ELECTRICAL MACHINES

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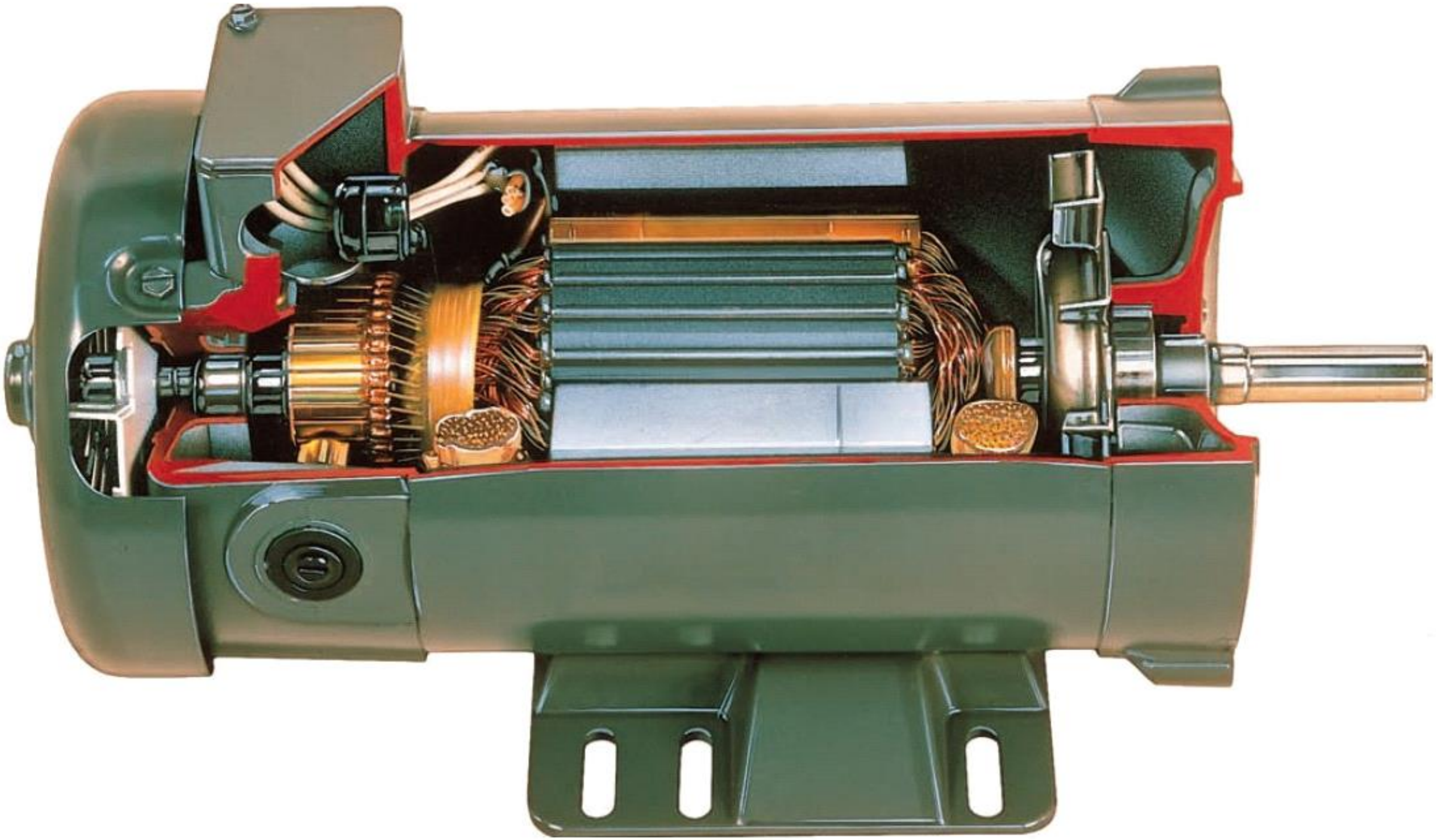
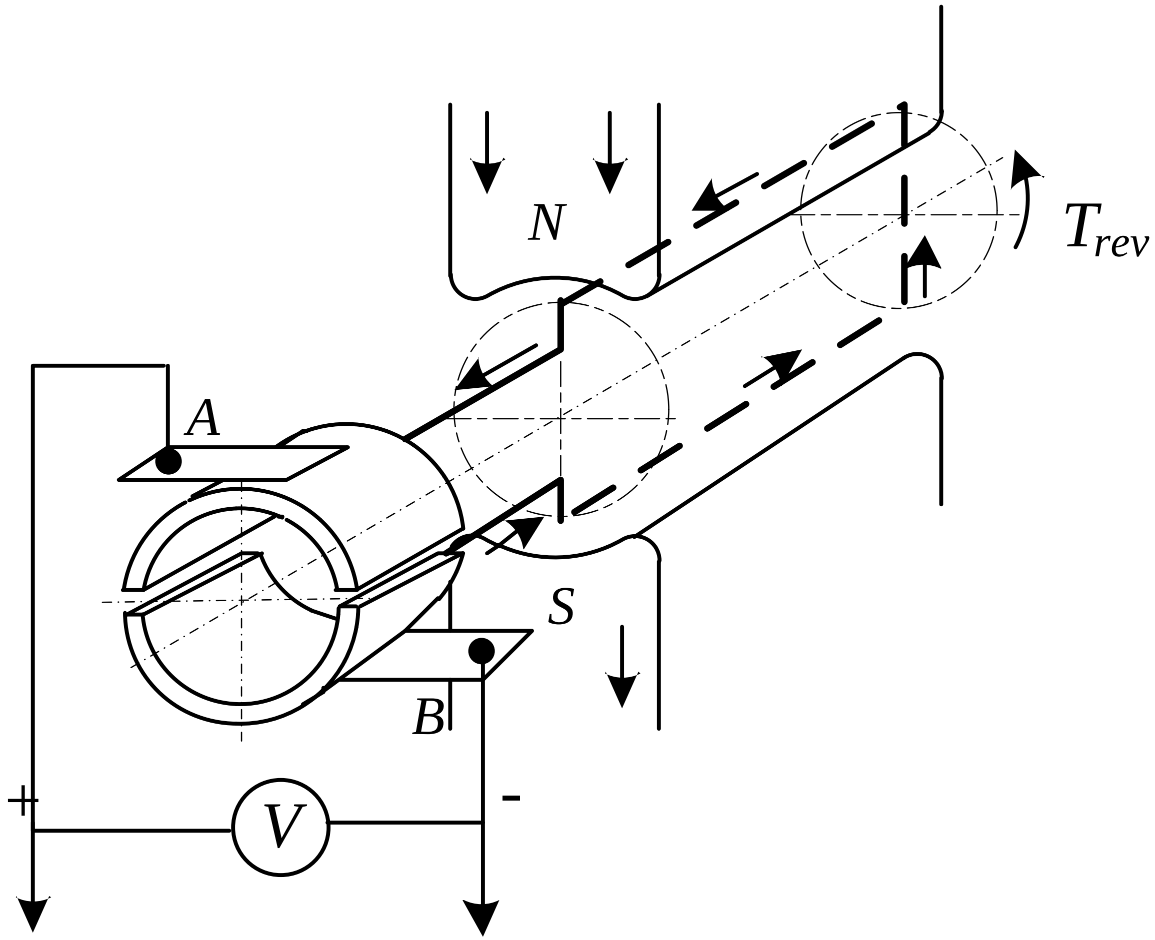
DIRECT CURRENT MACHINES 1

DC machine construction



Working principle of DC generator



- Single Loop DC Generator

Working principle of DC generator

- When the loop rotates from its vertical position to its horizontal position, it cuts the flux lines of the field. As during this movement two sides of the loop cut the flux lines there will be an EMF induced in these both of the sides of the loop.
- The value of induced EMF is:

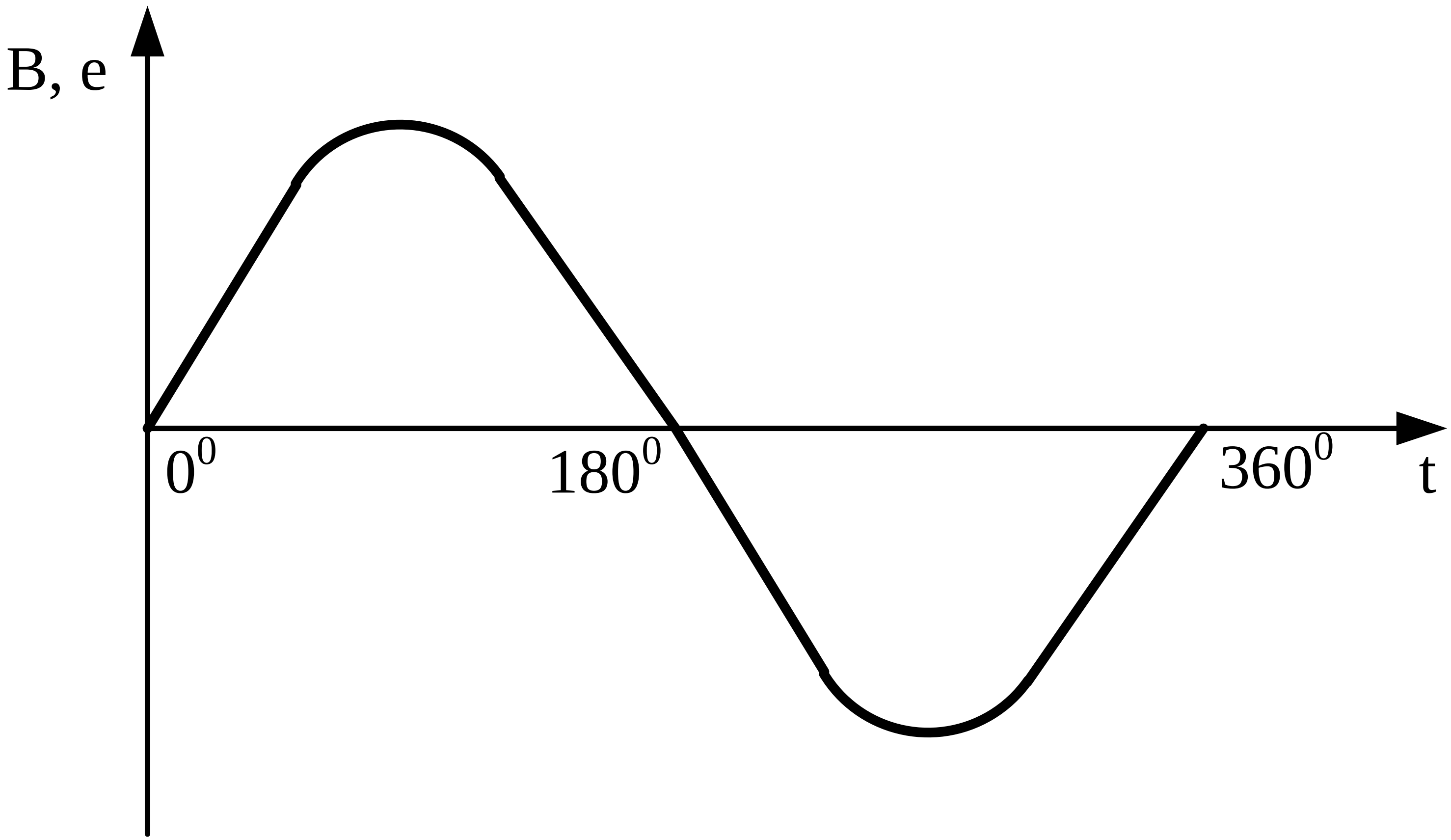
$$e_{cont} = B \cdot l \cdot v,$$

- where B – magnetic flux density, l - the active length of a conductor, v – linear speed of conductor.
- Total armature EMF is:

