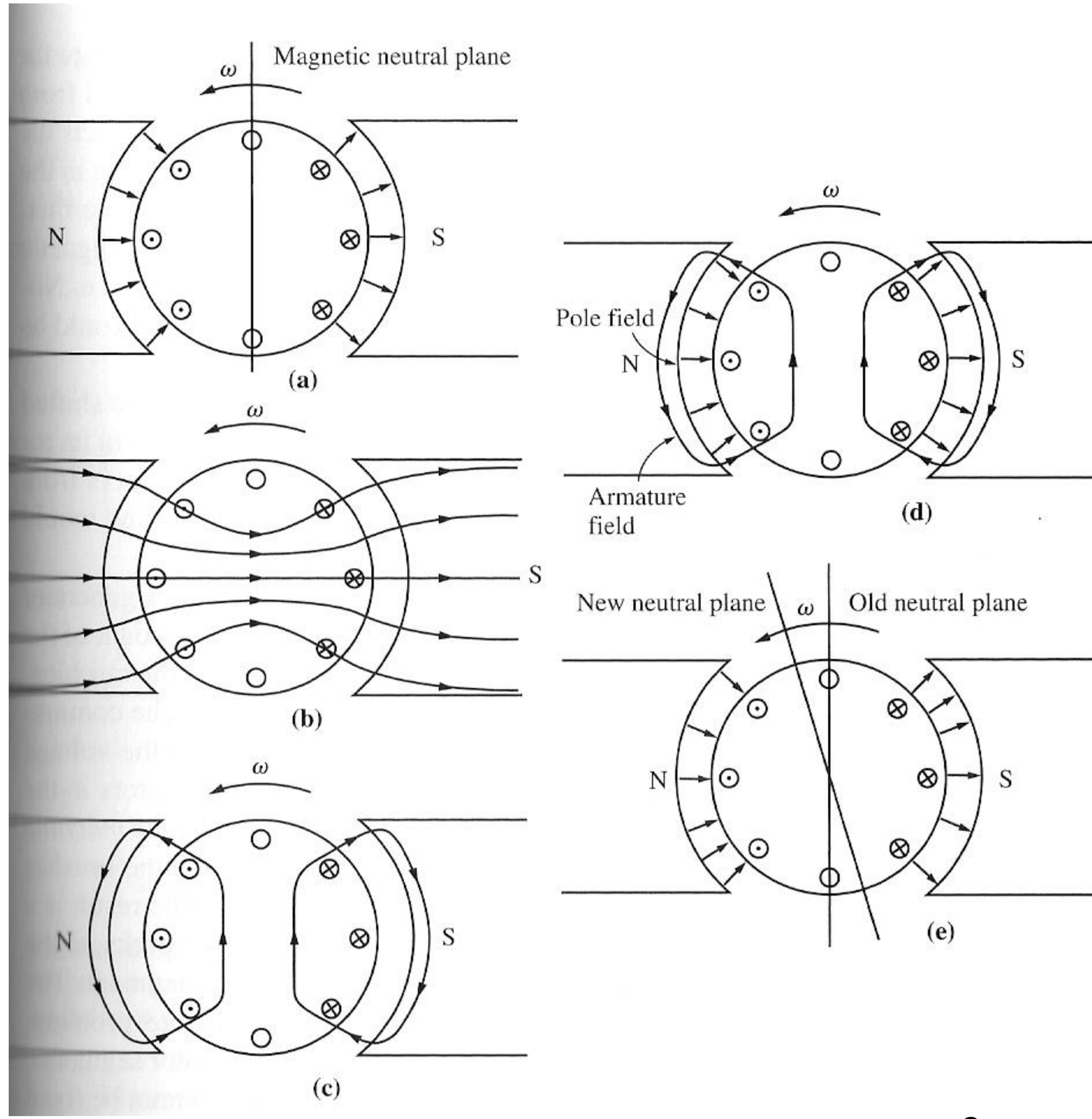
Topic 6: DC Machines (S. Chapman   ch. 8 &9)

- A Simple Rotating Loop between Curved Pole Faces.
- Structure of DC machines
- **Commutation Problems in Real Machine.**
- **The Internal Voltage and Torque Equations of Real DC Machine.**
- **The Equivalent Circuit of a DC Motor.**
- Power Flow and Losses in DC Machines.
- Separately Excited, Shunt, Permanent-Magnet and Series DC Motors.
- DC Motor Starter.
- Introduction to DC Generators.

