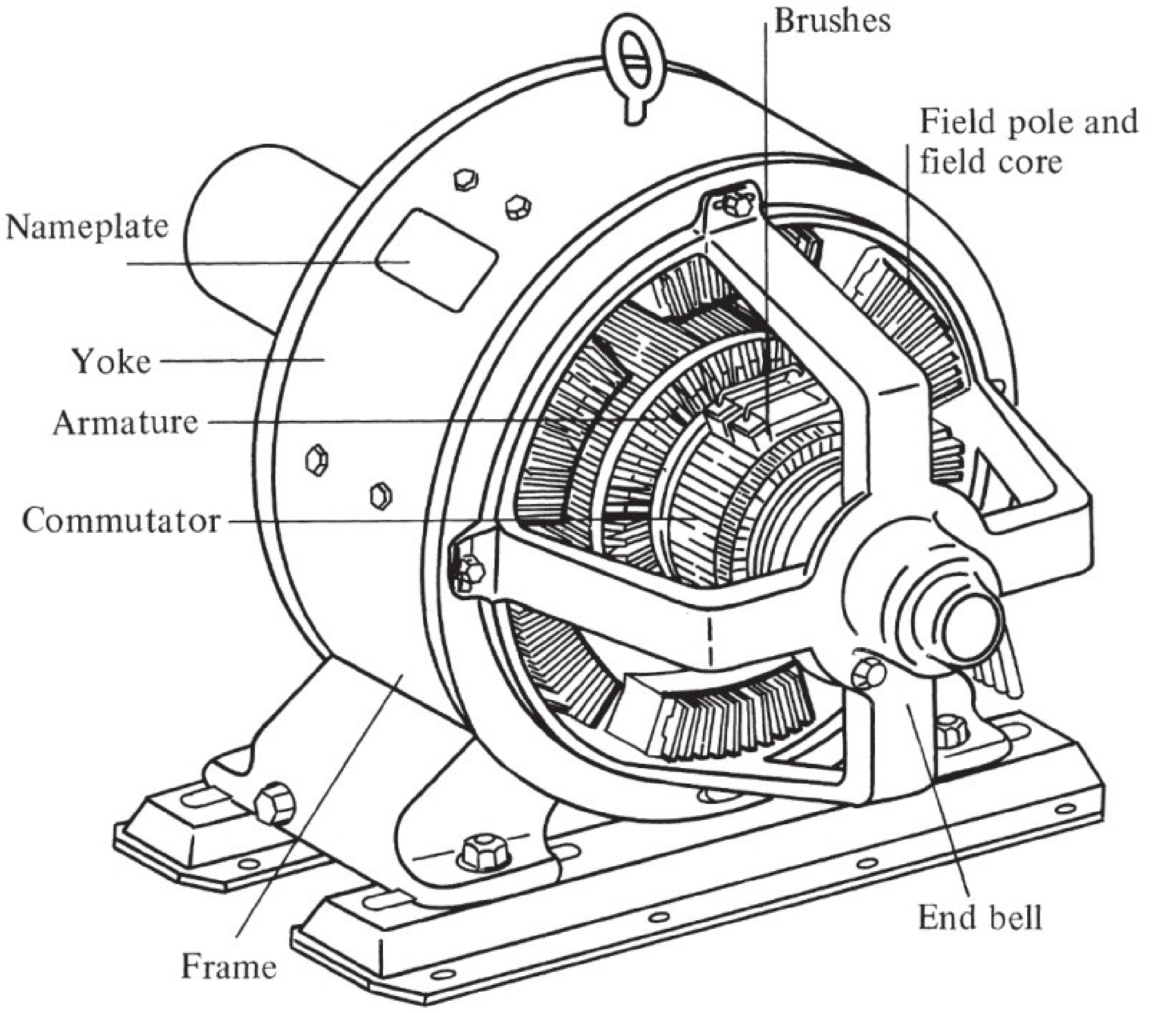
DC Machines

Introduction to Rotating Machines



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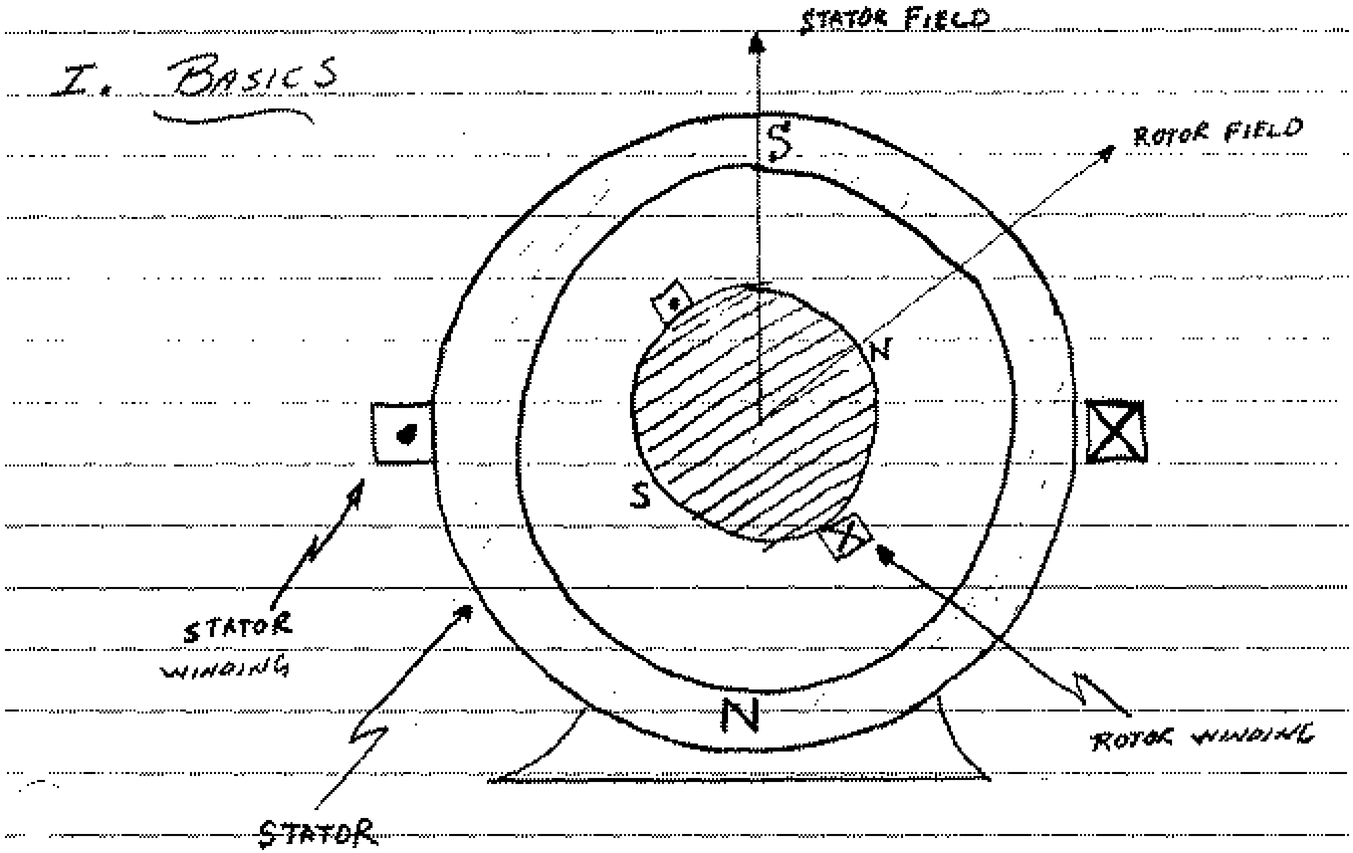

- STATOR – stationary member
- ROTOR – Rotating member

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- The <u>rotor and stator </u>each consist of a magnetic core,

some electrical insulation, and the windings necessary
to establish a magnetic flux (unless it is created by a permanent magnet).

