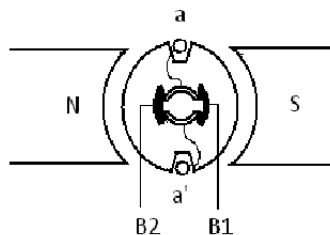## EN 206: Power Electronics and Machines
Direct Current (DC) Machines
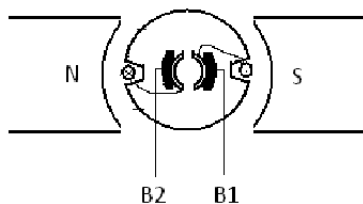
Suryanarayana Doolla

Department of Energy Science and Engineering
Indian Institute of Technology Bombay
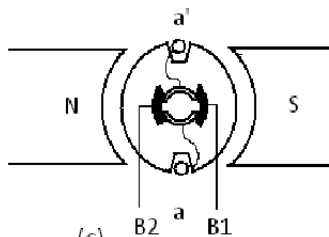email: suryad@iitb.ac.in

February 3, 2012

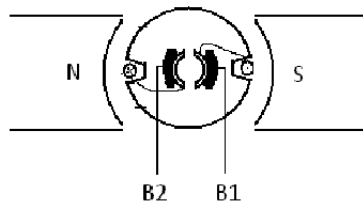# EMF Generation in DC machine

(a)

(b)

(c)

(d)

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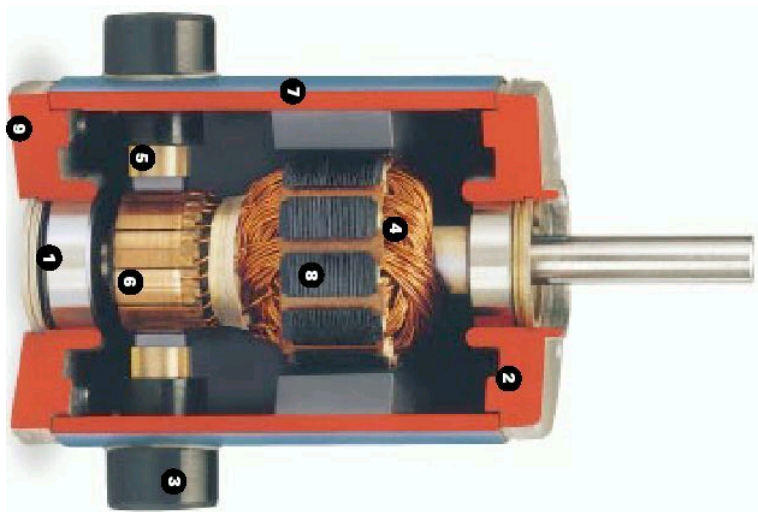
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- Brush and Commutator combination act as a mechanical rectifier.

DC Machine - Cut View

1

[1]Ref: http://zone.ni.com/devzone/cda/ph/p/id/50

Prof. Doolla (DESE)   EN 206: DC Machines   February 3, 2012   4 / 21

DC Machine - Rotor Structure
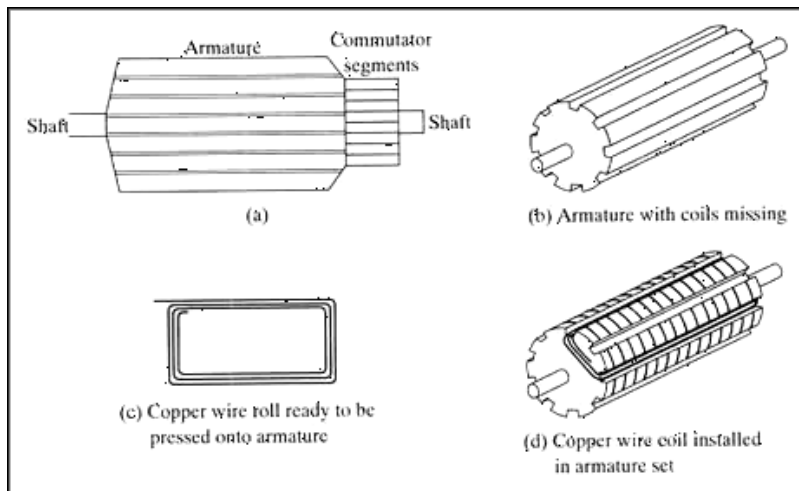
(a)

(b) Armature with coils missing

(c) Copper wire roll ready to be pressed onto armature

(d) Copper wire coil installed in armature set

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Where, ω_r is armature speed in rad/sec, N is number of turns, ϕ is flux per pole.

