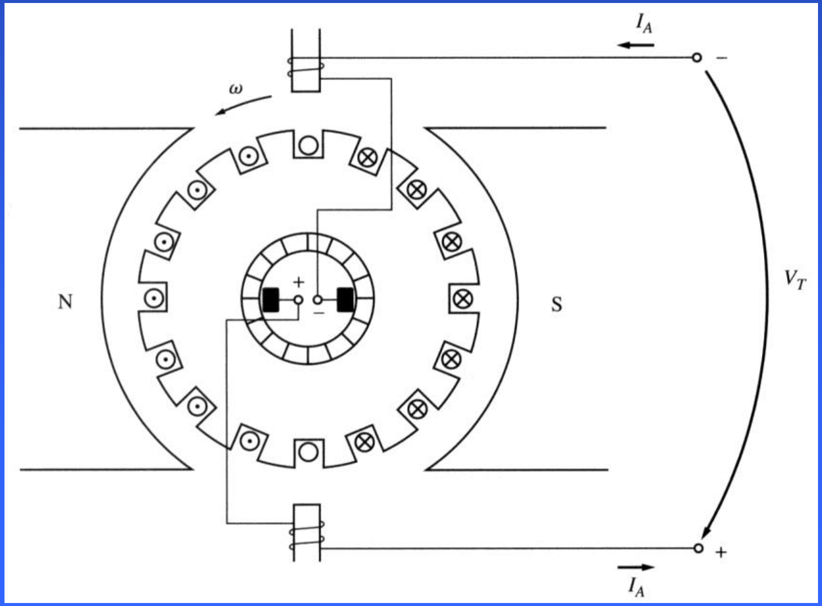
Solutions to the problems with commutation

1. Commutating poles or interpoles

To avoid sparkling at the brushes while the machine’s load changes, it is possible to introduce small poles (commutating poles or interpoles) between the main poles to make the voltage in the commutating wires to be zero. Such poles are *located* directly over the conductors being commutated and provide the flux that can exactly cancel the voltage in the coil undergoing commutation. Interpoles do not change the operation of the machine since they are so small that only affect few conductors being commutated. Flux weakening is unaffected.

Interpole windings are *connected* in series with the rotor windings. As the load increases and the rotor current increases, the magnitude of neutral-plane shift and the size of *Ldi/dt* effects increase too increasing the voltage in the conductors undergoing commutation.



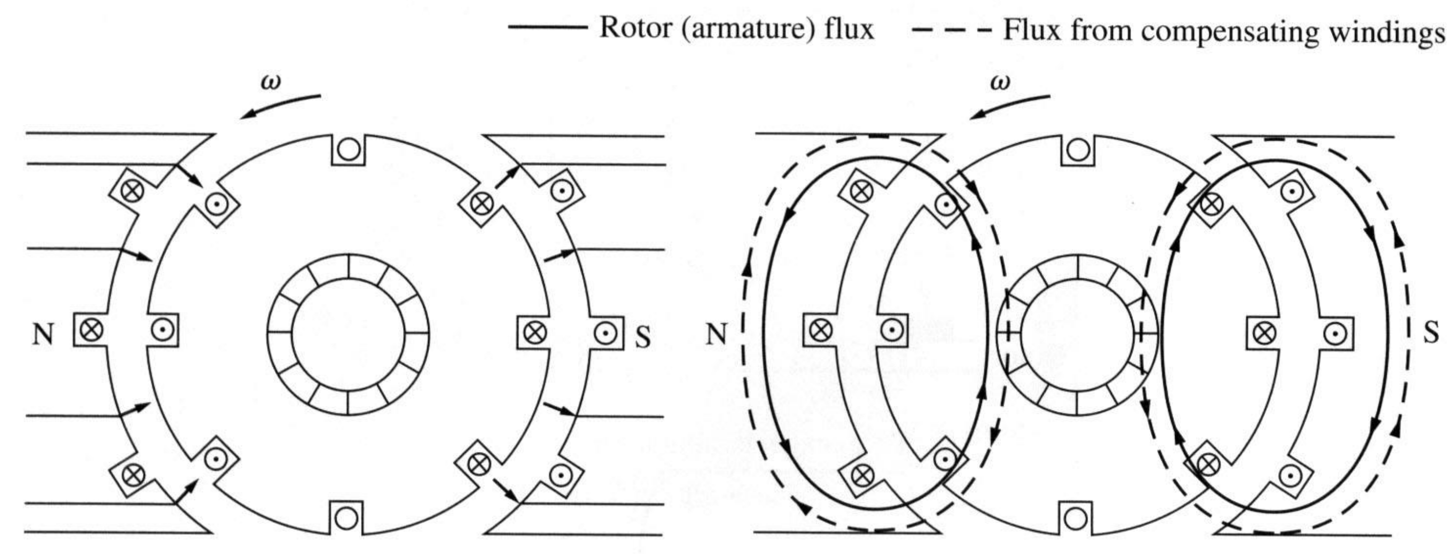
Solutions to the problems with commutation