- The rotor is mounted on a bearing supported shaft,

which can be connected to mechanical loads (motor) or to a primer mover (generator), by means of belts, pulleys or other mechanical couplings.

- The basic electrical machine creates two magnetic

Introduction to Rotating Machines

The <u>windings</u> carry the electrical currents that generate the magnetic fields and that flow to the electrical loads.

If the current serves the sole purpose of <u>providing a magnetic field</u> and is independent of the load, it is called a magnetizing, or exciting current. The winding in which it flows is called a <u>field winding</u>.

If the windings carry the <u>load current</u>, it is called the <u>armature winding or armature</u>.

Introduction to Rotating Machines

Machine Type	Winding Purpose	Winding Type	Location	Current Type
DC Machine	In/Out Excitation	Armature Field	Rotor Stator	AC->DC DC
AC Synchronous	In/Out Excitation	Armature Field	Stator Rotor	AC DC
AC Induction	Input Output	Primary Secondary	Stator Rotor	AC AC

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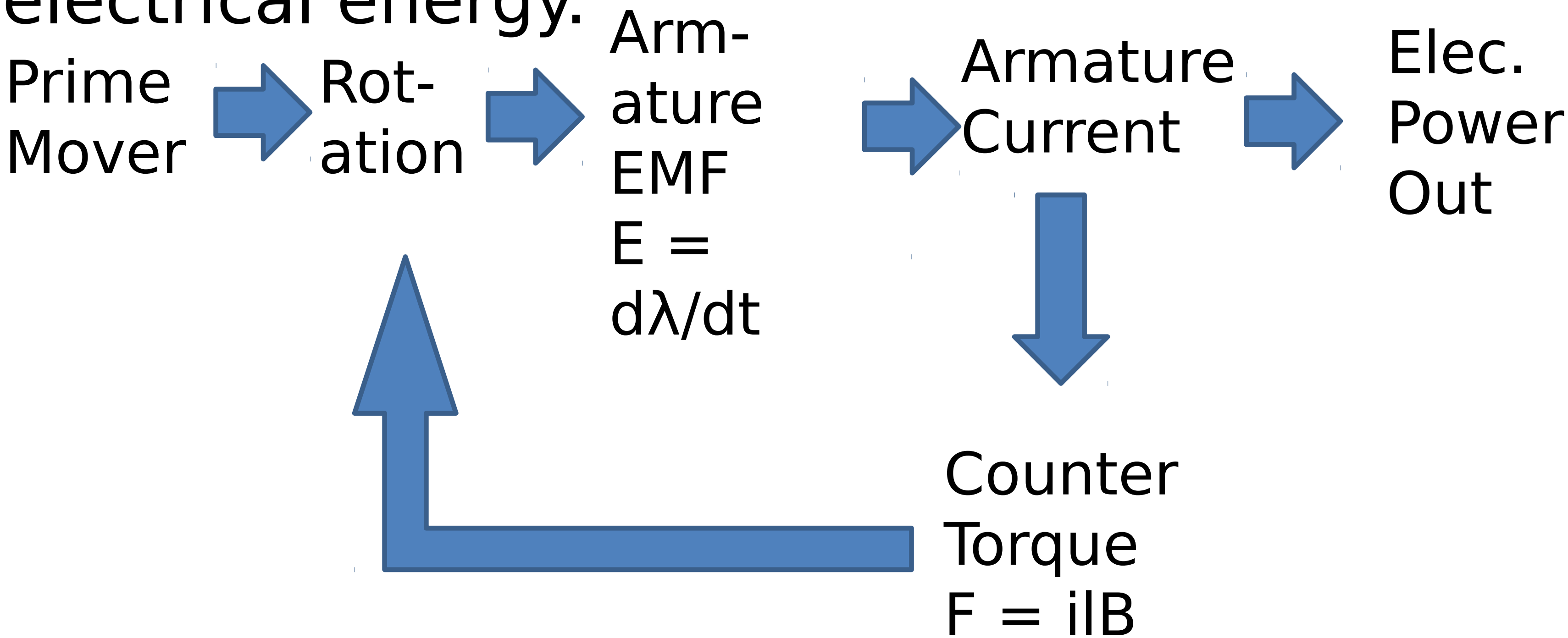
Generator : A machine that converts mechanical energy from a prime mover to electrical energy.



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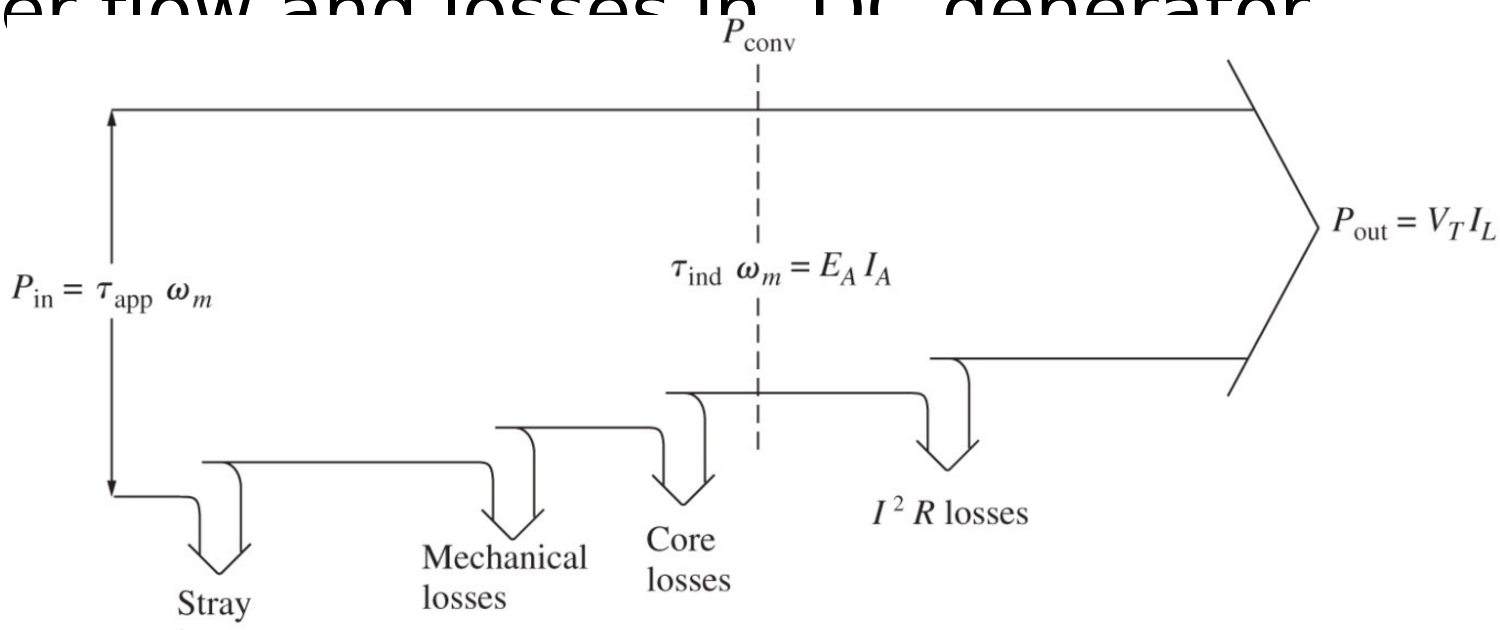
Generator: A machine that converts mechanical energy from a prime mover to electrical energy.