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- The voltage appearing at the brushes is unidirectional and hence average dc voltage is

$$E_c = \frac{1}{\pi}\int_0^\pi N\omega_r\phi\sin(\omega_r t)d(\omega_r t) = \frac{2}{\pi}N\omega_r\phi = 2NPn\phi$$

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- In dc machine, the armature winding is always double layer winding and is either lap connected or wave connected type.

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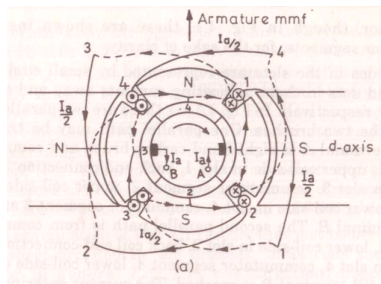
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  - Convert alternating quantities to direct quantities or vice-versa
  - Keep the rotor or armature mmf stationary in space

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- Four commutator segments (1 to 4) are insulated from each other and from the shaft.

(a)

Field MMF is in direct axis and armature mmf is in quadrature axis.

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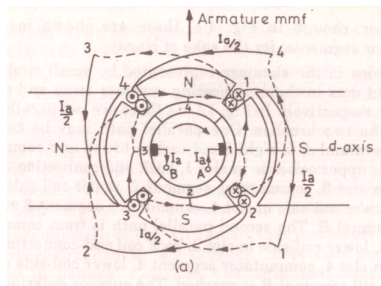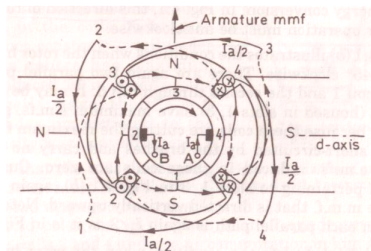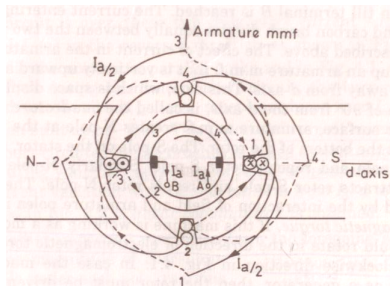

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- TerminalA-Commutator segment-1 $\rightarrow$ upper coil-side in slot-1 $\rightarrow$ back end connection 1 $\rightarrow$ lower coil-side in slot 3 $\rightarrow$ commutator segment 2 $\rightarrow$ upper coil side in slot 2 $\rightarrow$ coil 2 $\rightarrow$ lower coil side in slot 4 $\rightarrow$ commutator segment 3 $\rightarrow$ back to terminal B.

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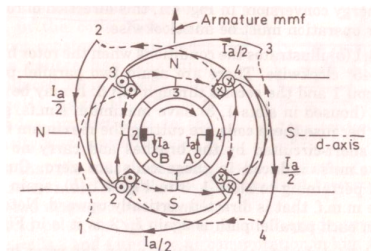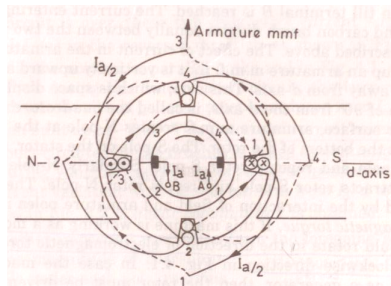
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- The process of current reversal in the coil short-circuited by the brushes is called commutation and the time duration is called commutation time.

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- Electromagnetic power or internal armature power is given by $E_a I_a$

Problem-1

A 4 pole machine has 60 slots and 8 conductors per slot. The total flux per pole is 20 mWb. For a relative speed of 1500 rpm between the field flux and armature winding, calculate the generated armature voltage if the machine is a dc machine with lap connected winding