$$E_a = 2 \cdot e_{cont}.$$

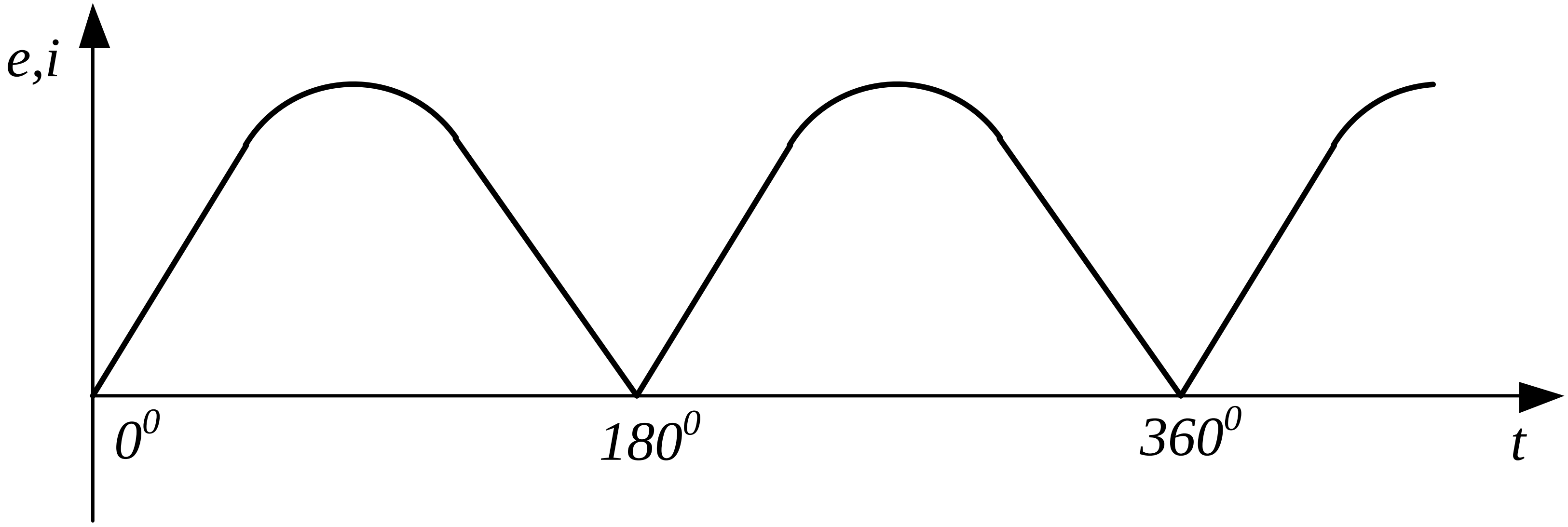
- The value of EMF is variable as armature winding conductors run downwards N-pole and S-pole. As a result the direction of EMF in the conductors changes.

Working principle of DC generator



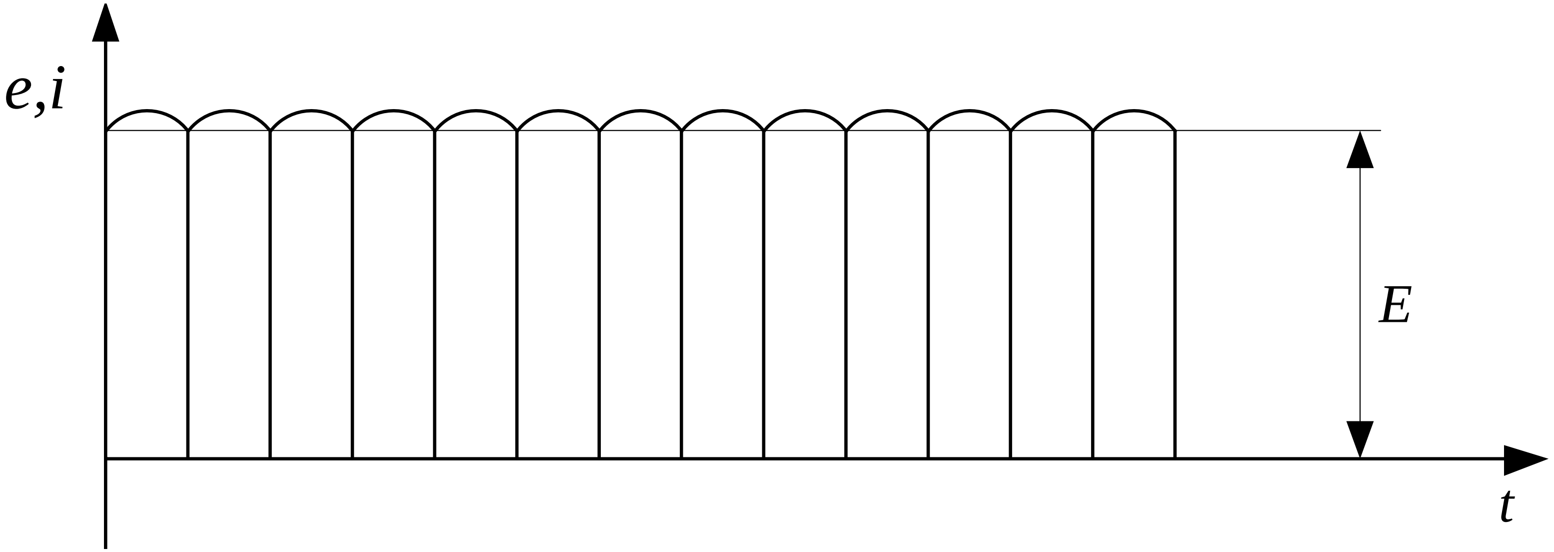
- Magnetic flux density and EMF curve

Working principle of DC generator



- Current curve through the load

Working principle of DC generator



- Current through the load curve in case of more segments in commutator

Working principle of DC generator

- The value of armature EMF is defined by N – number of turns in winding, a – number of parallel paths in the armature winding, $2p$ – number of pairs of poles, Φ – magnetic flux of in air gap and n – speed of rotation:

$$E_a = C \cdot \Phi \cdot n,$$

- where C – constructional constant:

$$C_e = \frac{p \cdot N}{60a}, C_m = \frac{p \cdot N}{2\pi \cdot a}.$$

Working principle of DC generator

- The output voltage of DC generator is smaller than induced EMF:

$$U = E_a - I \cdot R_a - 2 \cdot \Delta U_b,$$

- where ΔU_a – voltage drop across armature resistance:

$$\Delta U_a = I \cdot R_a + 2 \cdot \Delta U_b,$$

- where R_a – armature resistance, I – armature current, $2 \cdot \Delta U_b$ – voltage drop across commutator-and-brush assembly. Typically the voltage drop across commutator-and-brush assembly is $2 \cdot \Delta U_b = 2\ V$, so:

$$U = E_a - I \cdot R,$$

- where R – overall resistance of armature winding and commutator-and-brush assembly.

Working principle of DC generator

- As conductor moves in a magnetic field it cuts magnetic lines force:

$$F_{cont} = B \cdot l \cdot i_{cont}.$$

- These electromagnetic forces create electromagnetic torque that in case of generator acts as decelerating torque, thus it acts against direction of armature rotation:

$$M = C \cdot \Phi \cdot I.$$

- Output power of generator:

$$P_{out} = U \cdot I.$$

Working principle of DC motor

- As conductor moves in a magnetic field it cuts magnetic lines force:

$$F_{cont} = B \cdot l \cdot I_a.$$

- And electromagnetic torque developed by the machine is given by:

$$M = C \cdot \Phi \cdot I_a.$$

- The induced EMF:

$$E_a = C \cdot \Phi \cdot n = C \cdot \Phi \cdot w.$$

- The voltage equation for the armature circuit of the motor is:

$$U = E_a + I \cdot R_a + 2 \cdot \Delta U_b \; or$$
$$U = E_a + I \cdot R.$$

Working principle of DC motor

- Output power of DC motor:

$$P_{out} = w \cdot M_{out},$$

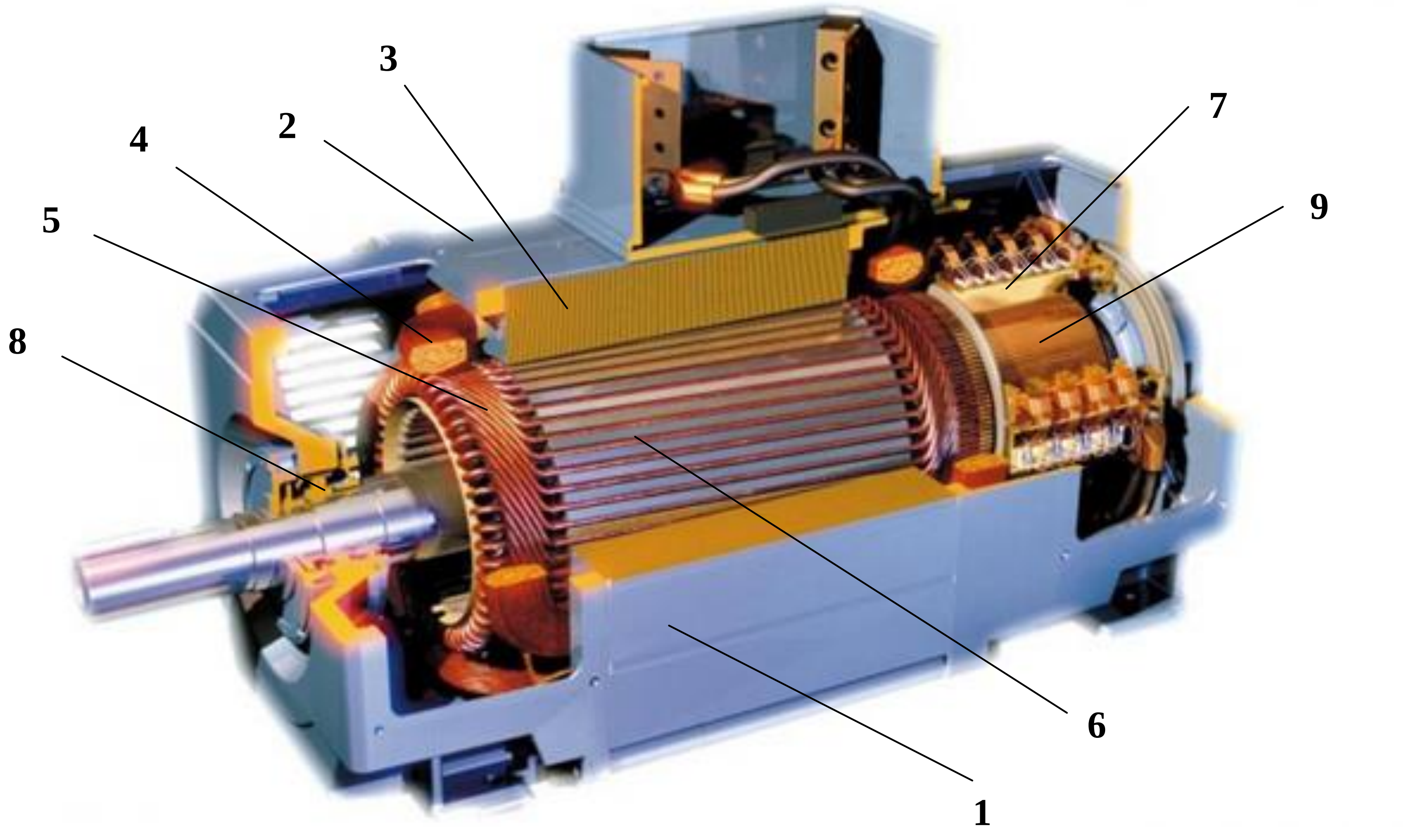
- where M_{out} – output torque of DC motor, w – angular velocity.

$$w = \frac{2\pi \cdot n}{60}.$$

So in DC generator $U < \mathrm{E}$,

and in DC motor $U > \mathrm{E}$.