Power flow and losses in DC generator



(a)

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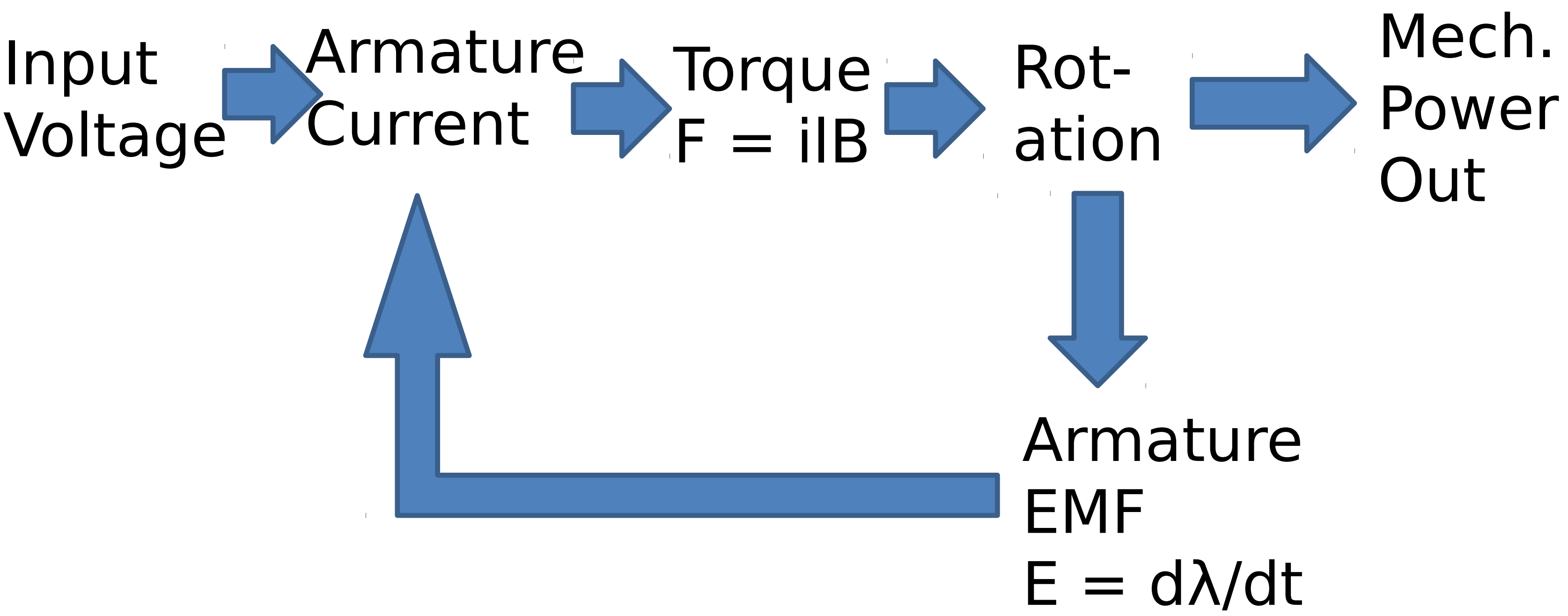
Motor : A machine that converts electrical energy from a source to mechanical energy.



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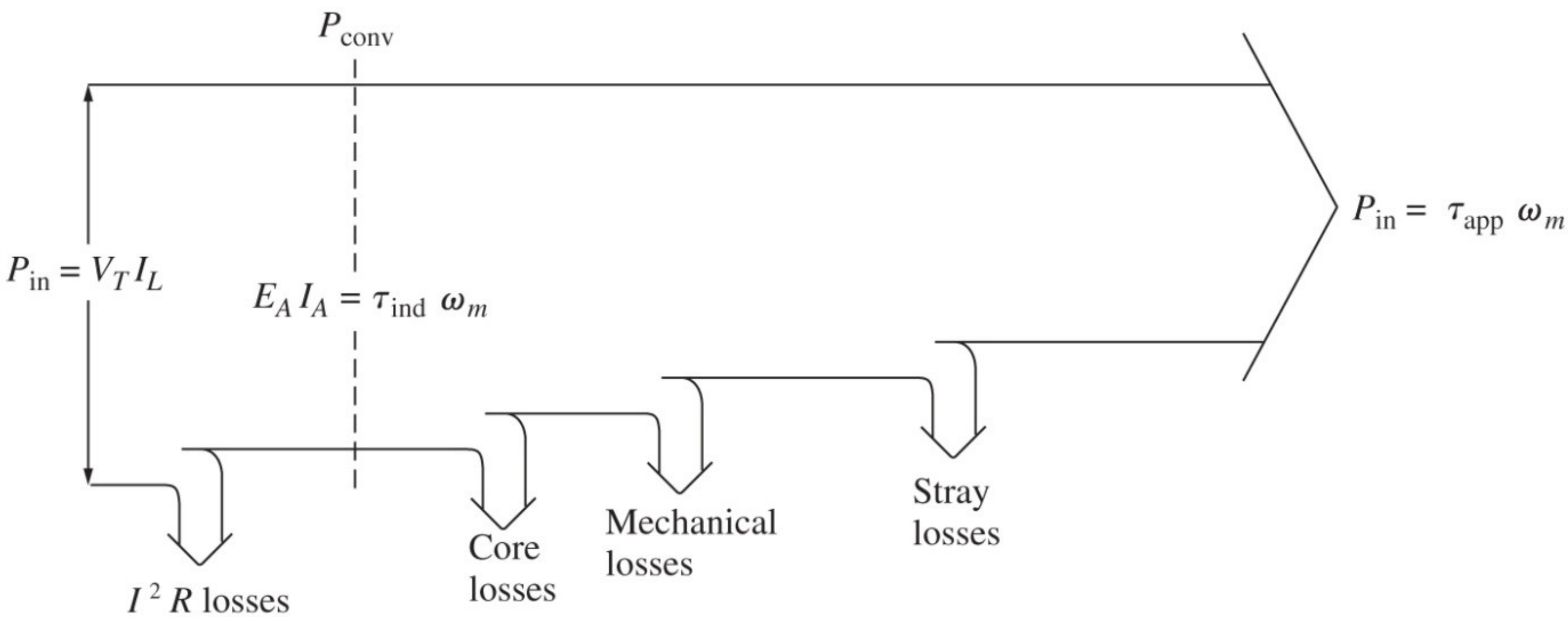
Motor: A machine that converts electrical energy from a source to mechanical energy.