Circuit representation of DC machine

- Each armature has several parallel paths connected to the brush terminals
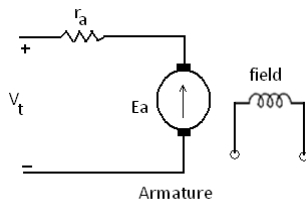
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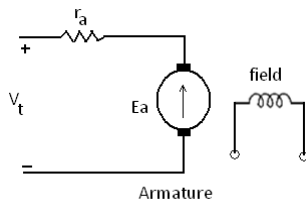
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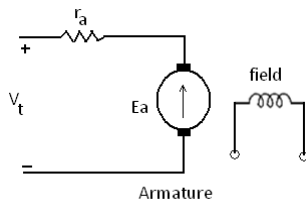
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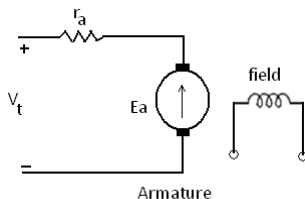
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Armature
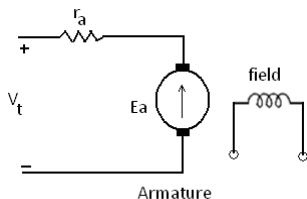
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- When the machine is operated as motor, the generated emf is called back emf or counter emf. It opposes flow of current I_a
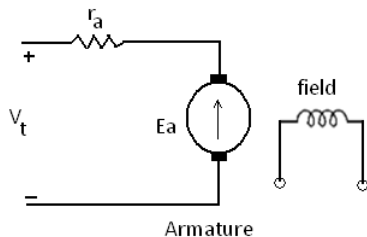
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- **When the armature rotates, a residual voltage appears across the brushed. This residual voltage should establish a current in the field winding so as to reinforce the residual flux**

Classification of DC Machine

Separately Excited Machine

- Field is supplied from an external source
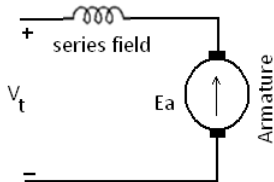
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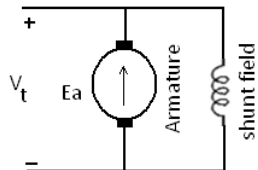- Voltage across field is independent of armature voltage and shall be designed to remain constant

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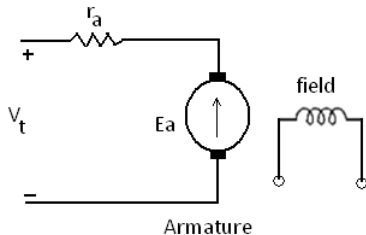
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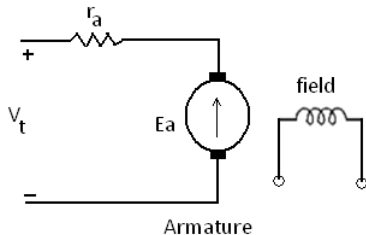
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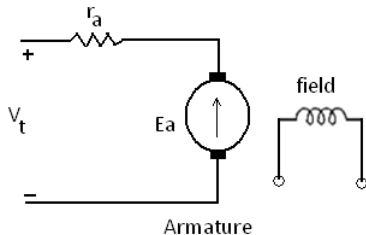
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- Field winding consist few turns of thick wire (R_{se})
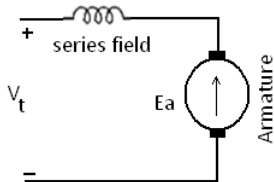
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Shunt Machine
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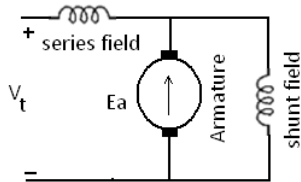## Shunt Machine

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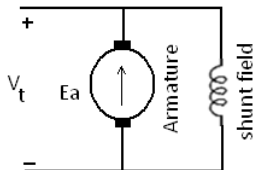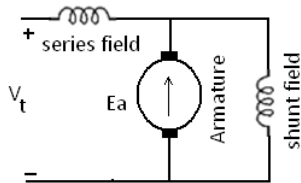- It has high resistance compared to the one connected in series (R_{sh})

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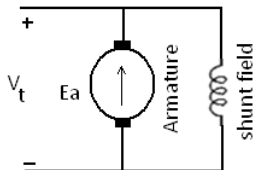
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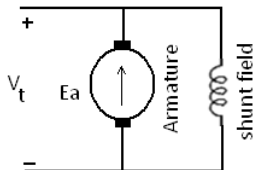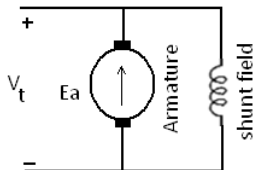
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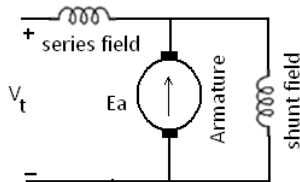
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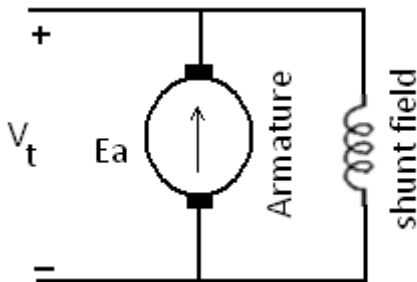