2. Compensating windings

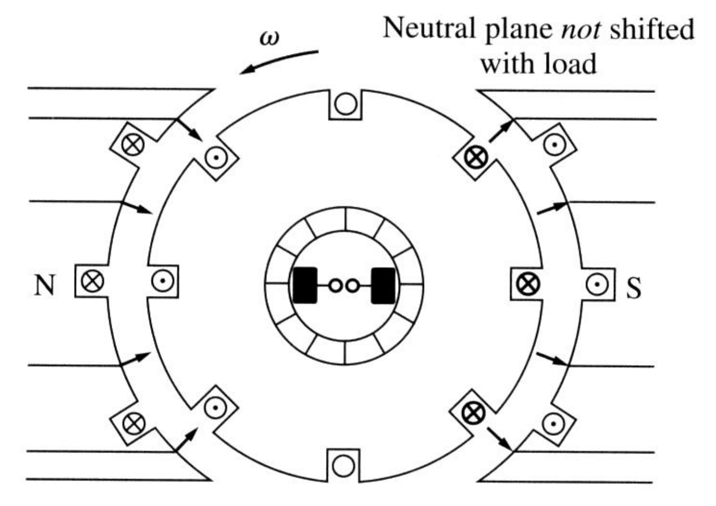
The flux weakening problem can be very severe for large DC motors. Therefore, compensating windings can be ***placed*** in slots carved in the faces of the poles parallel to the rotor conductors. These windings are ***connected*** in series with the rotor windings, so when the load changes in the rotor, the current in the compensating winding changes too…