Armature Reaction

1: Neutral plane shift

- Uniform flux in no-load machine.
- Neutral plane is vertical.
- Rotor current generates its own magnetic flux
- the neutral plane rotates!
- shift depends on rotor current.

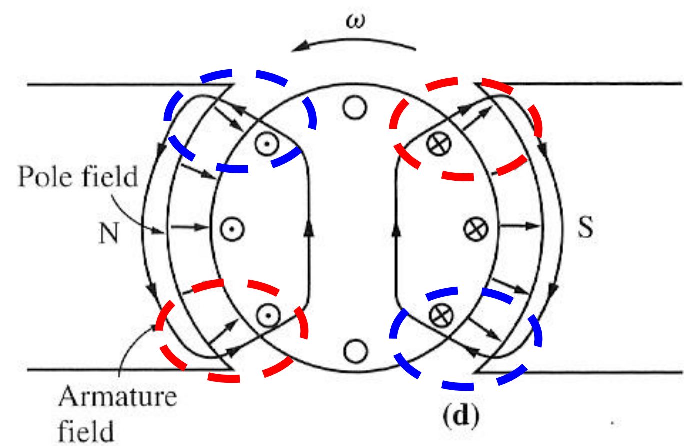


- commutator short out segments when voltage across them is zero.
- When the machine is loaded, the neutral-plane shifts
- a finite voltage across shorted segments
- circulating current between the shorted segments
- sparks at the brushes when current path is interrupted

Armature Reaction

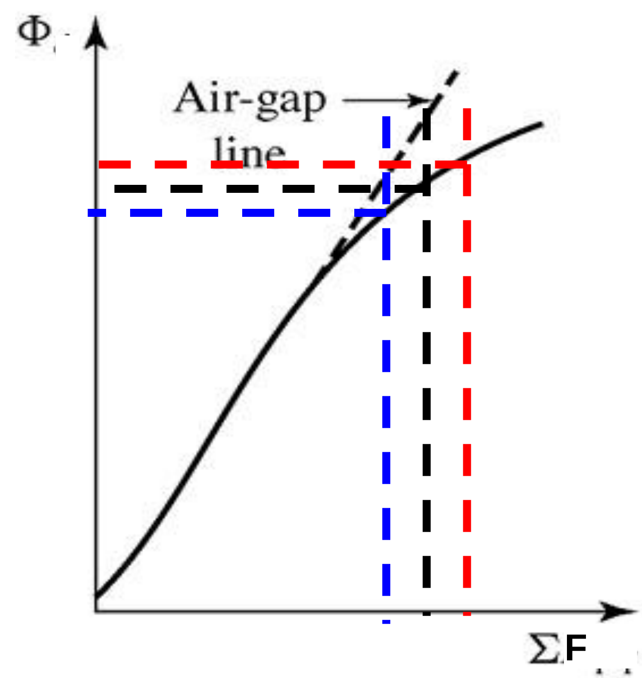
2: Flux weakening

- **Armature reaction decrease flux intensity in some parts of the magnetic poles.**
- **Armature reaction increases flux intensity in some parts of the magnetic poles.**
- **In linear systems the changes compensate each other.**
- **In saturated machines the increase is less than increase in flux.**