Power flow and losses in DC motor



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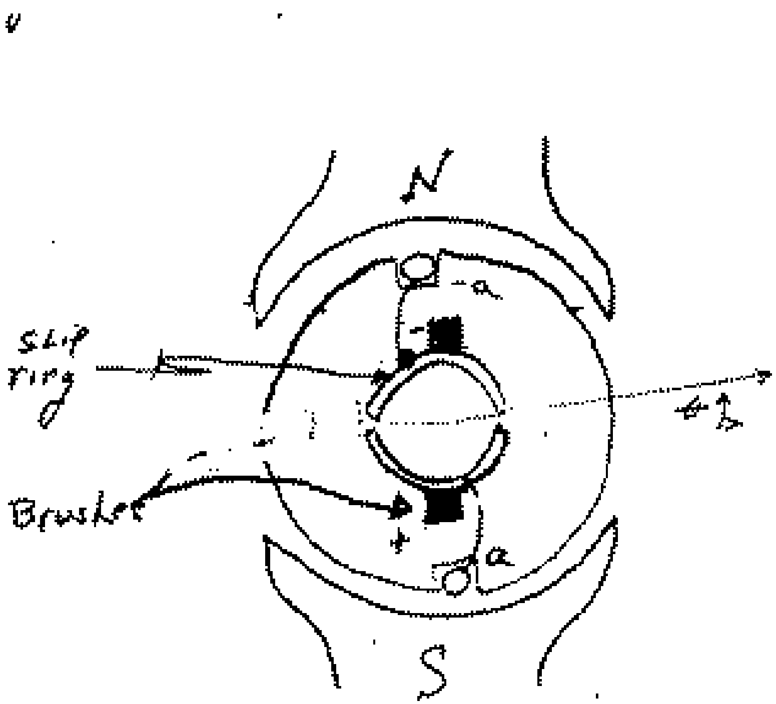
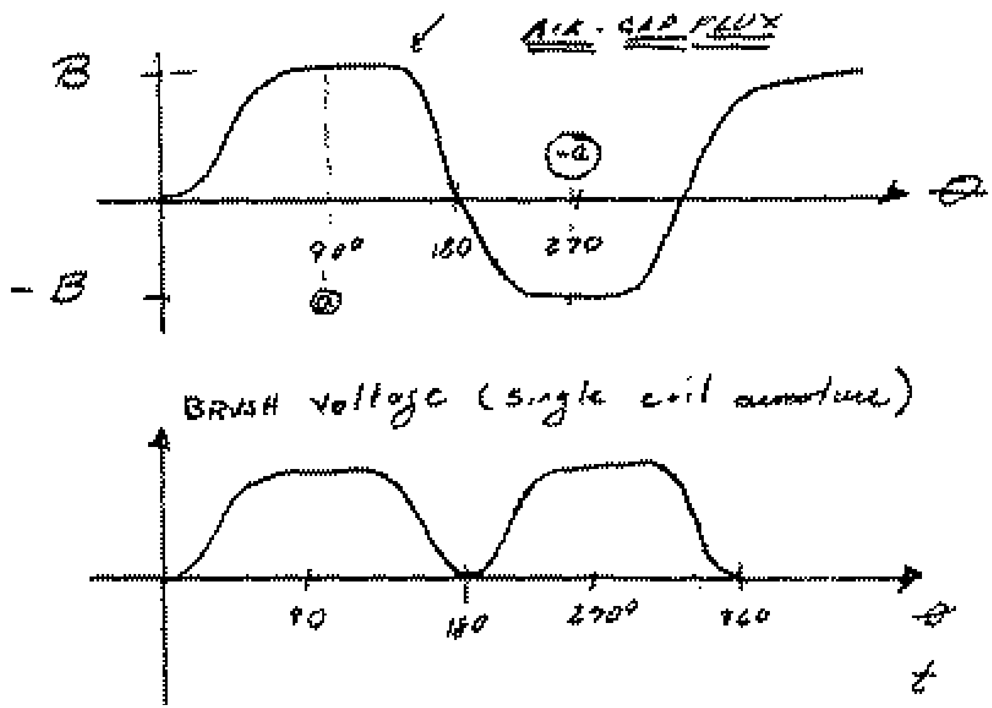
a generator the prime mover causes the rotation nd the commutator serves to rectify voltage at the rushes.

ectification occurs when the rotor winding experienc inimum flux.





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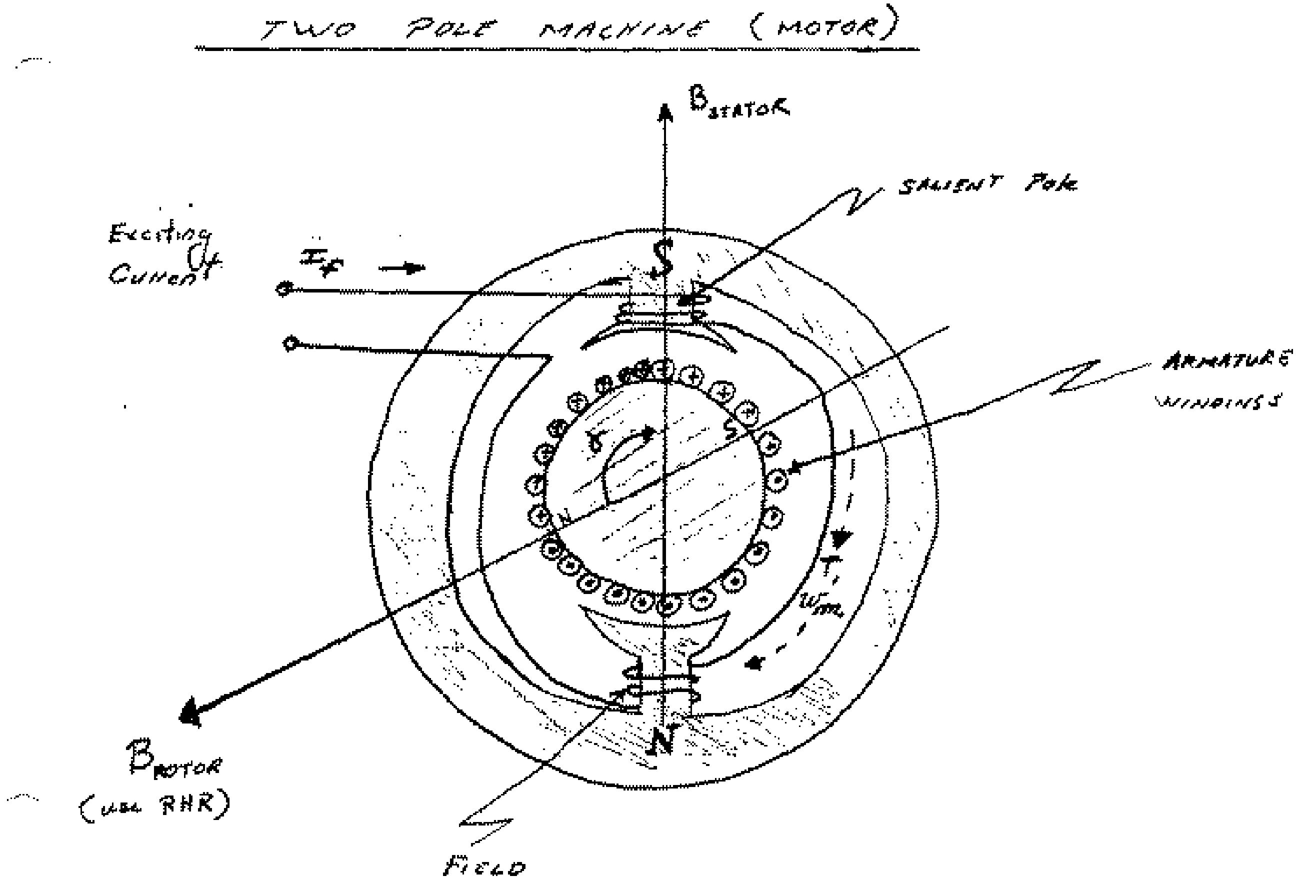

- The resulting torque T depends on the strength of the interacting B fields and the sine of angle γ between B_{STATOR} & B_{ROTOR}

- Note that when $\gamma = 0°$, $\sin(\gamma) = 0$ ∴ $T = 0$

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How to keep the rotor turning.