Solutions to the problems with commutation

Pole flux



Rotor and comp. fluxes

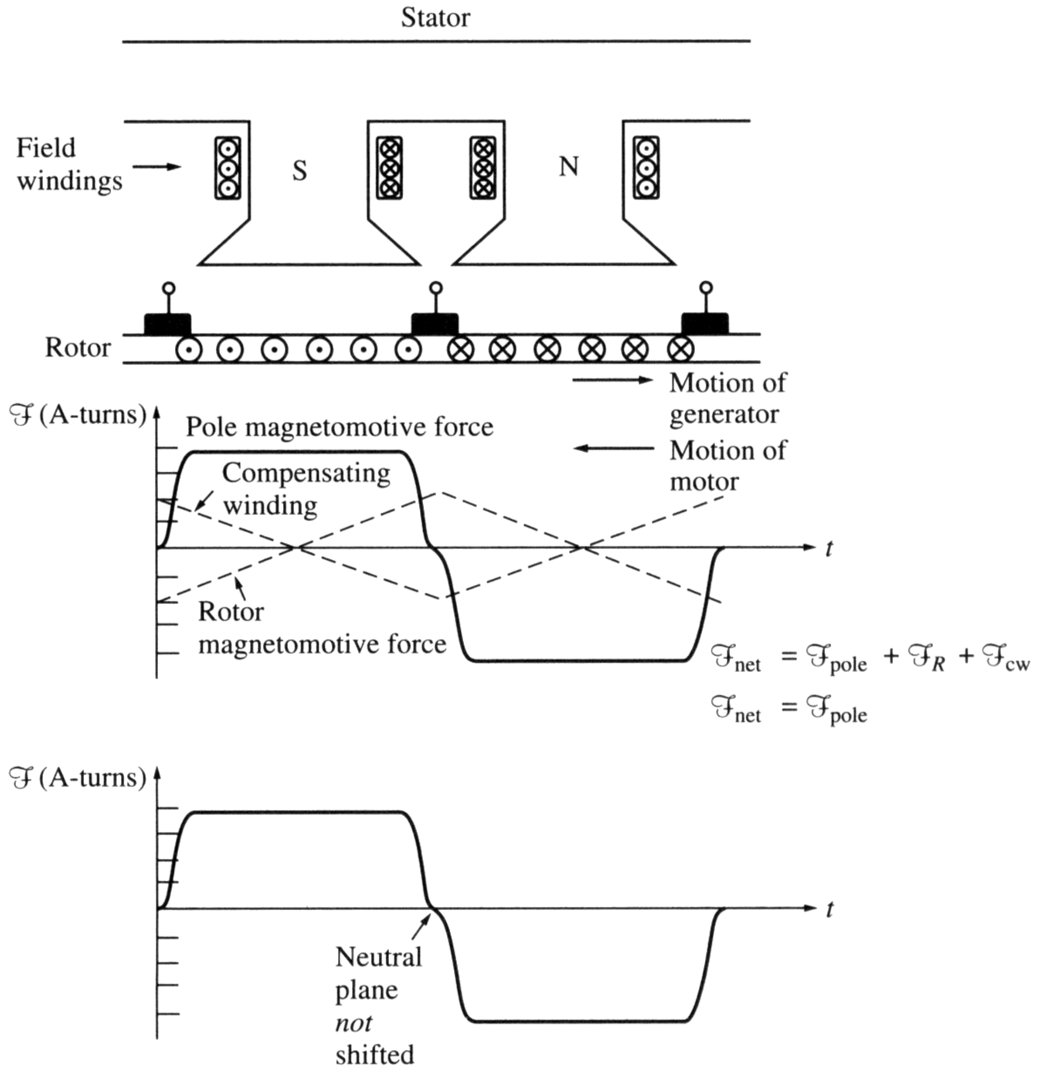


Sum of these three fluxes equals to the original pole flux.