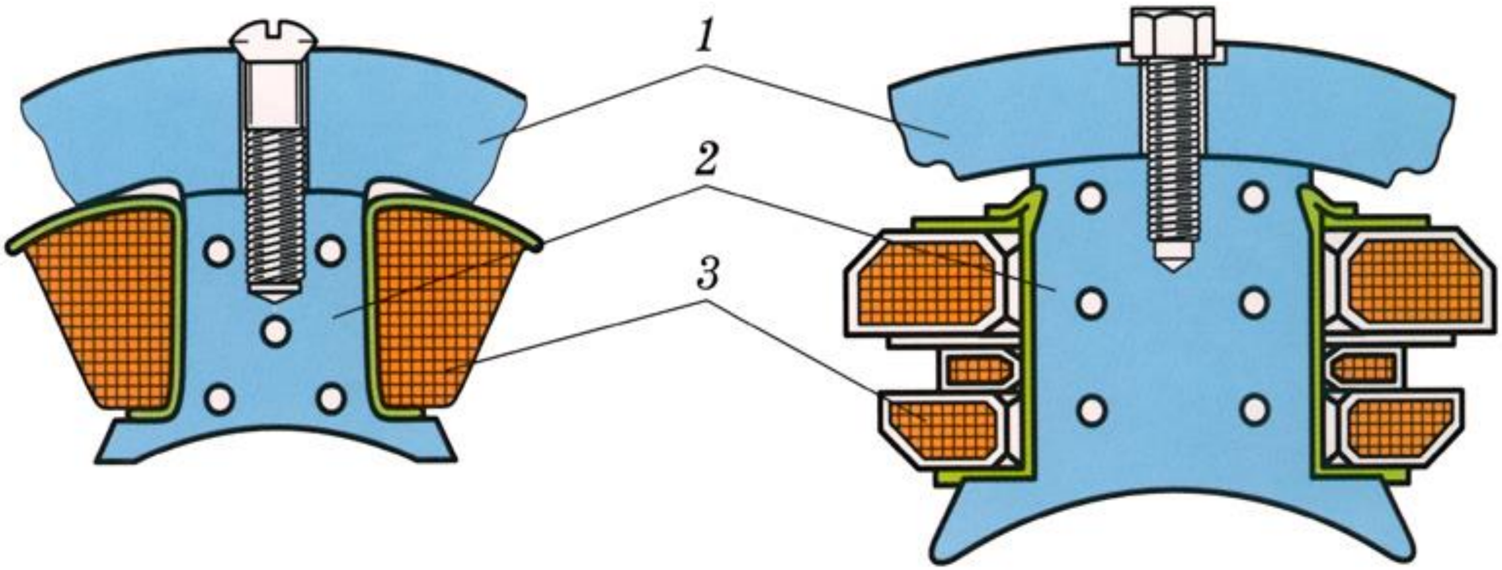
Construction of DC Machine



Construction of DC Machine

1. Stator or inductor – stationary part of DC machine that houses the field windings and receives the supply.
2. Yoke.
3. Pole of DC machine.
4. Field winding.
5. Armature winding.
6. Rotor or Armature of DC machine – rotational part of DC machine.
7. Brushes.
8. Bearing.
9. Commutator.

Pole cores and pole shoes of DC machine



- Poles of DC machine: 1 – yoke, 2 – pole cores, 3 – pole coils of DC machine

Armature Winding of DC machine

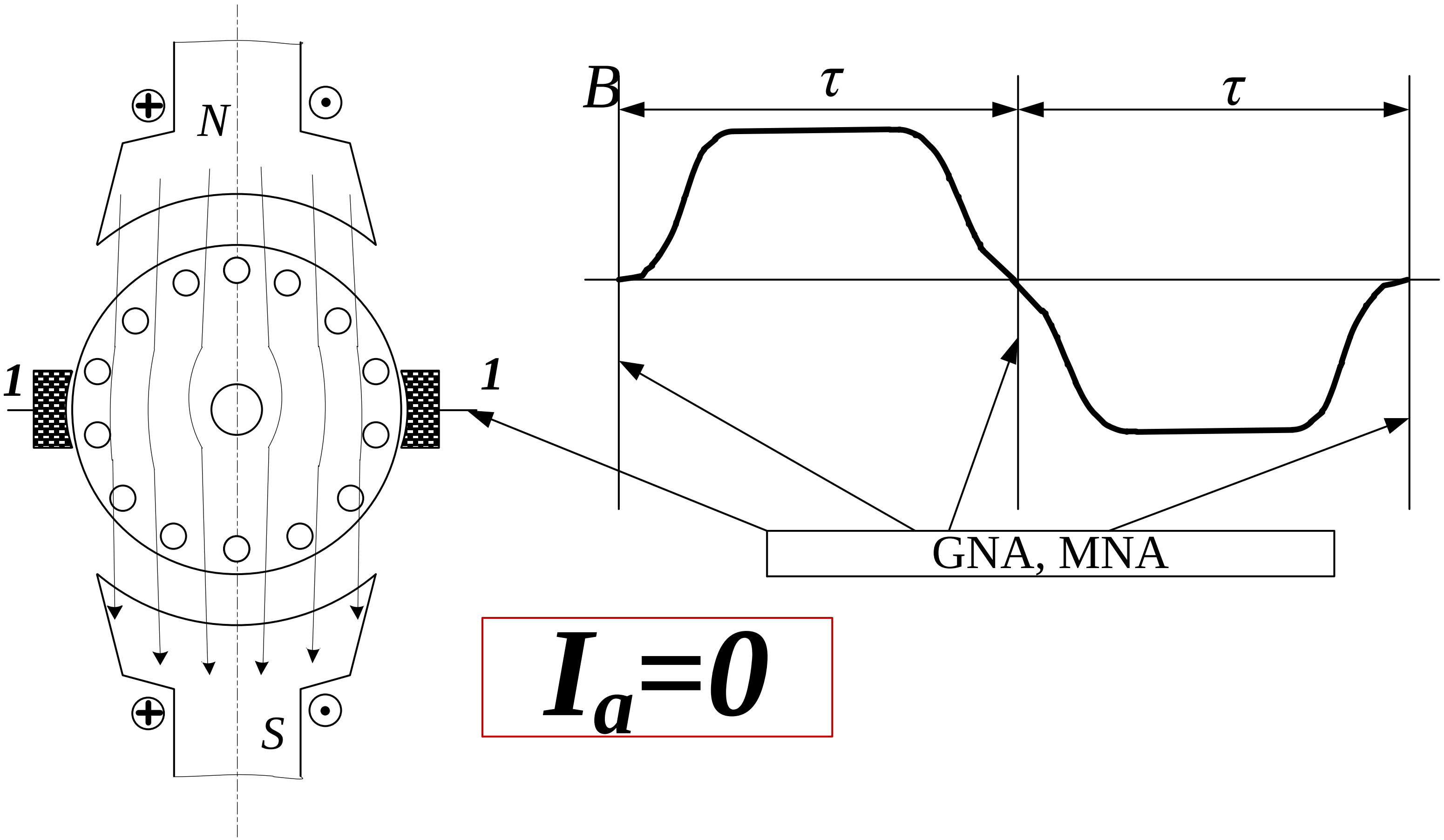
Commutator of DC machine

DIRECT CURRENT MACHINES 2

Armature reaction in DC machines

- If the magnetic field windings of a dc machine are connected to a power supply and the rotor of the machine is turned by an external source of mechanical power, then a voltage will be induced in the conductors of the rotor. This voltage will be rectified into a DC output by the action of the machine's commutator. Now connect a load to the terminals of the machine, and a current will flow in its armature windings. This current flow will produce a magnetic field of its own, which will distort the original magnetic field from the machine's poles. This distortion of the flux in a machine as the load is increased is called **armature reaction**.

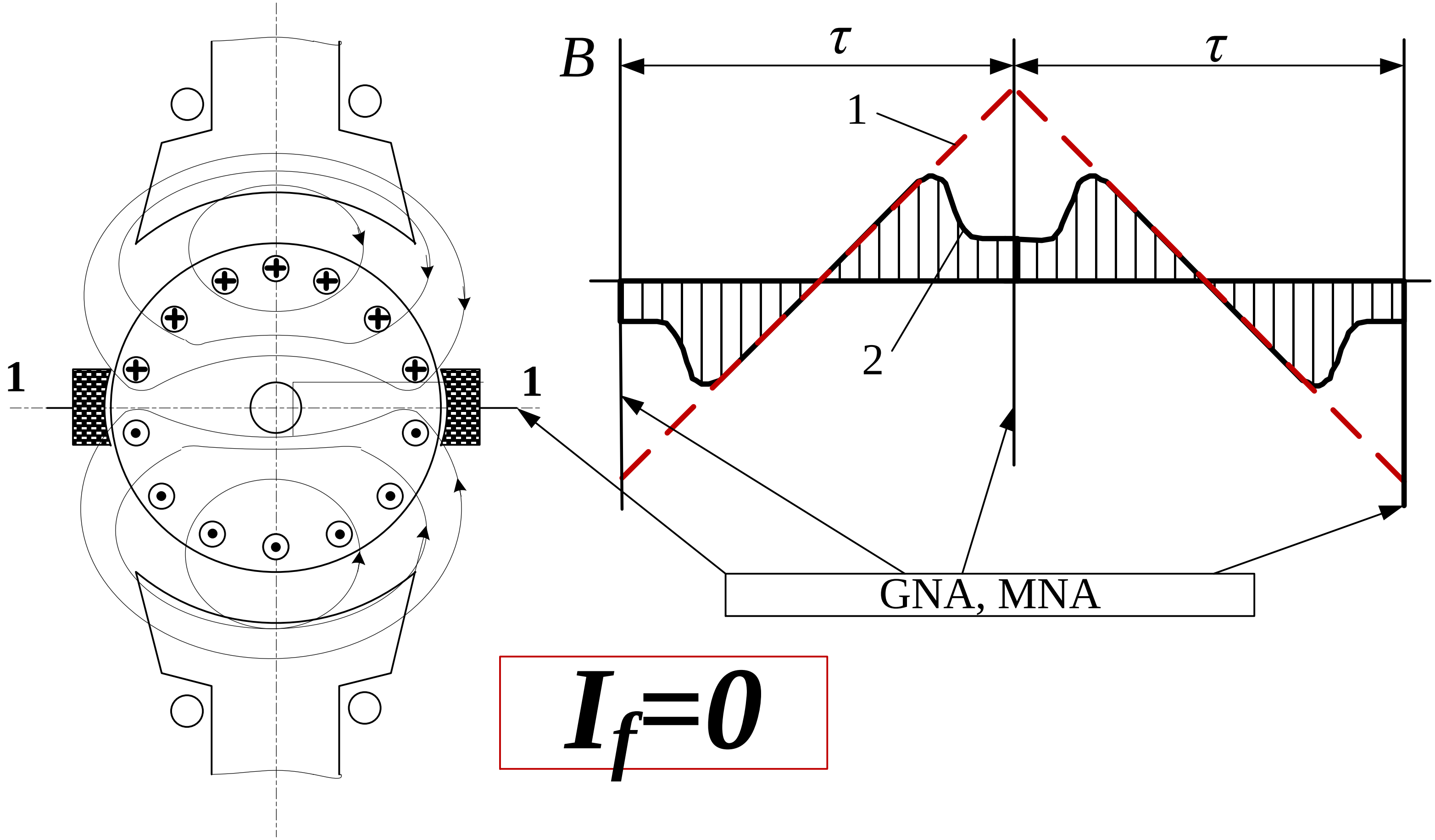
Armature reaction in DC machines



$I_a = 0$

- Flux distribution of a bipolar generator $I_a = 0$.