- In order to prevent the rotor from stopping for ϒ = 0° which implies alignment of B_{stator} and B_{rotor} two schemes are possible.

1. Supply the stator windings with an alternating current causing it's B_{stator} field to change direction periodically. Thus preventing the rotor field from aligning with that of the stator. This is how an AC synchronous machine works.

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<u>How to keep the rotor turning.</u>

2. Supply the rotor winding with an alternating current causing B_{rotor} to change direction periodically. The reversal is accomplished by the comutator assembly attached to the rotor.

- Since the torque is a maximum for $\Upsilon = 90°$, the commutator is configured so that the current distribution in the rotor windings remain constant and the <u>rotor poles are always at 90° with respect to the fixed stator poles</u>.

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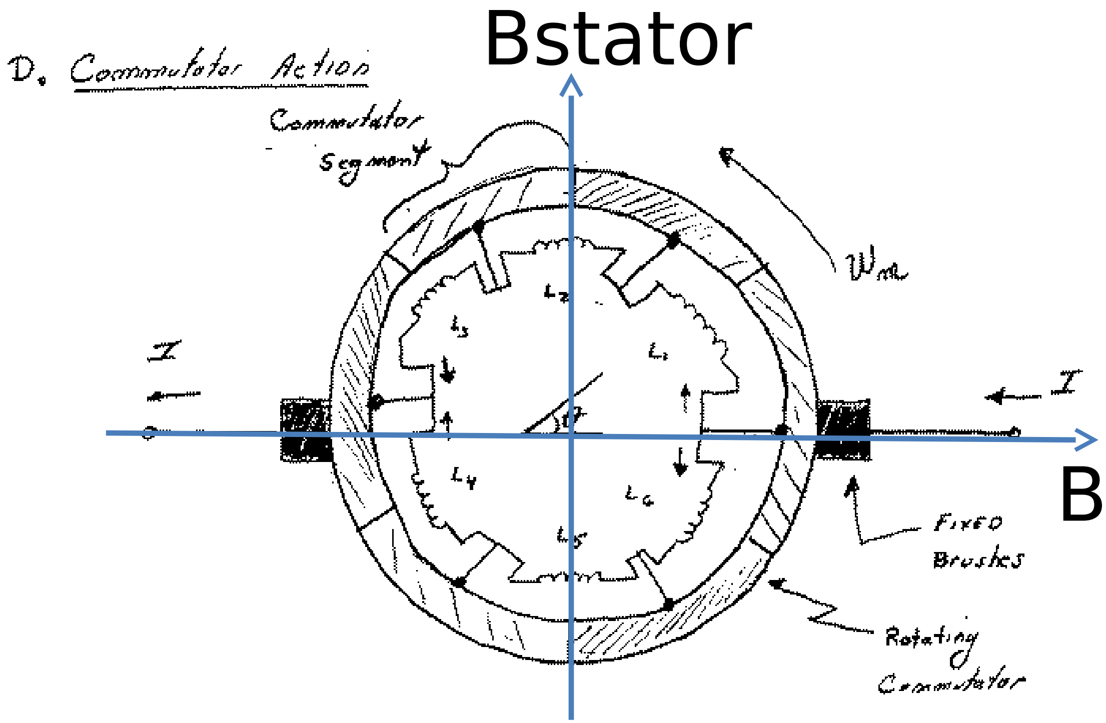
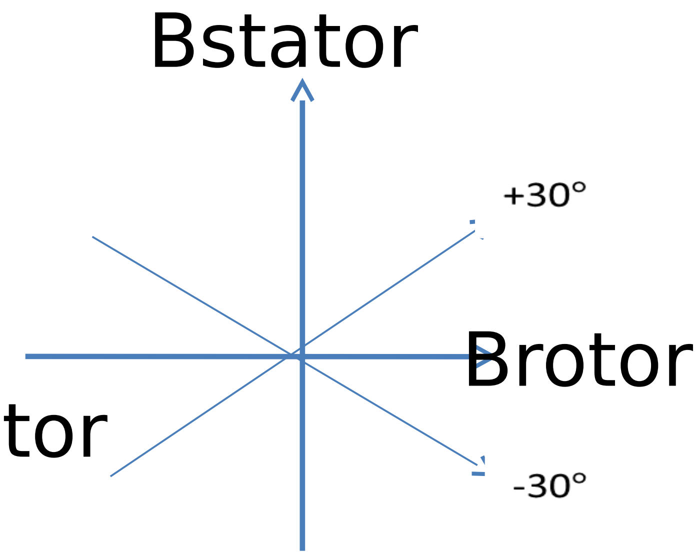
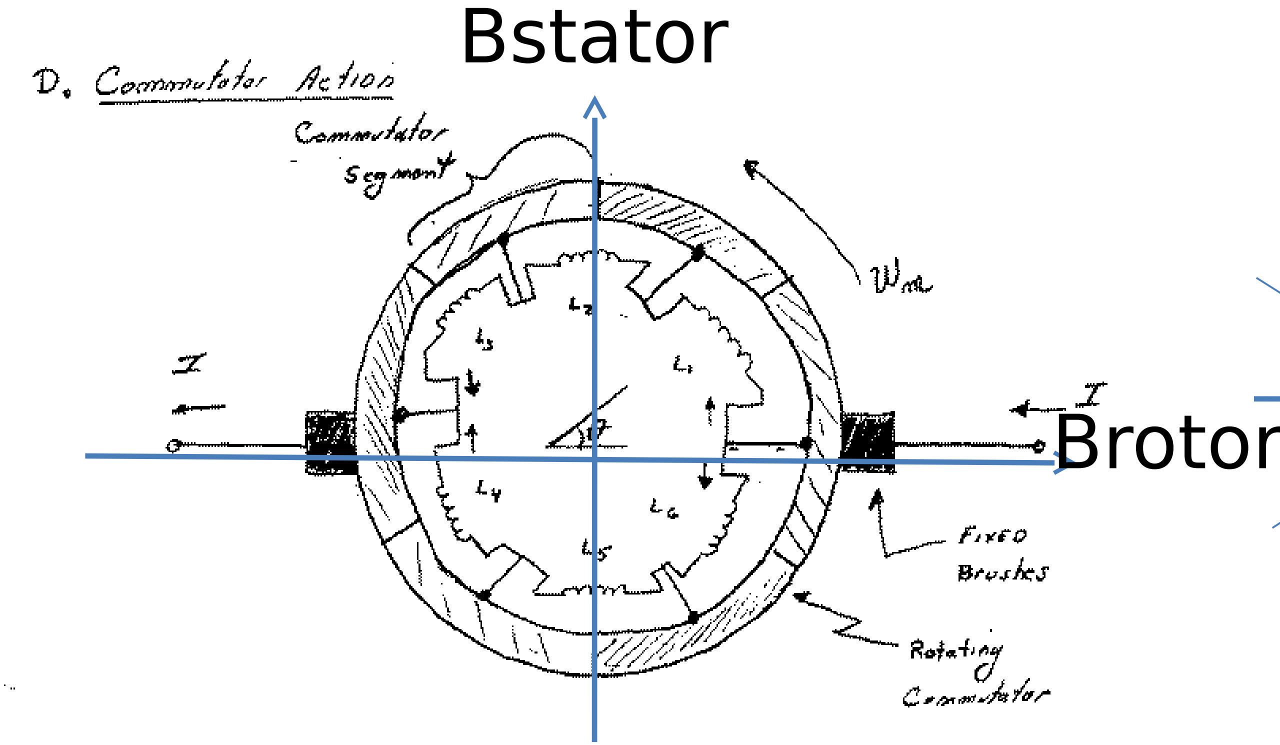
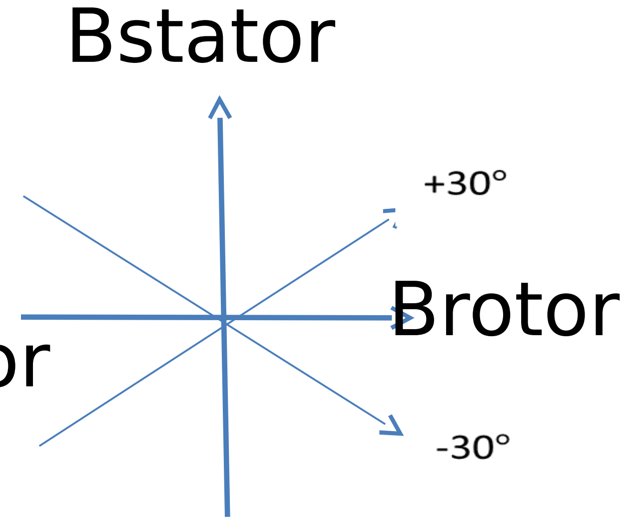