Solutions to the problems with commutation

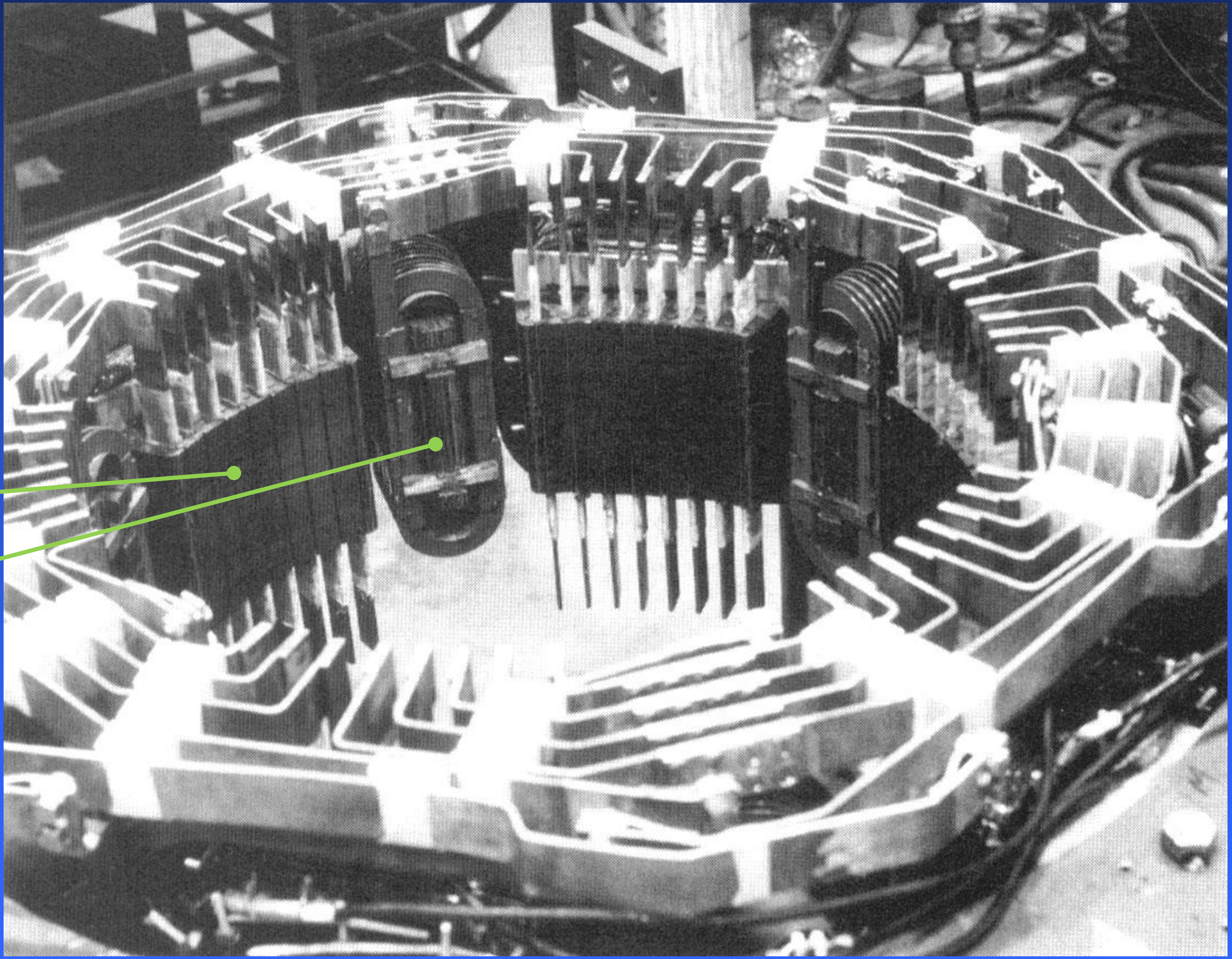
The mmf due to the compensating windings is equal and opposite to the mmf of the rotor. These two mmfs cancel each other, such that the flux in the machine is unchanged.

The main disadvantage of compensating windings is that they are expensive since they must be machined into the faces of the poles. Also, any motor with compensative windings must have interpoles to cancel *L di/dt* effects.



Solutions to the problems with commutation

A stator of a six-pole DC machine with interpoles and compensating windings.



pole

interpole

Power flow and losses in DC machines

Unfortunately, not all electrical power is converted to mechanical power by a motor and not all mechanical power is converted to electrical power by a generator…

The efficiency of a DC machine is:

$$\boxed{\eta = \frac{P_{out}}{P_{in}} \cdot 100\%} \tag{5.36.1}$$

or

$$\boxed{\eta = \frac{P_{in} - P_{loss}}{P_{in}} \cdot 100\%} \tag{5.36.2}$$

The losses in DC machines

There are **five** categories of losses occurring in DC machines.

1. Electrical or copper losses – the resistive losses in the armature and field windings of the machine.

Armature loss: $$P_A = I_A^2 R_A \tag{5.37.1}$$

Field loss: $$P_F = I_F^2 R_F \tag{5.37.2}$$

Where I_A and I_F are armature and field currents and R_A and R_F are armature and field (winding) resistances usually measured at normal operating temperature.

The losses in DC machines

2. Brush (drop) losses – the power lost across the contact potential at the brushes of the machine.

$$P_{BD} = V_{BD} I_A \tag{5.38.1}$$

Where I_A is the armature current and V_{BD} is the brush voltage drop. The voltage drop across the set of brushes is approximately constant over a large range of armature currents and it is usually assumed to be about 2 V.

Other losses are exactly the same as in AC machines…

The losses in DC machines

3. Core losses – hysteresis losses and eddy current losses. They vary as B^2 (square of flux density) and as $n^{1.5}$ (speed of rotation of the magnetic field).