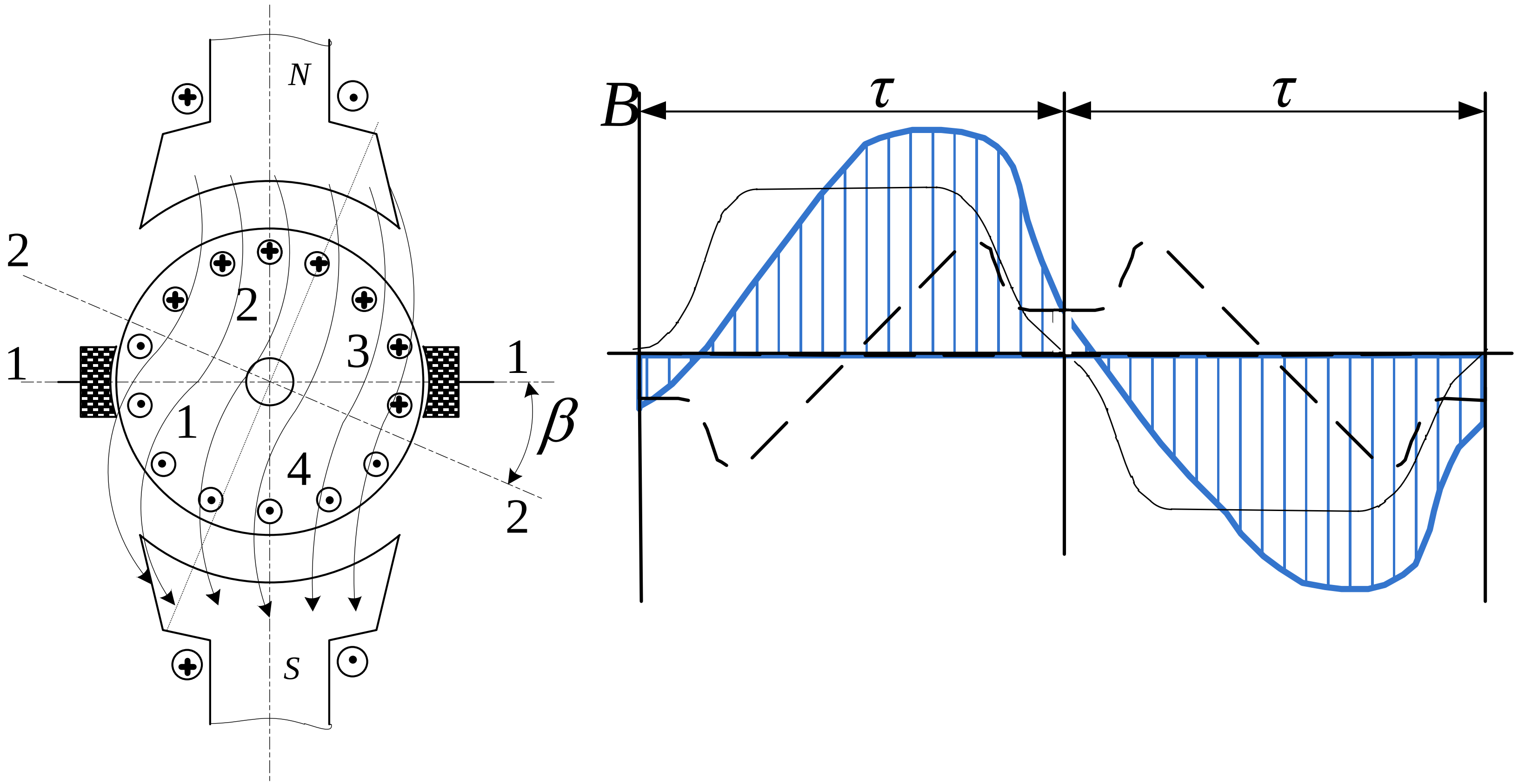
Armature reaction in DC machines



$I_f=0$

- Flux distribution of a bipolar generator $I_f = 0$.

Armature reaction in DC machines



- Flux distribution of a bipolar generator, 1-1 – GNA, 2-2 – MNA, β – neutral plane shift

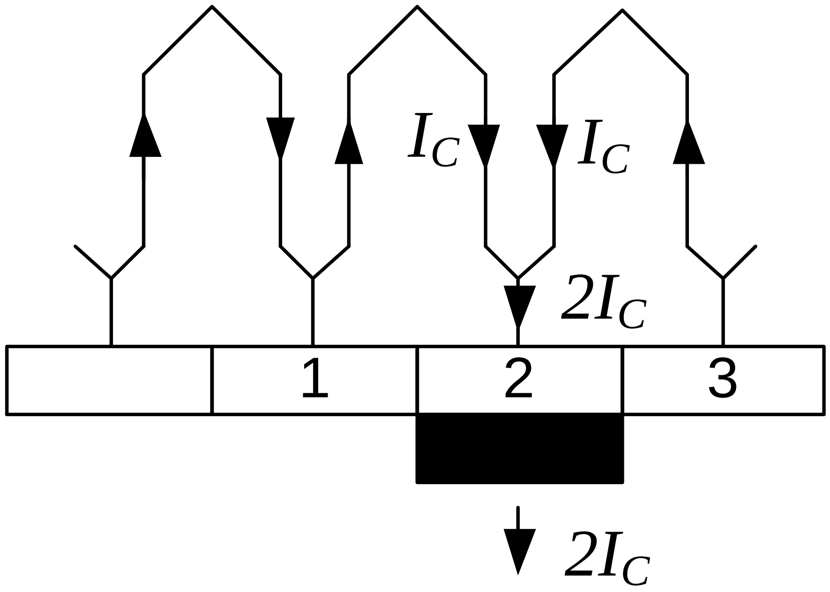
Armature reaction in DC machines

- To reduce the adverse effects of armature reaction and to improve the machine’s performance, following methods are used:
- **Brush Shift.**
- **Inter Pole.**
- **Compensating Winding.**

Commutation in DC Machine

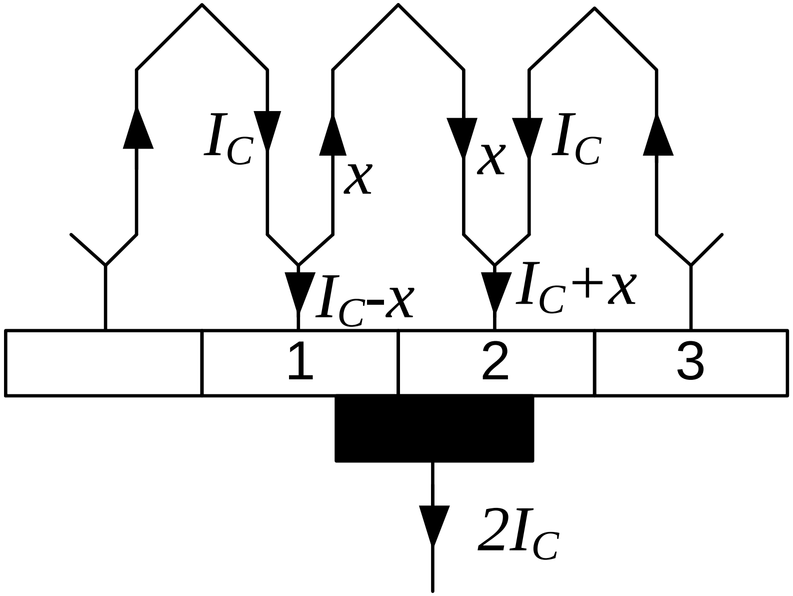
- The currents induced in armature conductors of a DC generator are alternating. These currents flow in one direction when armature conductors are under N-pole and in the opposite direction when they are under S-pole. As conductors pass out of the influence of a N-pole and enter that of S-pole, the current in them is reversed. This reversal of current takes place along magnetic neutral axis or brush axis i.e. when the brush spans and hence short circuits that particular coil undergoing reversal of current through it. This process by which current in the short-circuited coil is reversed while it crosses the MNA is called **commutation**.

Physical Concept of Commutation in DC Machine



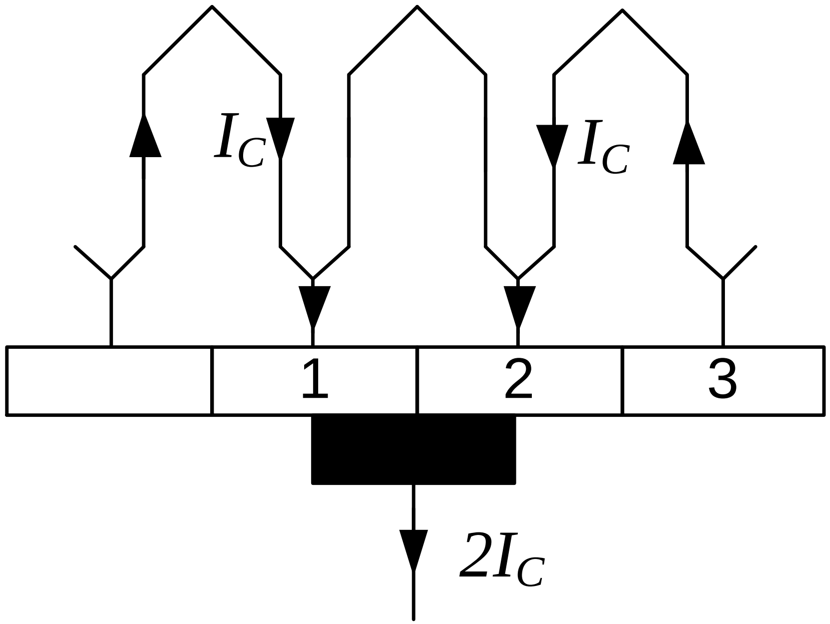
- At the first position, the brush is connected the commutator bar 2 (as shown in fig.). Then the total current conducted by the commutator bar 2 into the brush is $2I_C$.

Physical Concept of Commutation in DC Machine



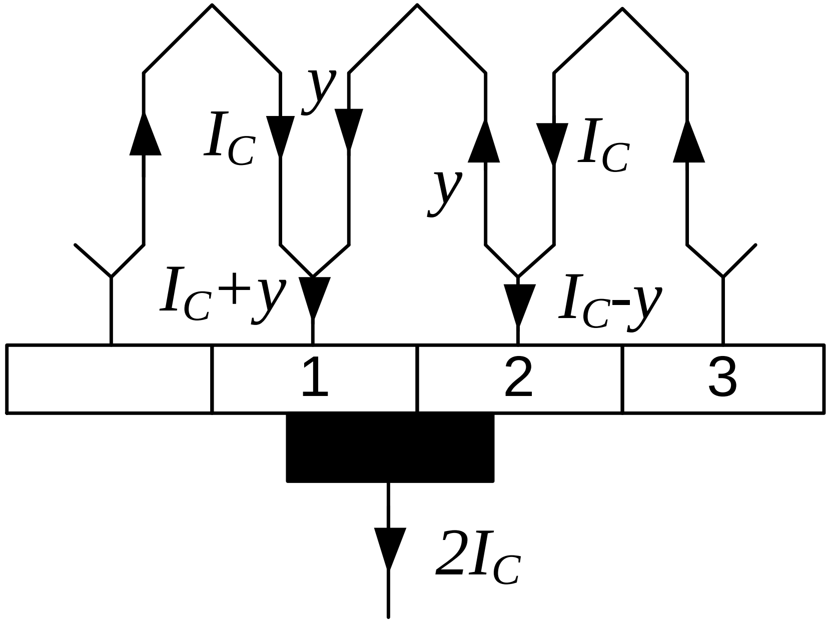
- When the armature starts to move right, then the brush comes to contact of bar a. Then the armature current flows through two paths and through the bars 1 and 2 (as shown in fig.). The total current ($2I_C$) collected by the brush remain same.

Physical Concept of Commutation in DC Machine



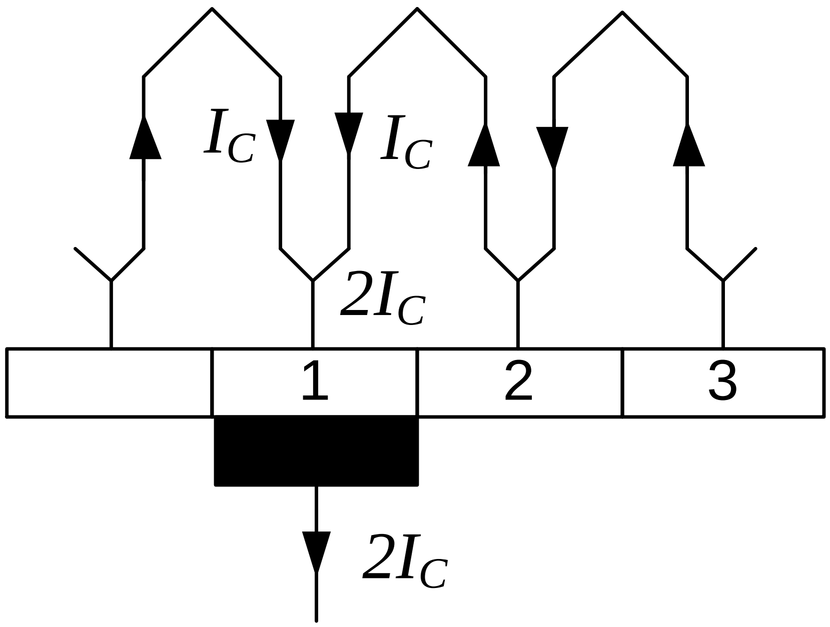
- As the contact area of the bar a with the brush increases and the contact area of the bar 2 decreases, the current flow through the bars increases and decreases simultaneously. When the contact area become same for both the commutator bar then same current flows through both the bars.