As the commutator rotates CCW with the rotor, the magnetic field Br also rotates CCW . After θ = 30°, a new segment pair will be connected to the brushes. The current through winding coils L3 and L6 will reverse direction and the rotor magnetic field will shift by 60° in the direction opposite to rotation (CW).

shift by 60in the direction opposite to rotation (CW).





As the commutator continues to rotate, the magnetic field B_{rotor} will change from -30 to +30°. Then a new segment pair will be connected to the brushes and the rotor magnetic field will again shift by 60° in the CW direction.

by 60in the CW direction.

Introduction to Rotating Machines

In this machine, the torque angle (between Bstator and Brotor) is not always the ideal value of 90° , but actually varies from 60 ° to 120° as the machine rotates. The resulting torque will vary by up to 14% {sin 30 ° = 0.86} from the maximum value.

As the number of segments are increased, the torque fluctuations produced by commutation will be reduced. For example, with 60 segments the torque angle will vary from 90° by +/- 3 °. The resulting torque will vary by only 0.5% from the maximum value.

In this way a DC motor can produce nearly constant torques and DC generators can produce nearly constant voltages.

Introduction to Rotating Machines

- **ARMATURE REACTION (AR)**

The mmf produced in the armature windings effects the spatial distribution of the air gap flux and the magnitude of the net flux per pole.

The effect of armature reaction is to create flux crossing the main field flux. This is called cross magnetizing armature reaction, or just armature reaction.

Armature reaction causes a decrease in the air gap flux under part of the pole face and an increase under the other part of the pole. Because of magnetic saturation of the machine iron, the net flux is decreased by a greater

Armature Reaction Effects

- The effect of the *magnetic flux generated by the armature current* on the *main magnetic field* of the machine is called *armature reaction*.
- Shift in the *magnetic neutral plane*: arching and sparking at the brushes when machine is loaded.

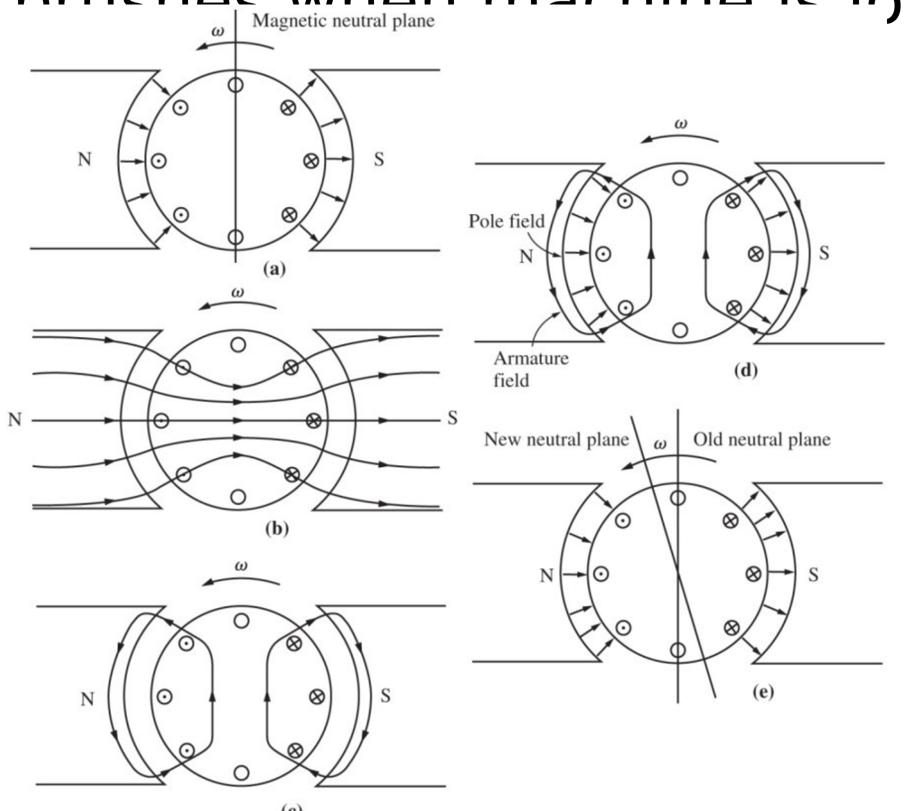
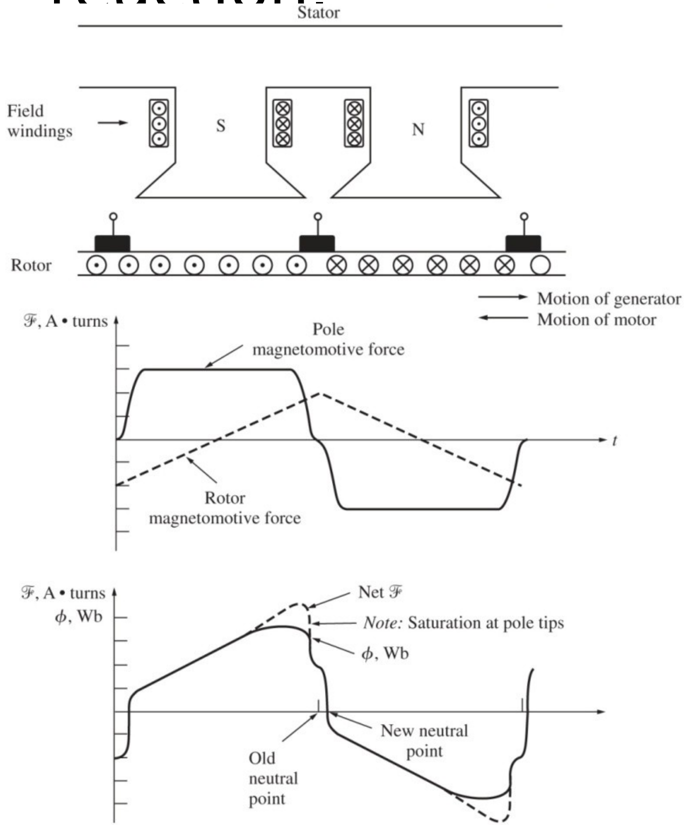
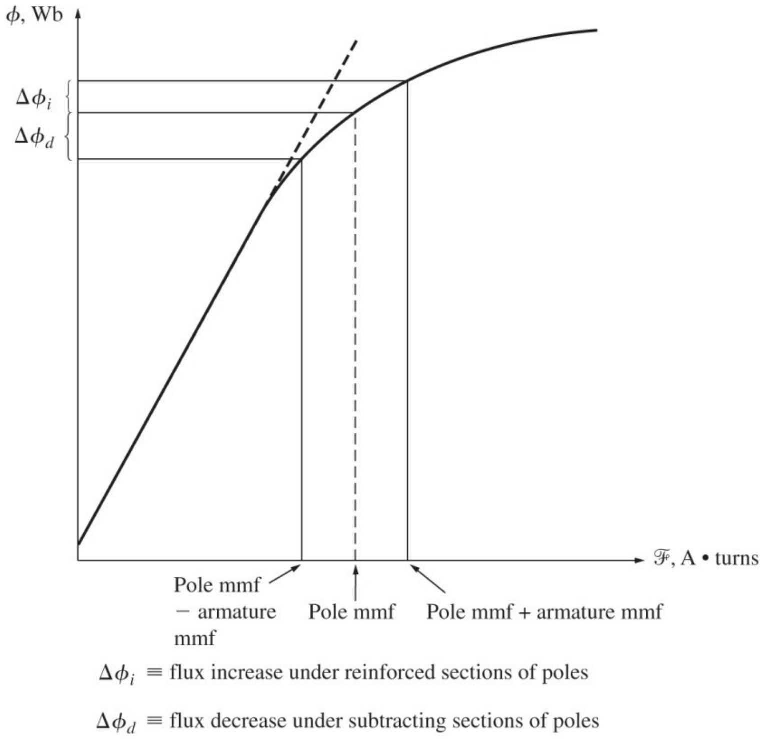