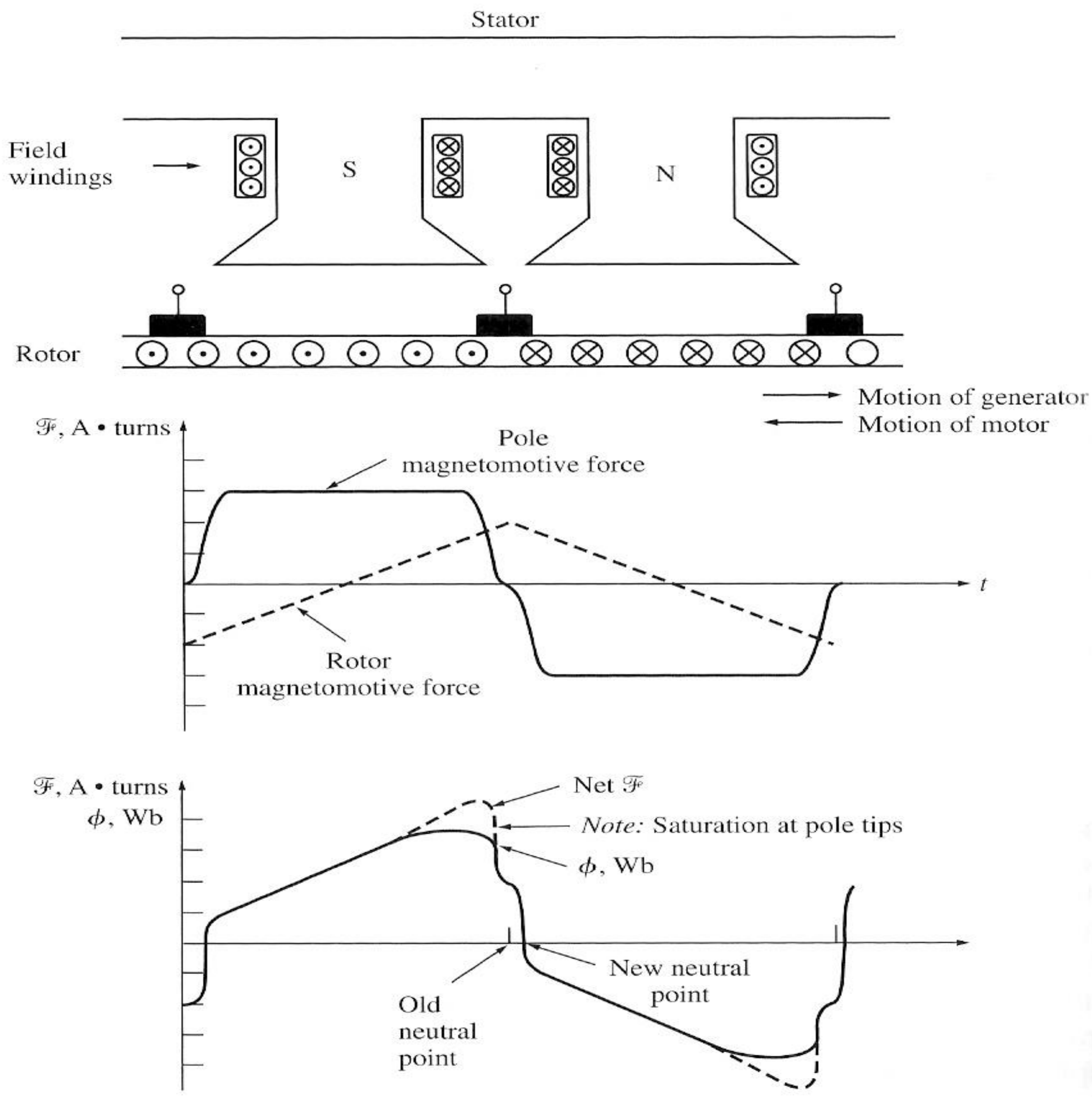
- **Reduced equivalent pole flux ϕ**

Reduced induced voltage & higher speed motor



(a)