Physical Concept of Commutation in DC Machine



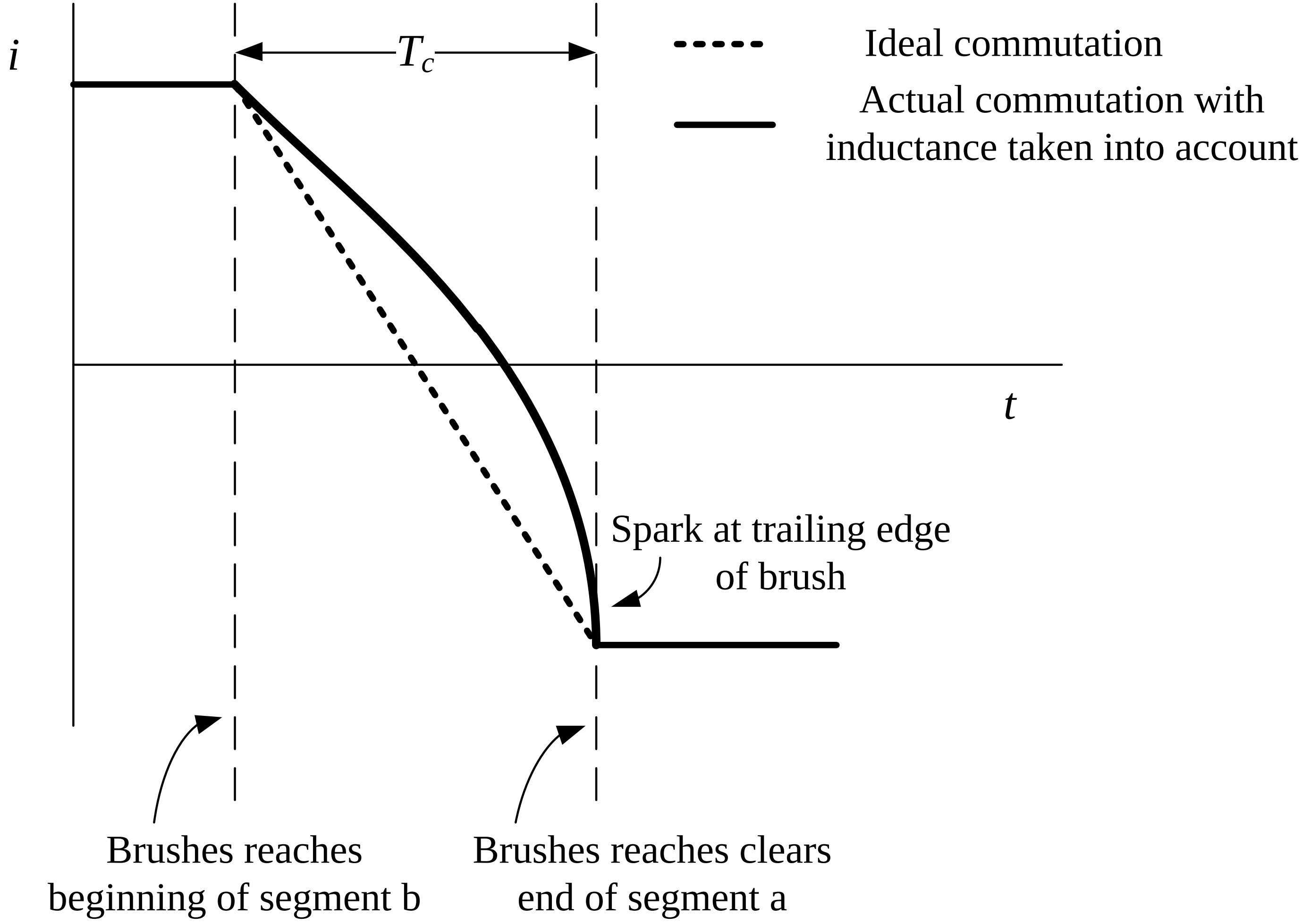
- When the brush contact area with the bar 2 decreases further, then the current flowing through the coil changes its direction and starts to flow counter-clockwise.

Physical Concept of Commutation in DC Machine



- When the brush totally comes under the bar 1 and disconnected with the bar 2 then current I_C flows through the coil in the counter-clockwise direction and the short circuit is removed. In this process the reversal of current or the process of commutation is done.

The current reversal in the coil undergoing commutation

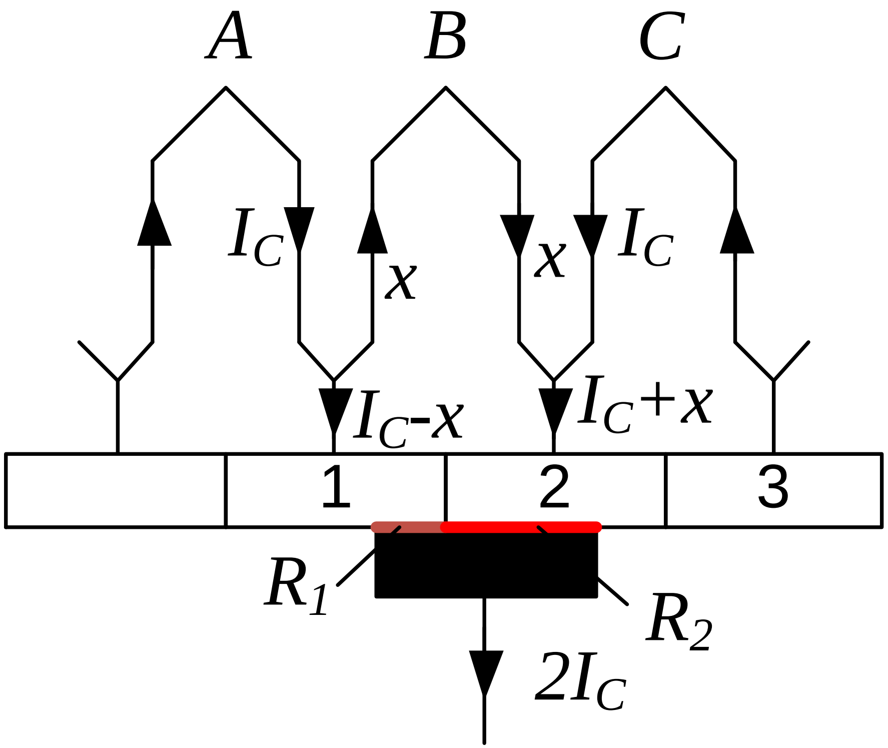


Methods of improving commutation

There are two main methods of improving commutation. These are

- Resistance commutation
- EMF commutation

Resistance commutation



EMF commutation

The voltage rise in the short circuit coil due to inductive property of the coil, which opposes the current reversal in it during the commutation period, is called the reactance voltage.

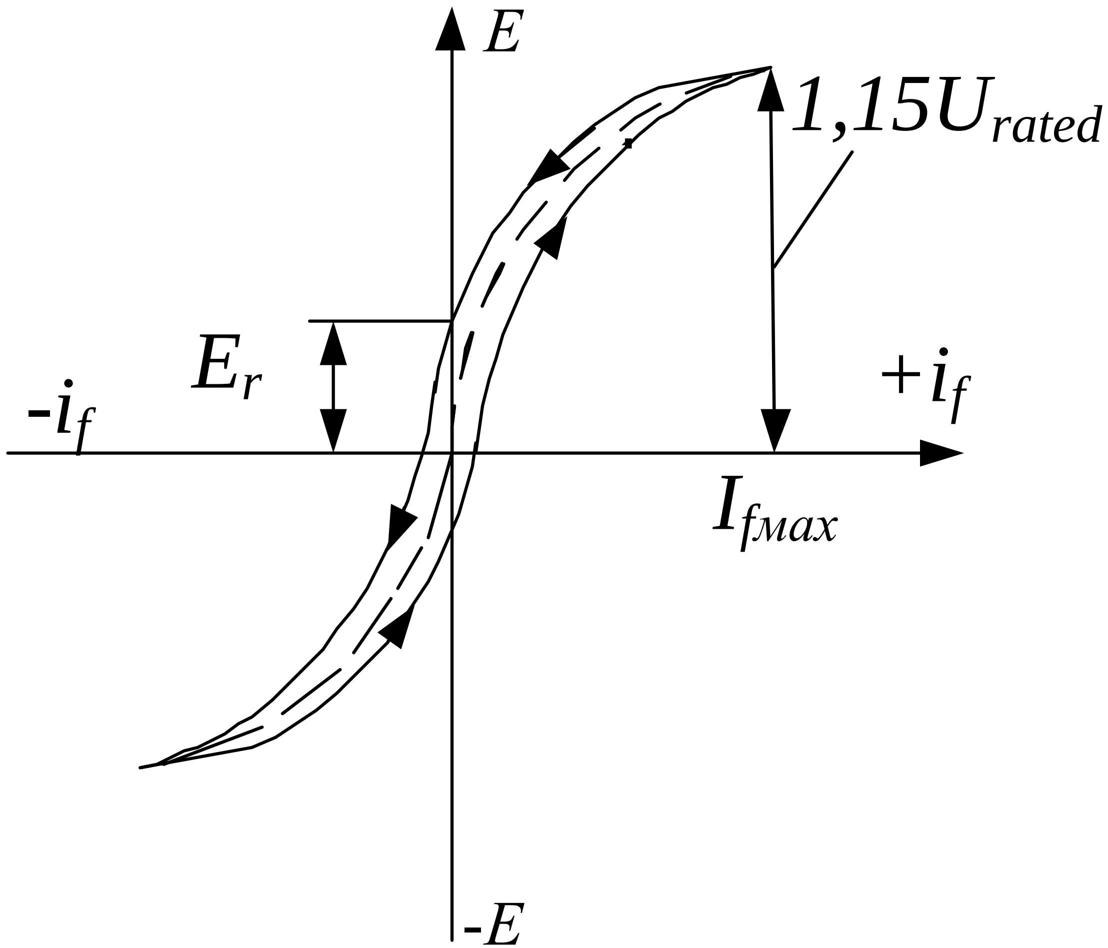
We can produce reversing EMF in two ways

- 1. By brush shifting.
- 2. By using inter-poles or commutating poles.