Figure 7-23
The development of armature reaction in a dc machine.

Armature Reaction Effects

- The *flux-weakening* caused by the armature reaction.





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- **ARMATURE REACTION**

Quantitatively, the effect of AR is complex due to the non-linear behavior of machine saturation. Typically the effects of AR are determined experimentally, and are displayed via the machines <u>magetization curve</u>.

The effect on the net field is loosely <u>proportional to the armature current Ia</u>. Therefore, a family of mag. curves are drawn for a series of values of Ia. So for analysis purposes, the effect of AR can be accounted for simply by using the appropriate curve for the Ia in question.

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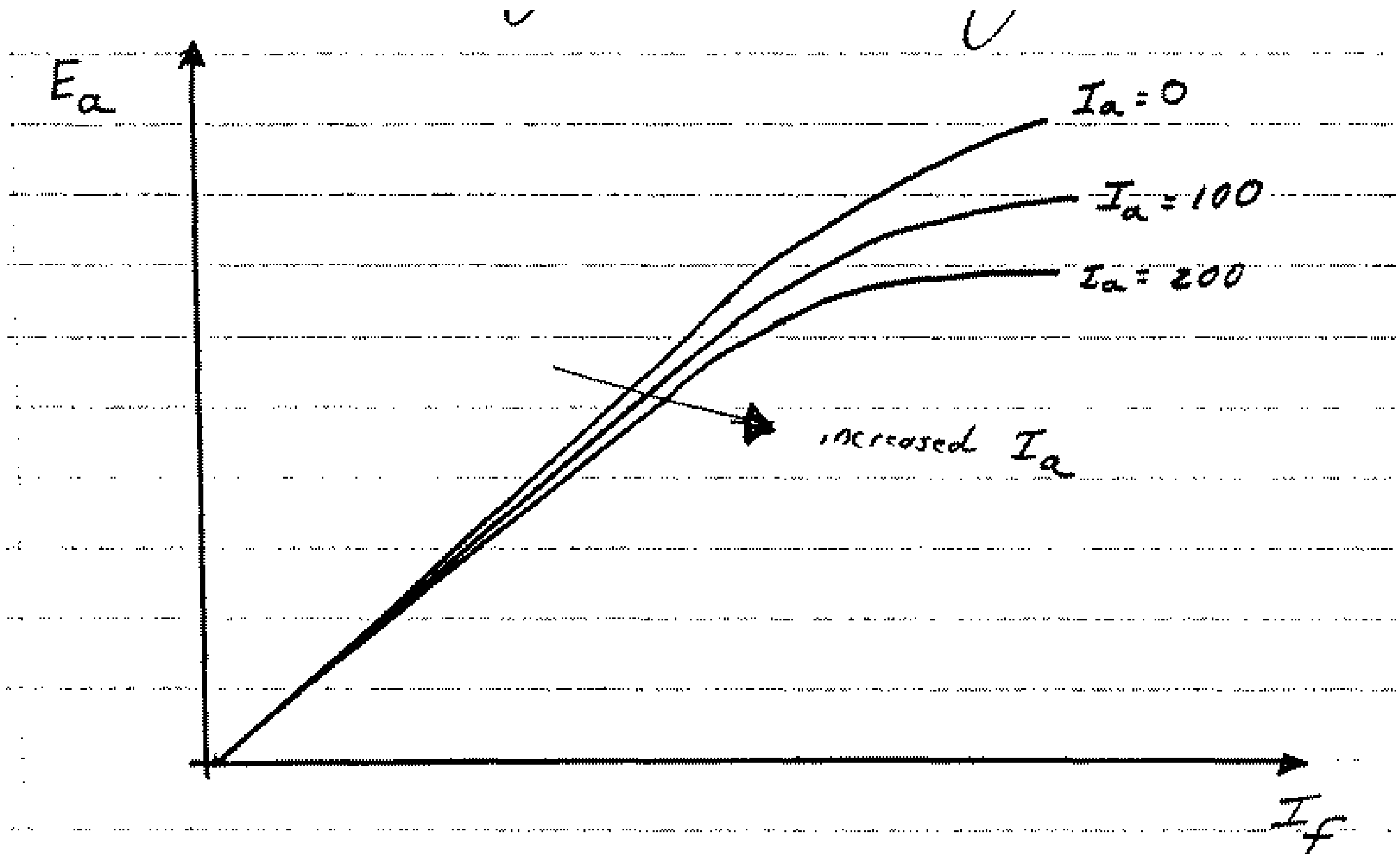
- **ARMATURE REACTION**

In general the amount of AR increases proportional to Ia. Therefore, the result of AR is to shift the curve to the right for increasing Ia.