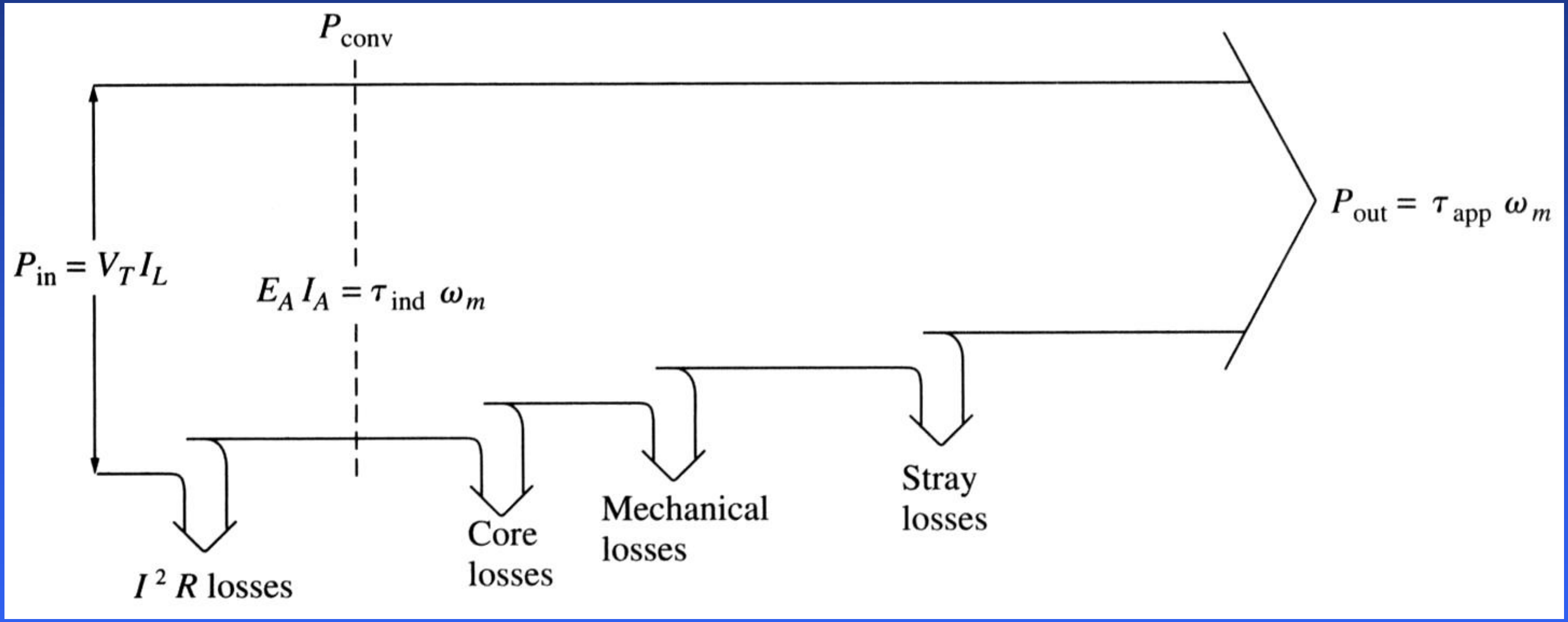
4. Mechanical losses – losses associated with mechanical effects: friction (friction of the bearings) and windage (friction between the moving parts of the machine and the air inside the casing). These losses vary as the cube of rotation speed n^3.

5. Stray (Miscellaneous) losses – losses that cannot be classified in any of the previous categories. They are usually due to inaccuracies in modeling. For many machines, stray losses are assumed as 1% of full load.

The power-flow diagram

On of the most convenient technique to account for power losses in a machine is the power-flow diagram.

For a DC motor:



Electrical power is input to the machine, and the electrical and brush losses must be subtracted. The remaining power is ideally converted from electrical to mechanical form at the point labeled as P_{conv}.

The power-flow diagram

The electrical power that is converted is

$$P_{conv} = E_A I_A \tag{5.41.1}$$

And the resulting mechanical power is

$$P_{conv} = \tau_{ind} \omega_m \tag{5.41.2}$$

After the power is converted to mechanical form, the stray losses, mechanical losses, and core losses are subtracted, and the remaining mechanical power is output to the load.