DIRECT CURRENT MACHINES 3

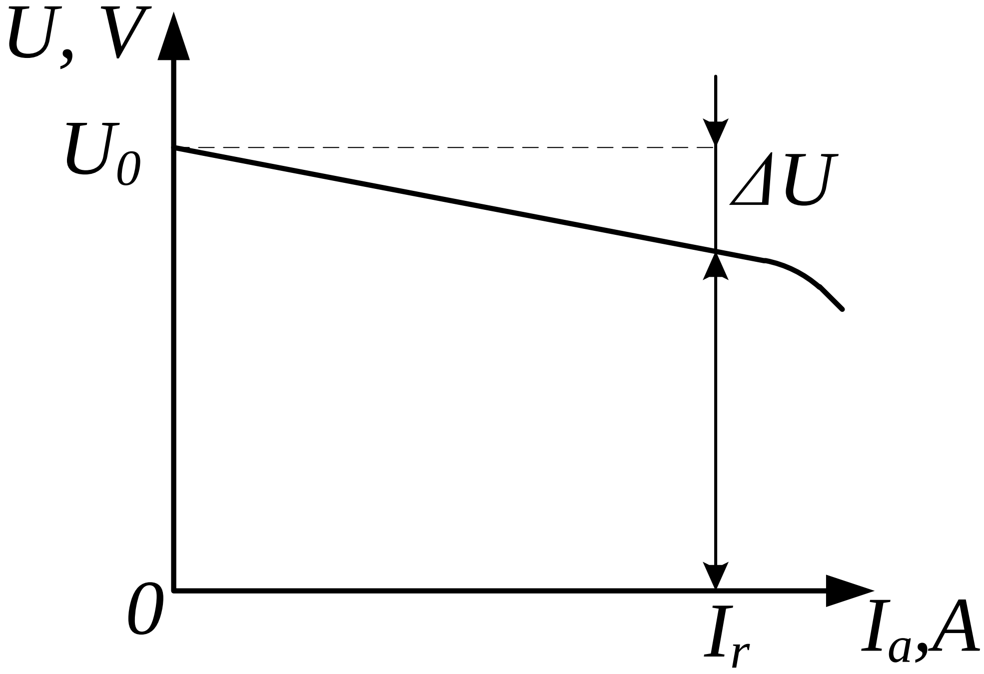
No-load characteristic or magnetization curve of DC generator

$E = f(i_f)$, when $I_a = 0$ and $n = const$



The terminal or external characteristics of DC generators

$U = f(I), i_f = const(r_f = const), n = const.$

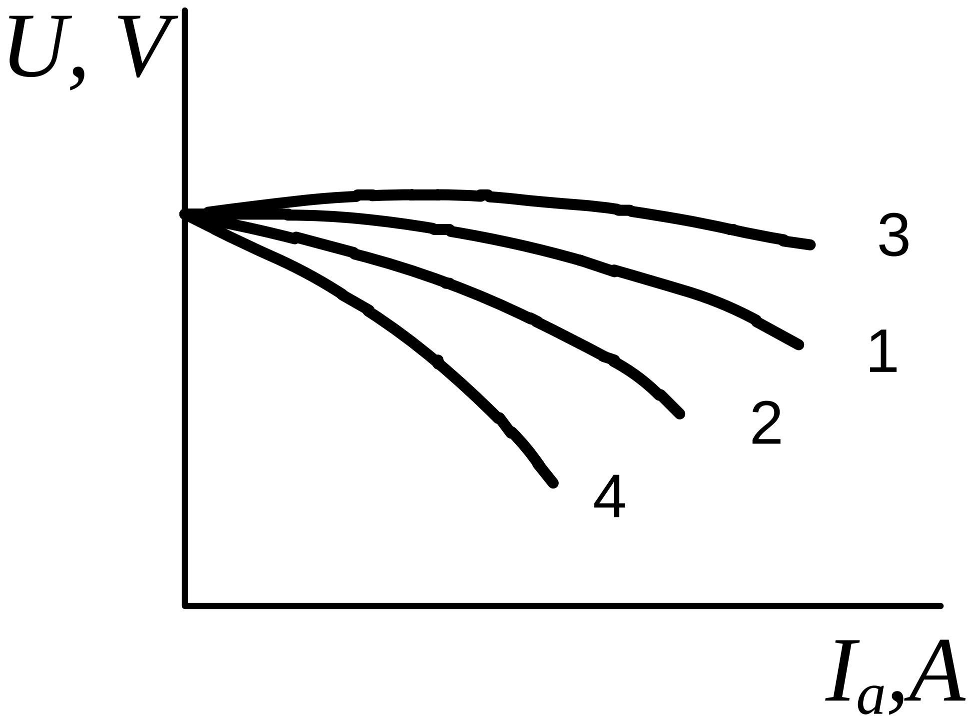


- Voltage regulation is defined by:

$$\Delta U = \frac{U_0 - U_r}{U_0} \cdot 100\% =$$
$$= 5 \ldots 10\%.$$

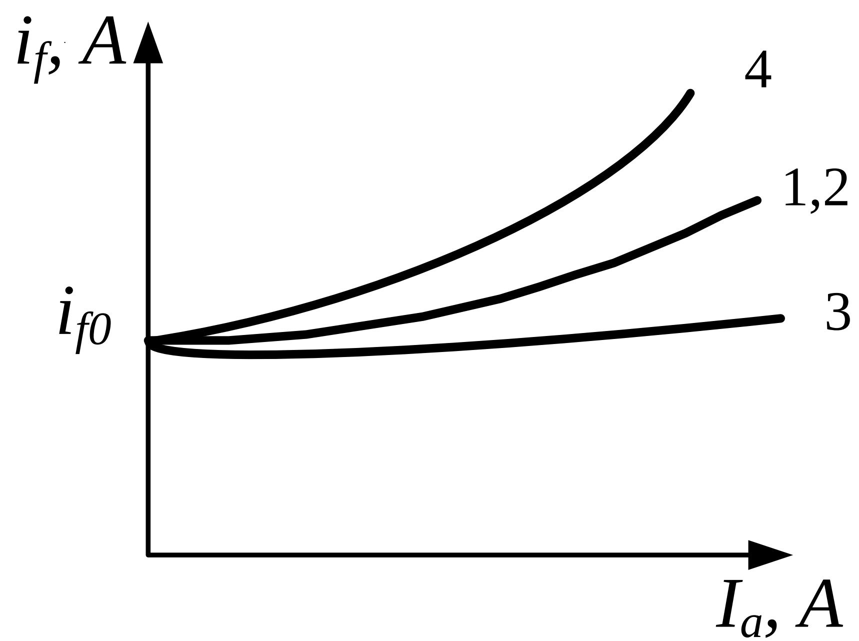
The terminal or external characteristics of DC generators

$U = f(I),\ i_f = const(r_f = const), n = const.$



- 1 - separately excited DC generator,
- 2 - shunt wound DC
- 3 - cumulatively compound wound DC generator
- 4 - differentially compounded self-excited DC

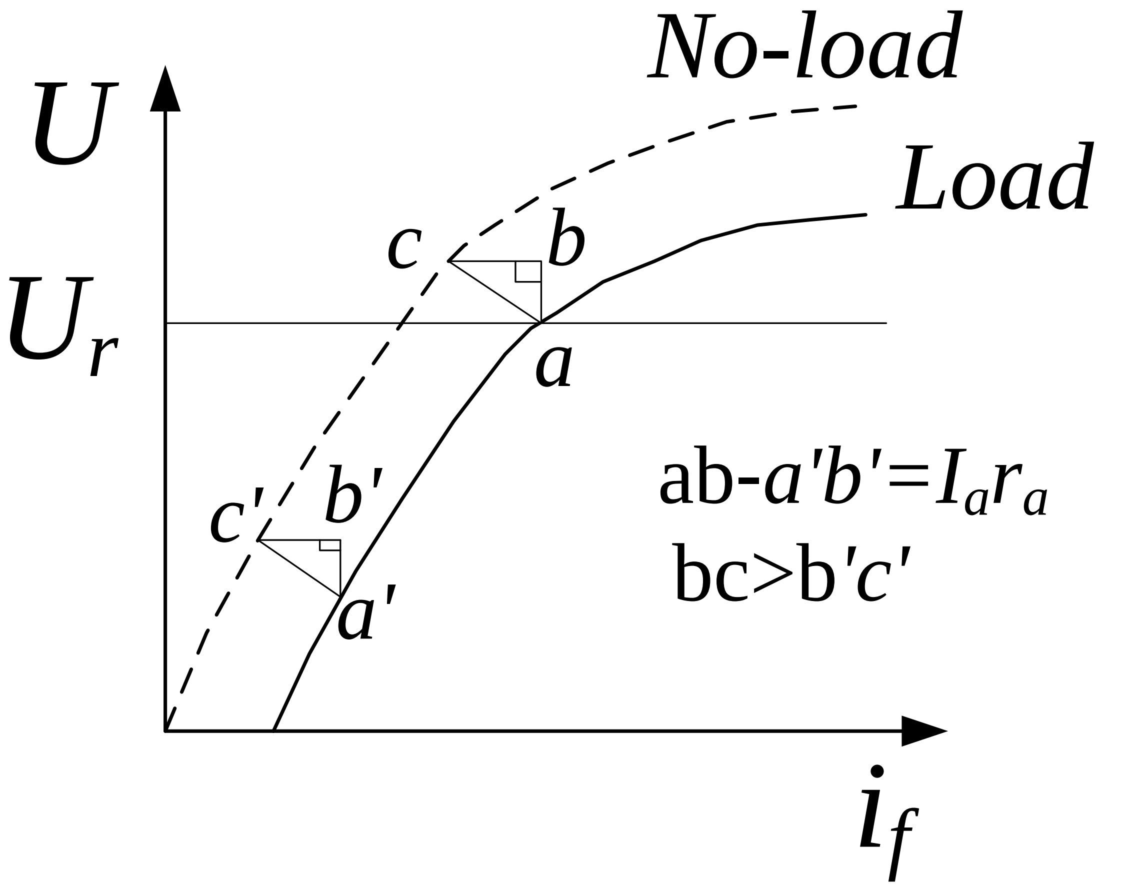
Control characteristic of DC generators $i_f = f(I_a)$ when $U = const, n = const$.



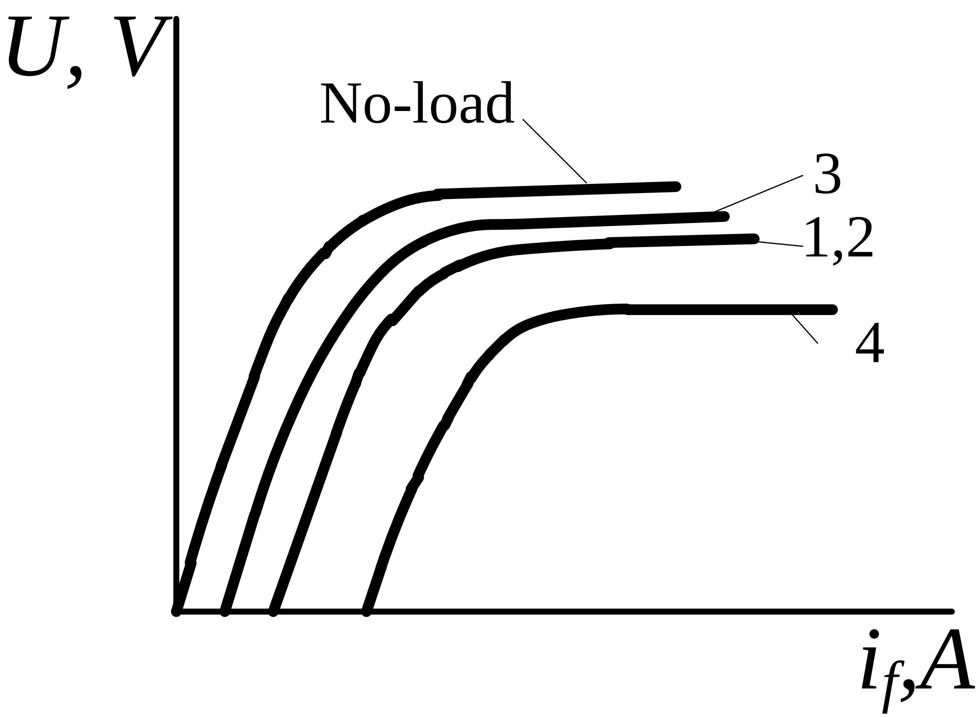
- 1 - separately excited DC generator,
- 2 - shunt wound DC
- 3 - cumulatively compound wound DC generator
- 4 - differentially compounded self-excited DC

Load characteristics of DC generators

$U = f(i_f)$ when $I_a = const,\ n = const.$



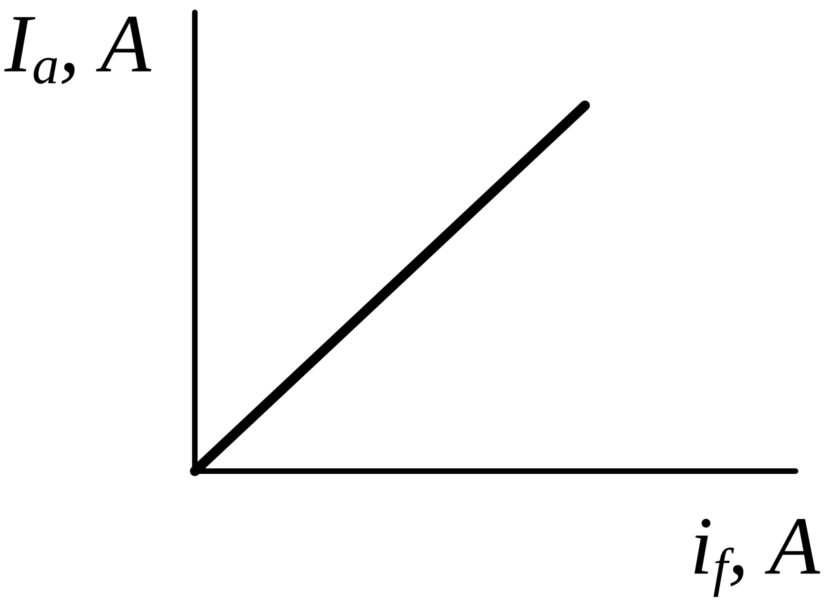
Load characteristics of DC generators $U = f(i_f)$ when $I_a = const,\ n = const.$



- 1 - separately excited DC generator,
- 2 - shunt wound DC
- 3 - cumulatively compound wound DC generator
- 4 - differentially compounded self-excited DC

Short circuit characteristics of DC generators

$I_a = f(i_f)$ when $U = 0, n = const$



- Terminal voltage is defined by:

$$U = E_a - I_a \cdot R_a,$$

- So in case short circuit mode $U = 0$ and

$$I_a = \frac{E_a}{R_a},$$

- as R_a is negligible small value we have to decrease EMF E_a or I_a armature current will be extremely high.