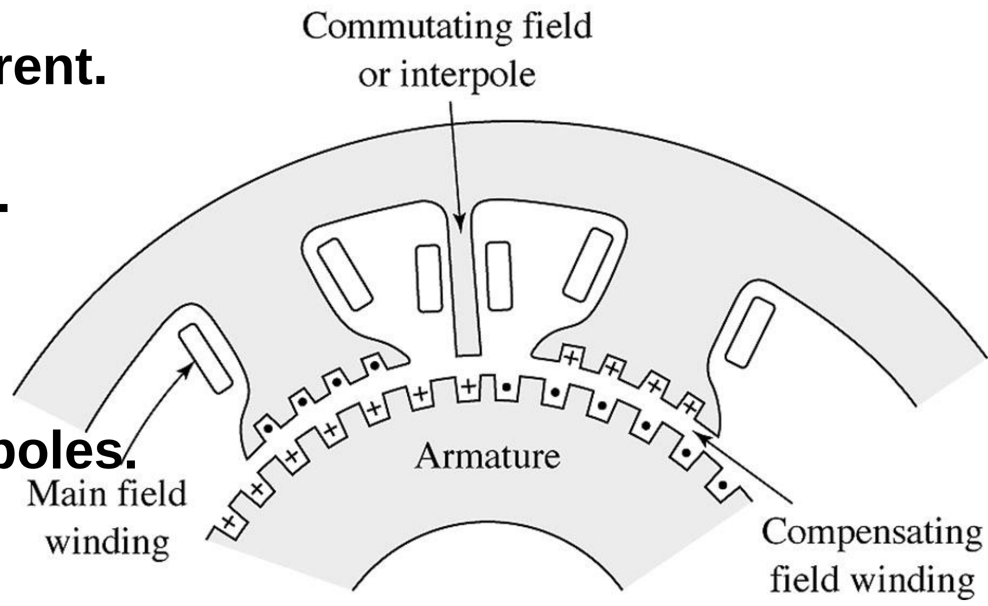
Armature Reaction



Solutions for Armature Reaction

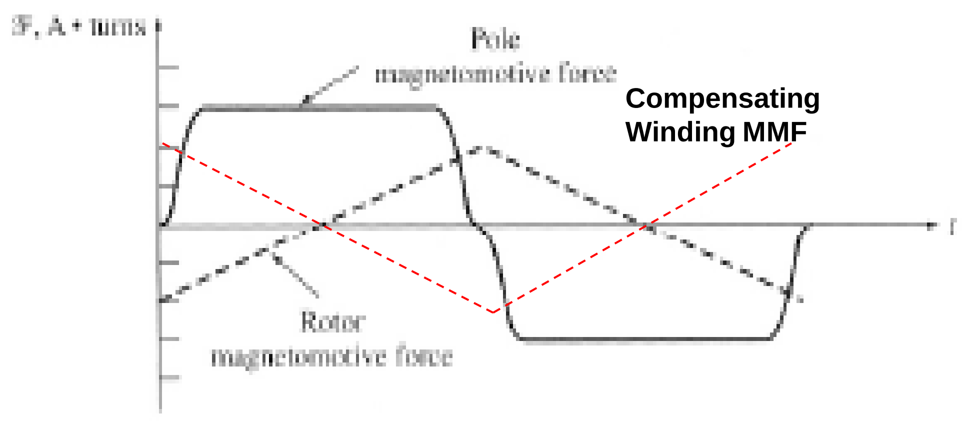
Interpoles situated between poles.
Interpoles conducting Armature current.

Compensate effect of armature field.



Compensating winding in the main poles.
Conducting Armature current.

Compensate for Armature MMF.



Internal induced voltage

- **Rotating rotor series / parallel conductors.**
- **Flux under poles due to stator winding /Permanent magnets.**
- **Induced voltage in the rotor windings.**
- **Brushes and commutator action.**
- **Induced DC voltage in the armature terminals.**