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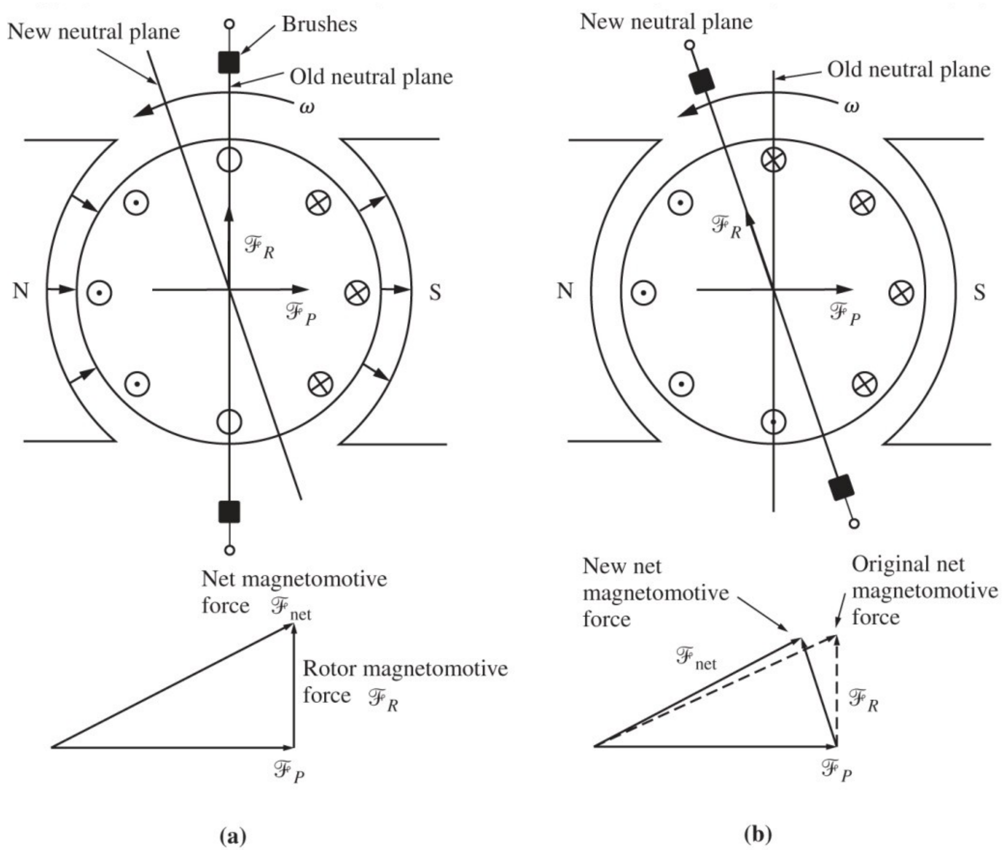
- **ARMATURE REACTION**

AR can be reduced by design**.** It is beneficial to ensure that the main field is predominant in the air gap. Thus favor a strong field mmf and weak armature mmf as far as practical.

More elaborate designs will include pole face shaping, armature teeth shaping, additional windings (compensating windings) and additional poles (interpoles). All in an effort to counter the ill effects of AR.

Solution to the Problems with Armature Reaction

- Brush shifting



(a) The net mmf with brushes in the vertical position. (b) The net mmf with its brushes over the shifted neutral plane. Note that now there is a net opposing armature-reaction mmf.

Solution to the Problems with Armature Reaction

- Commutating Poles or Interpoles, are placed midway between main poles producing an mmf equal but opposite to the mmf of the armature reaction.

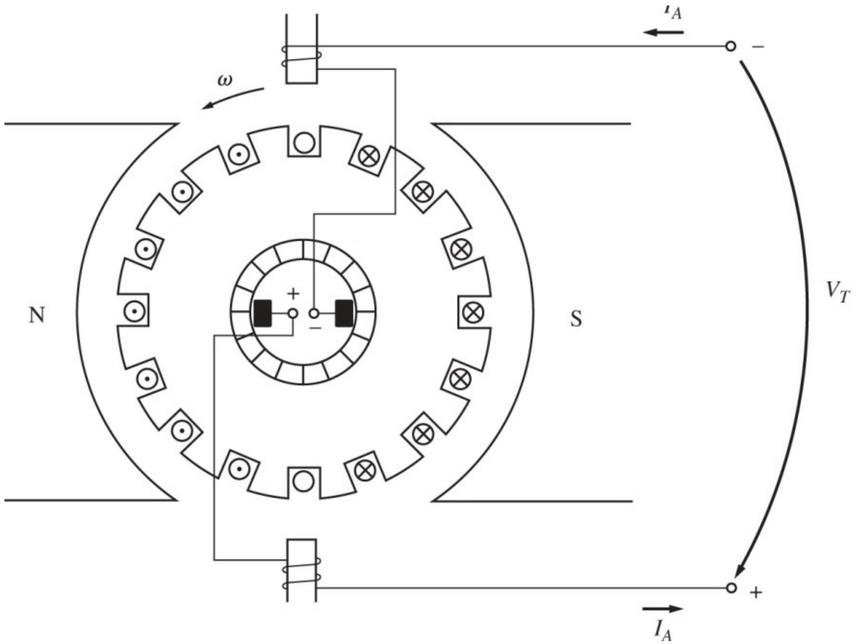


Figure 7-28
A dc machine with interpoles.

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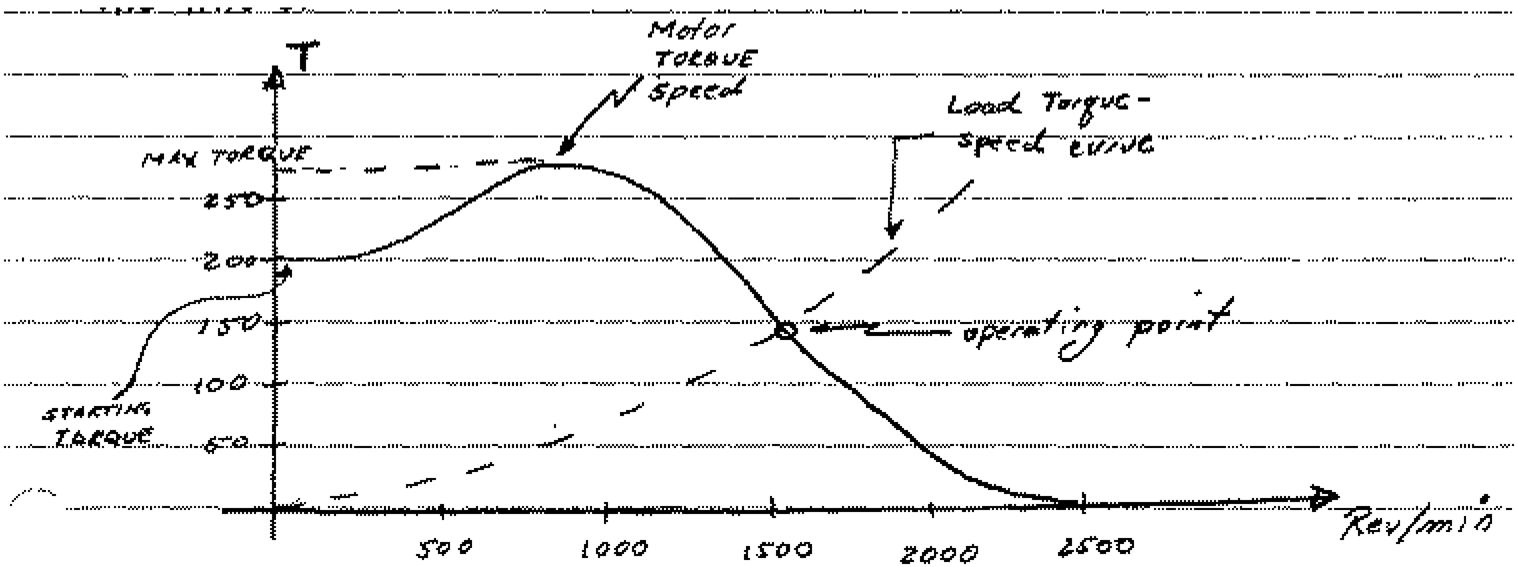
- **Torque Speed Curve (Motor)**

  The T-S characteristic of a motor describes how the torque supplied by the machine varies as a function of the speed of rotation of the mo



A motor is not an ideal source of torque (if it were the T-S curve would be horizontal line)