DIRECT CURRENT MACHINES 4

Construction of DC Generator

- Listen and translate terminology in red.

Construction of DC Generator

- It is frequently used in____________and ____________ but do you know how it is constructed.
-
- Out of these parts the pole core, the armature core, the Yoke and air gaps between ____________ and the ____________ form the ____________.
- Yoke is the ____________ of DC generator which serves two purposes.
- Much for large generators Yokes are usually made of ____________ or ____________.

Construction of DC Generator

- Pole coils consist of the ____________ which is wounded on the former.
- When current is passed through these coils the poles get electromagnetized and produce the ____________ that is cut by revolving the armature conductors.
- The slot are either die-cast or punched on the ____________ of the disc and the key way is located in the inner diameter.

Construction of DC Generator

- The difference between the two is merely due to the different ________________ of connections at the front of commutator end of the armature.

- it is suitable for high voltage low current machines like generators used for ________________.

- commutator ________________ the collection of current from the armature conductors and converts the alternating current induced in the armature conductors into ________________ in the external load circuit.

Construction of DC Generator

- they are usually made of ________________ and are in the shape of a rectangular block.
- The number brushes per ________________ depends upon the magnitude of the current to be collected from the commutator.
- And ball bearings are frequently ________________ because of their reliability.

Construction of DC Generator

- It is frequently used in houses and officers but do you know how it is constructed.
- Out of these parts the pole core, the armature core, the Yoke and air gaps between the poles and the armature core form the magnetic circuit.
- Yoke is the outer frame of DC generator which serves two purposes.
- Much for large generators Yokes are usually made of cast steel or rolled steel.
- Pole coils consist of the copper wire or strip which is wounded on the former.
- When current is passed through these coils the poles get electromagnetized and produce the necessary flux that is cut by revolving the armature conductors.
- The slot are either die-cast or punched on the outer periphery of the disc and the key way is located in the inner diameter.

Construction of DC Generator

- The difference between the two is merely due to the different arrangement of connections at the front of commutator end of the armature.
- it is suitable for high voltage low current machines like generators used for lighting.
- commutator facilitates the collection of current from the armature conductors and converts the alternating current induced in the armature conductors into uni-directional current in the external load circuit.
- they are usually made of carbon or graphite and are in the shape of a rectangular block.
- The number brushes per spindle depends upon the magnitude of the current to be collected from the commutator.
- And ball bearings are frequently employed because of their reliability.

Construction of DC Generator

- Explain the construction of a DC generator. we know that a DC generator uses electromagnetic induction to convert mechanical energy into electrical energy. it is frequently used in houses and officers but do you know how it is constructed. let's try to understand this. a DC generator consists of a magnetic frame or Yoke, the pole core, the pole coils or field coils, the armature core, the armature windings, the commutator, the brushes and the bearings. Out of these parts the pole core, the armature core, the Yoke and air gaps between the poles and the armature core form the magnetic circuit. let's briefly describe each of these components.
- joke is the outer frame of DC generator which serves two purposes. it acts as a protective shield for the generator and provides mechanical support for the poles. in small generators which cheapness rather than weight is the main consideration yokes are made of cast Iron. much for large generators Yokes are usually made of cast steel or rolled steel. field magnet consists of the pole core and the pole shoes. it basically spreads out the flux in the air gap. since it generally has a large cross-section so it reduces reluctance of the magnetic path. it acts as a support for the field coils. Pole coils consist of the copper wire or strip which is wounded on the former. after getting the cut up to dimensions the former is removed and the wound coil is put into place over the core. When current is passed through these coils the poles get electromagnetized and produce the necessary flux that is cut by revolving the armature conductors.
- Armature core houses the armature conductors or coils and causes them to rotate cutting the magnetic flux of the field magnet. it also provides a path a very low reluctance to the flux through the armature. it is cylindrical or drum shaped and is built up of usually circular sheet steel disks or laminations approximately .5 millimeter thick. the slot are either die-cast or punched on the outer periphery of the disc and the key way is located in the inner diameter.

Construction of DC Generator

- armature windings are mostly employed for the armature of a dc machine. they are of two types: lap winding and wave windings. the difference between the two is merely due to the different arrangement of connections at the front of commutator end of the armature. in lap winding the number of parallel paths is always equal to the number of poles and also the number of brushes. it is suitable for high current low voltage machines like welding plans. whereas in wave winding the number of parallel paths is always two and they may be two or more brush positions. it is suitable for high voltage low current machines like generators used for lighting.
- commutator facilitates the collection of current from the armature conductors and converts the alternating current induced in the armature conductors into uni-directional current in the external load circuit. it is of cylindrical structure and is built up of a wedge-shaped segments of high conductivity hard drawn or drop forced copper. the segments are insulated from each other by thin layers of my mica and the number of segments is equal to the number of armature coils.
- Brushes collect current from the commutator. they are usually made of carbon or graphite and re in the shape of a rectangular block. they are housed in the brush holder which is mounted on the spindle. these brushes can slide in the rectangular box which is open at both the ends. a flexible copper pig tail mounted at the top of the brush conveys current from the brushes to the holder. the number brushes per spindle depends upon the magnitude of the current to be collected from the commutator.
- and ball bearings are frequently employed because of their reliability. the ball and rollers are generally packed in hard oil for quitter operations. Note that sleeve bearings are used in order to reduce bearing wear.
- basically the schematic diagram of the DC generator is shown and its main parts are .

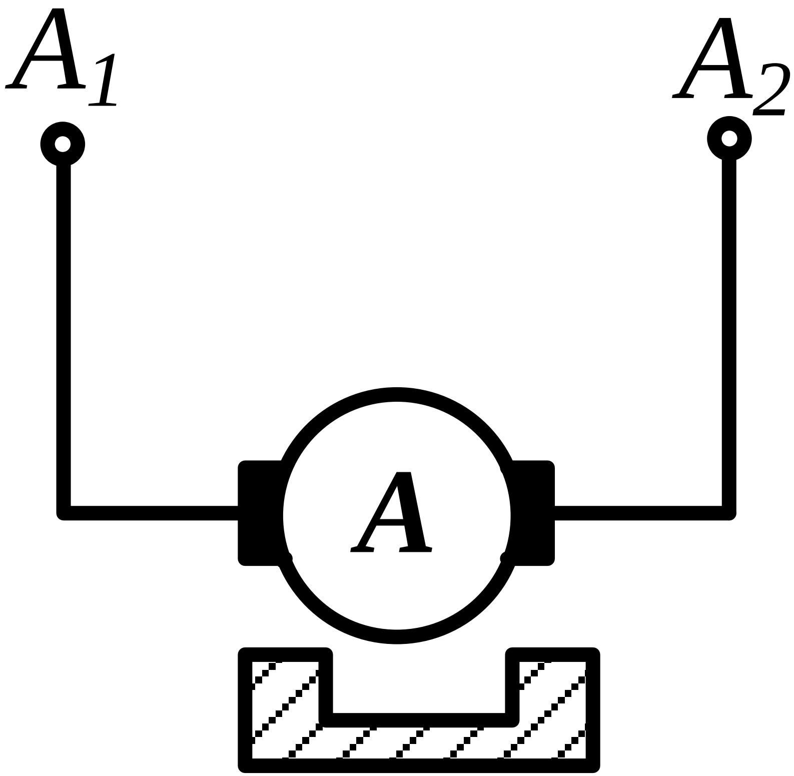
DIRECT CURRENT MACHINES 5

Types of DC machines

Generally DC machines are classified according to the ways of excitation of their fields.

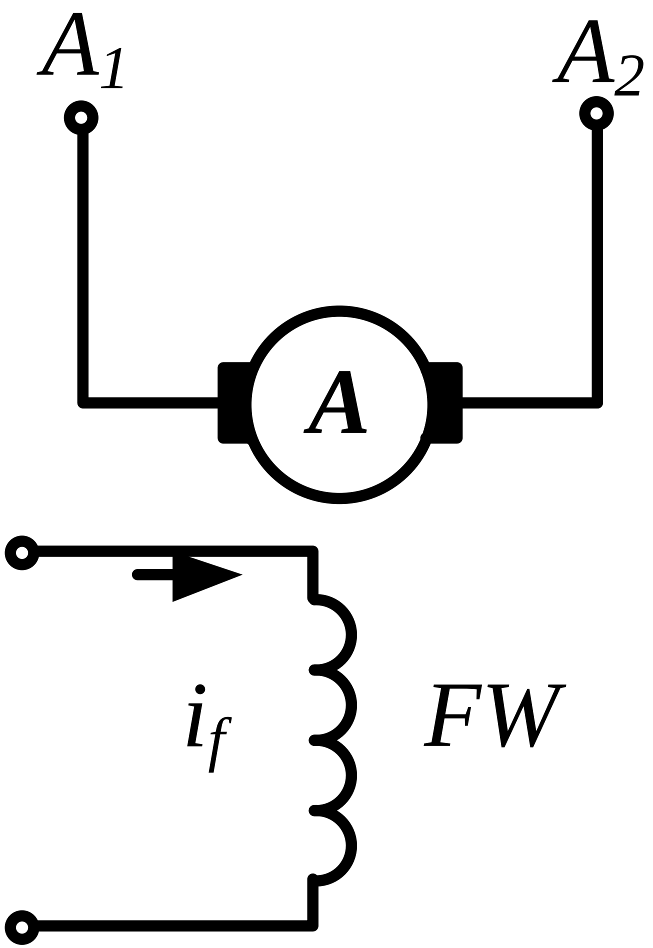
- Field coils excited by permanent magnets – **Permanent magnet DC machines**.
- Field coils excited by some external source – **Separately excited DC machines**.
- Field coils excited by the machine itself – **Self excited DC machines**:
    - **Shunt wound DC machines.**
    - **Series wound DC machines.**
    - **Compound wound DC machines.**

Permanent magnet DC machine



- This type of dc generators generates very low power. So, they are rarely found in industrial applications. They are normally used in small applications like dynamos in motor cycles.
- Permanent magnet DC motor is extensively used where small DC motors are required and also very effective control is not required, such as in automobiles starter, toys, wipers, washers, hot blowers, air conditioners, computer disc drives and in many more.