$$E_A = K \phi \omega$$

$$K = Zp / 2\pi a$$

Z: Total No. of rotor conductors

p: No. of poles

a: Number of parallel current paths

Induced Torque

- **Current in rotor series / parallel conductors.**

- **Flux under poles due to stator winding /Permanent magnets.**

- **Induced torque.**

- **Brushes and commutator action.**

$$T_A = K \phi I_A$$

$$K = Zp / 2\pi a$$

Torque is proportional to Armature current

$$E_A = K \phi \omega$$

Induced voltage is proportional to speed

Steady-State Equivalent Circuit of a DC Machine

- **Induced voltage in the armature due to rotation: E_a**

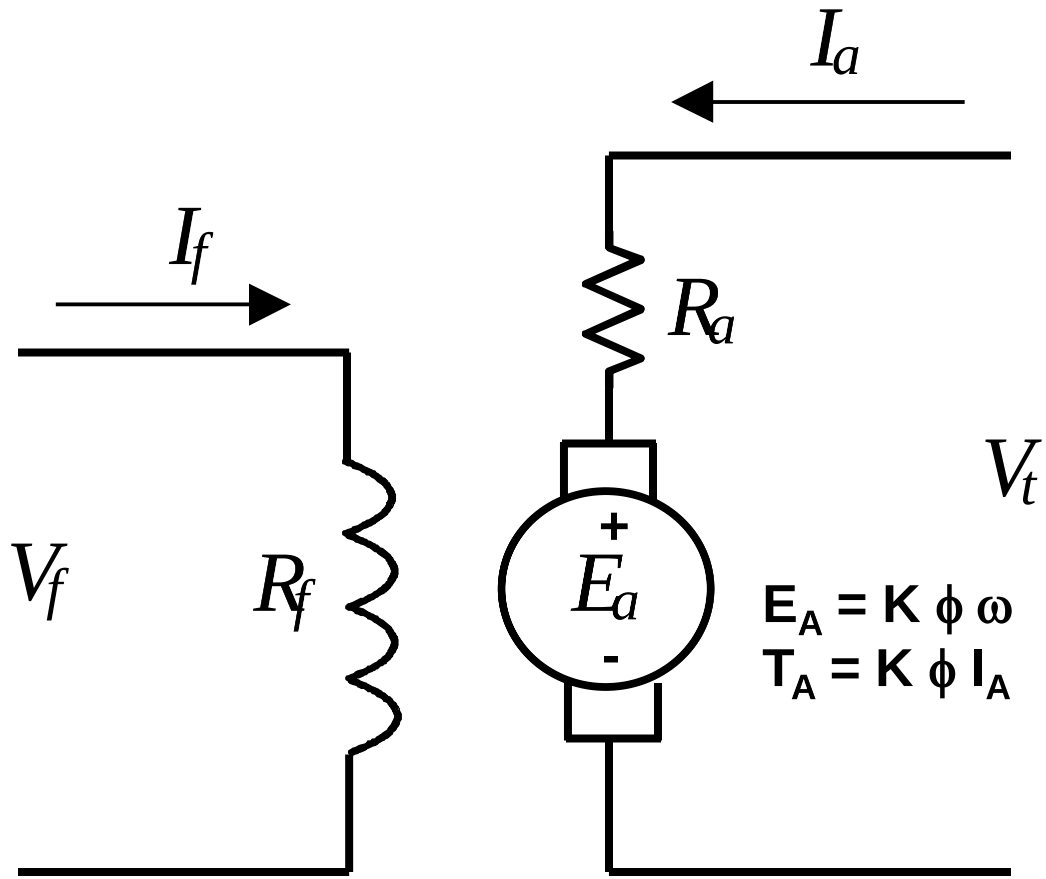
- **Armature winding has an equivalent series resistance: R_a**

- **Field winding has an equivalent series resistance: R_f**

- **Armature equivalent series inductance and field equivalent series inductance neglected in steady state modeling.**

- **Voltage drop across brushes is neglected (or included in winding resistance).**

I_a can be considered in opposite directions in motor and generator models.