Compound Machine

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- The series field and armature field may aid (cumulative) or oppose each other (differential)

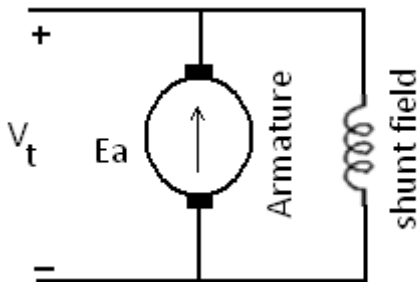# Classification of DC Machine

Long Shunt Machine

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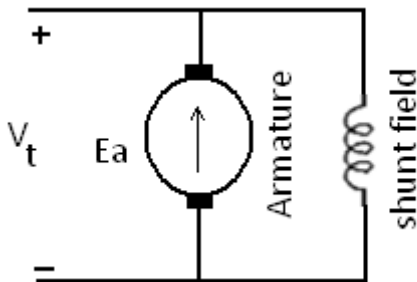
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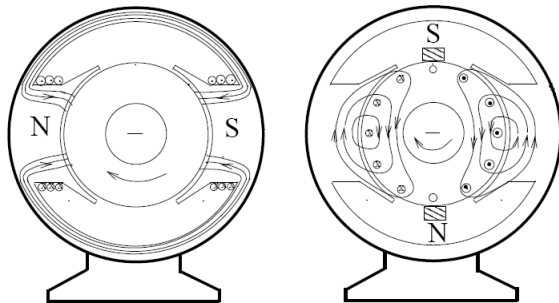- Thumb rule: Long shunt requires longer wire to connect.

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- The effect of armature mmf on field flux distribution in the air-gap is termed as **"armature reaction"**.
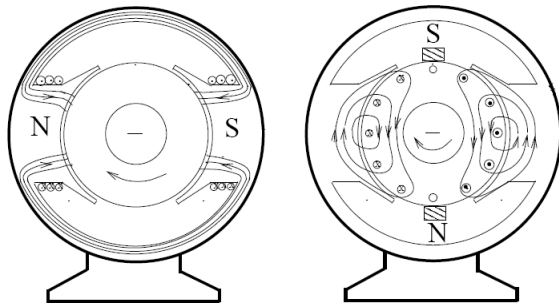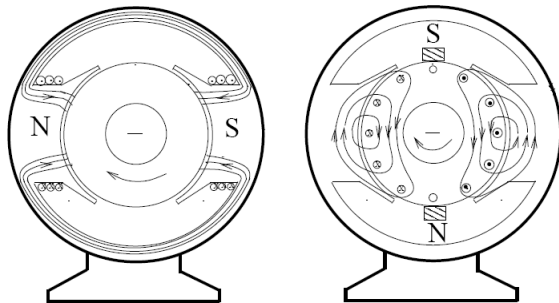
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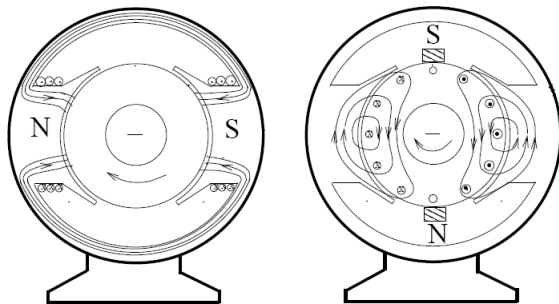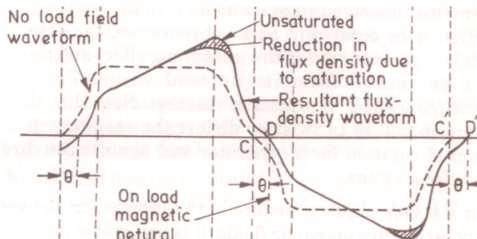
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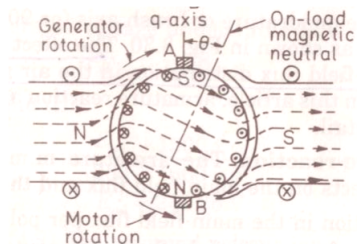 - Total main field flux will reduce per pole - reduction in generated emf and torque
  - Main field flux wave is distorted along the periphery-limits successful "commutation"

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