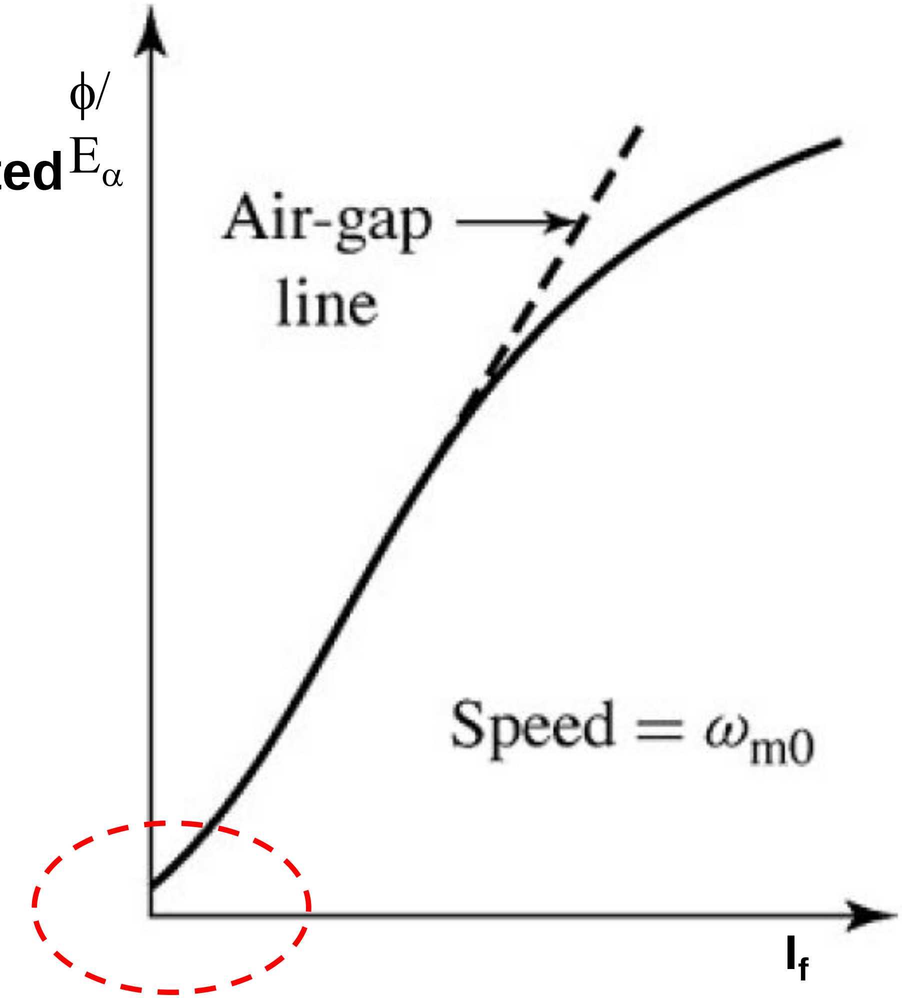


$E_A = K \phi \omega$

$T_A = K \phi I_A$

Magnetization Curve

Magnetization Curve: Ea as a function of field current (I_f) in a given speed

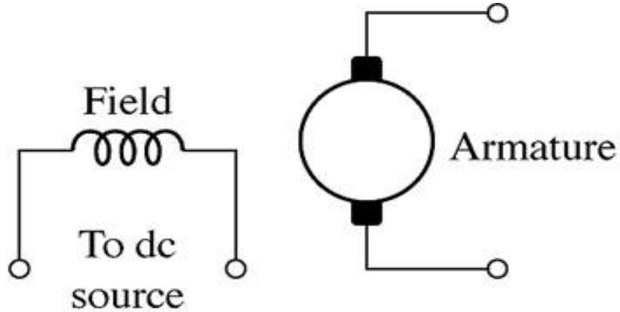


Φ a linear function of I_f ,in non-saturated situation.

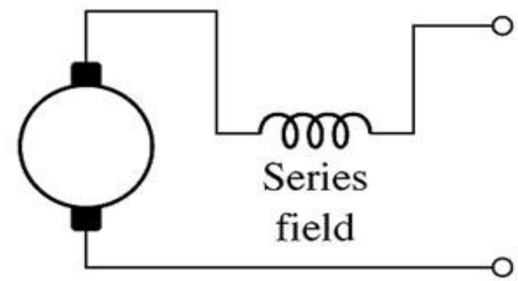
Saturation decrease the slope of Φ increase

How can be measured?

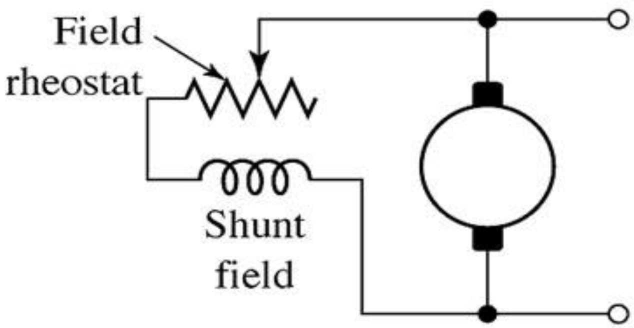
Different Connection of DC Machines



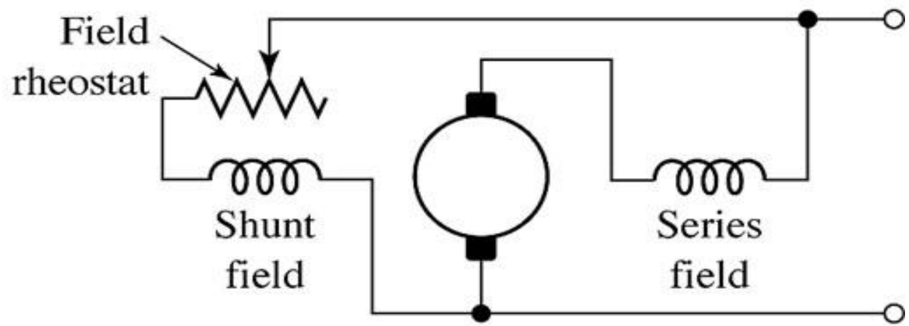
(a) Separately Excited



(b) Series



(c) Shunt



(d) Compound

What is the advantages of Series and Shunt machines compared to separately excited ones? Can we call them self-excited machines?

Compare Series field and Shunt field windings?

How series field can avoid run away of DC motors in Compound ones?