Separately excited DC machine



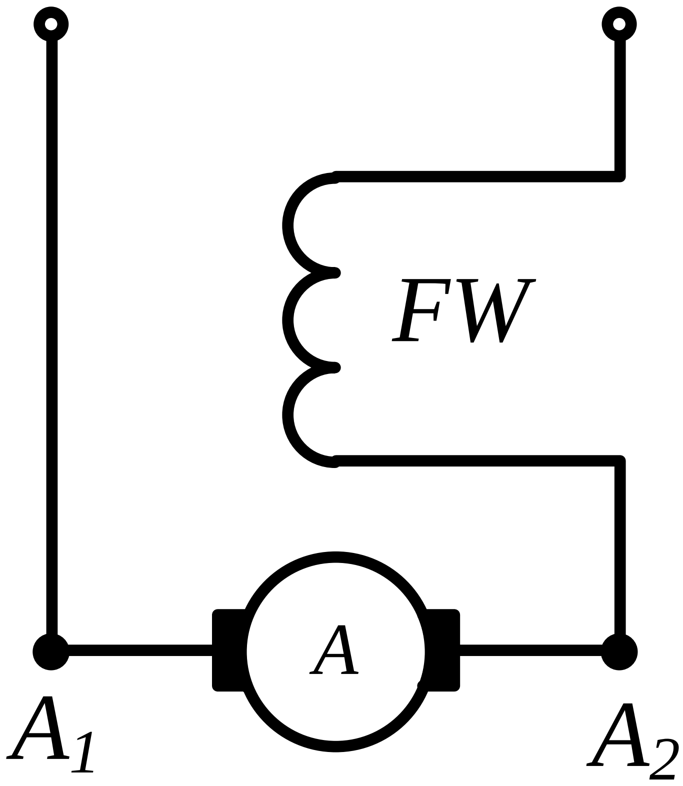
- The main distinguishing fact in these types of DC motor is that, the armature current does not flow through the field windings, as the field winding is energized from a separate external source of DC.
- In case of DC generators, these are the generators whose field magnets are energized by some external dc source such as battery

Self-excited DC machines

According to the position of the field coils the Self-excited DC machines may be classified as:

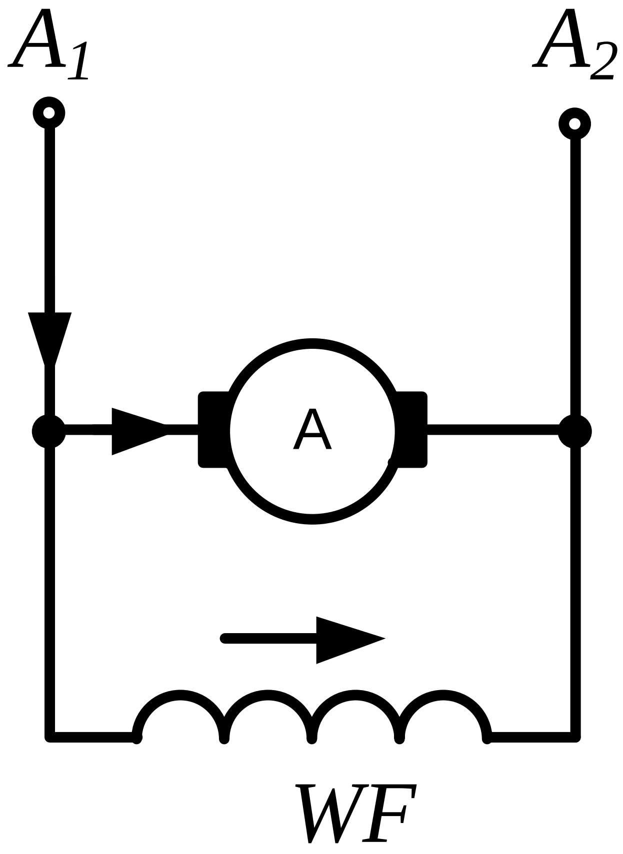
- Series wound machines.
- Shunt wound machines.
- Compound wound machines.

Series Wound machines



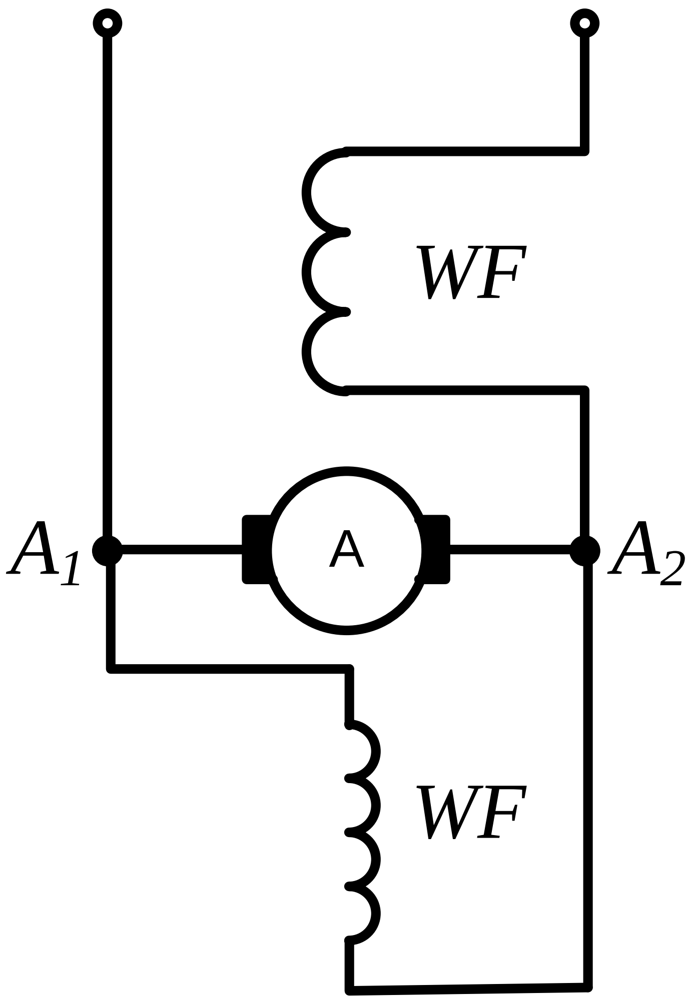
- In these type of machines, the field windings are connected in series with armature conductors as shown in figure below. So, whole electric current flows through the field coils as well as the load. As series field winding carries full load current it is designed with relatively few turns of thick wire.

Shunt Wound DC Machines



- In case of a shunt wound DC machines, the field windings are exposed to the entire terminal voltage as they are connected in parallel to the armature winding as shown in the figure below. In shunt wound generators the voltage in the field winding is same as the voltage across the terminal.

Compound Wound DC machines



- The compound excitation characteristic in a DC machines can be obtained by combining the operational characteristic of both the shunt and DC machines. The compound wound self excited dc machine essentially contains the field winding connected both in series and in parallel to the armature winding.

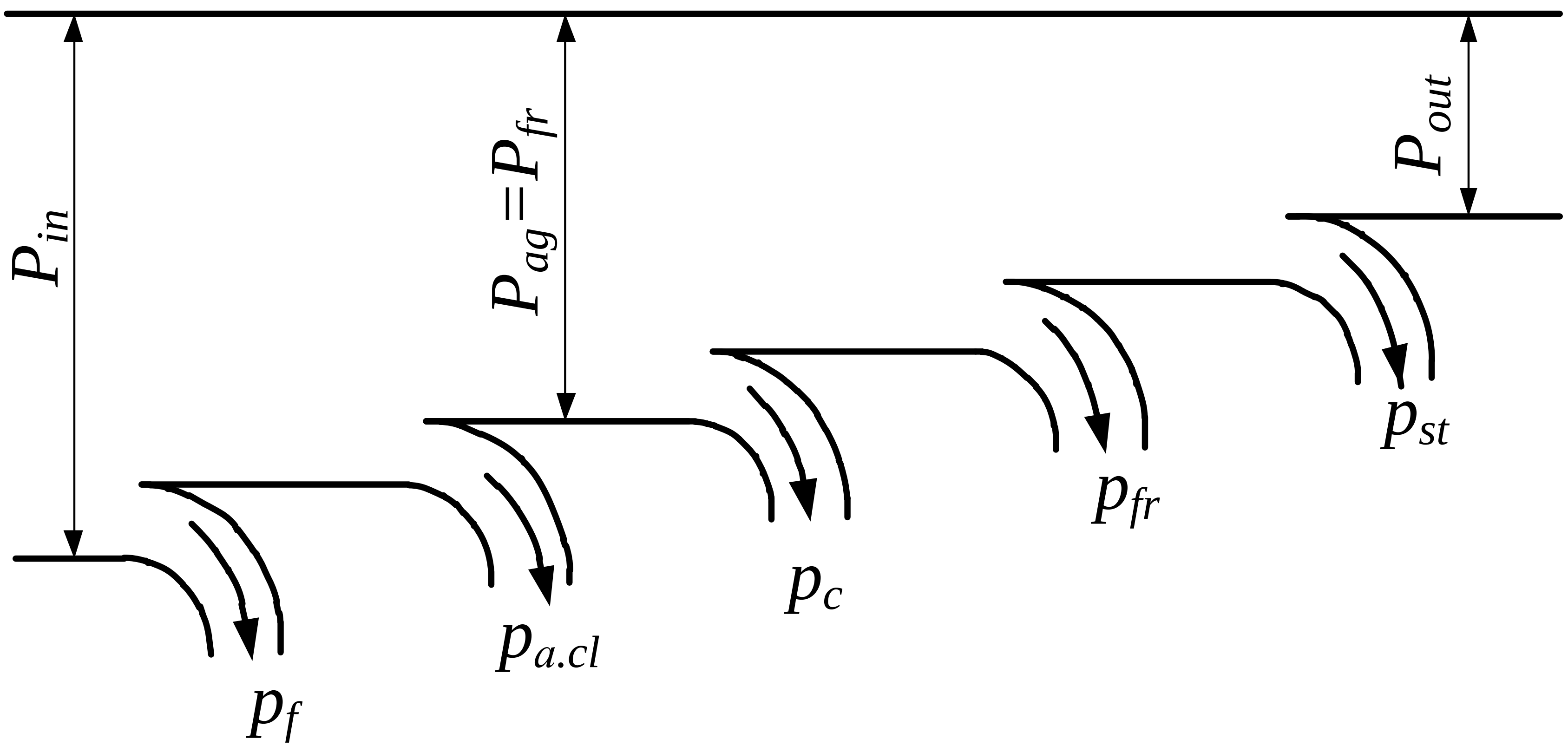
Losses and efficiency of DC motors

- The motor takes up electrical power from the main supply. At a constant load, the input is larger than the mechanical output that the motor is able to provide due to losses – or inefficiencies – in the motor. The relation between output and input is the motor efficiency, η.

$$\eta = \frac{P_{out}}{P_{in}},$$

- where P_{out} - output power, P_{in} - input power of the motor.

Energy flow diagram of DC motor



Losses and efficiency of DC motors

- Copper losses occur in the ohmic resistors of the armature winding $p_{a.cl}$ and field winding p_f. And also copper losses in commutator-and-brush assembly p_{cb}.

$$p_{a.cl} = I^2 \cdot R_a,$$
$$p_f = U_f \cdot I_f,$$
$$p_{cb} = 2 \cdot \Delta U_b \cdot I,$$

- where I – armature current, I_f – field current, R_a – armature resistance winding, U_f – voltage across the field winding, $2 \cdot \Delta U_b$ – voltage drop across commutator-and-brush assembly. Thus copper losses are:

$$p_{cl} = p_{a.cl} + p_f + p_{cb}.$$

Losses and efficiency of DC motors

- Iron or core losses, p_c consist of hysteresis losses and eddy current losses.
- Friction and fan losses p_{fr} occur due to the air resistance of the motor fan and in the ball bearings of the armature.
- Stray losses p_{st}. These include harmonic losses in the core and current flow through the core (rather than staying in the conductors where you would like it to be).
- Overall losses in DC motor could be calculated as:

$$\sum \mathrm{P} = p_{cl} + p_c + p_{fr} + p_{st}.$$

Losses and efficiency of DC motors

- Efficiency of the motor could be given by:

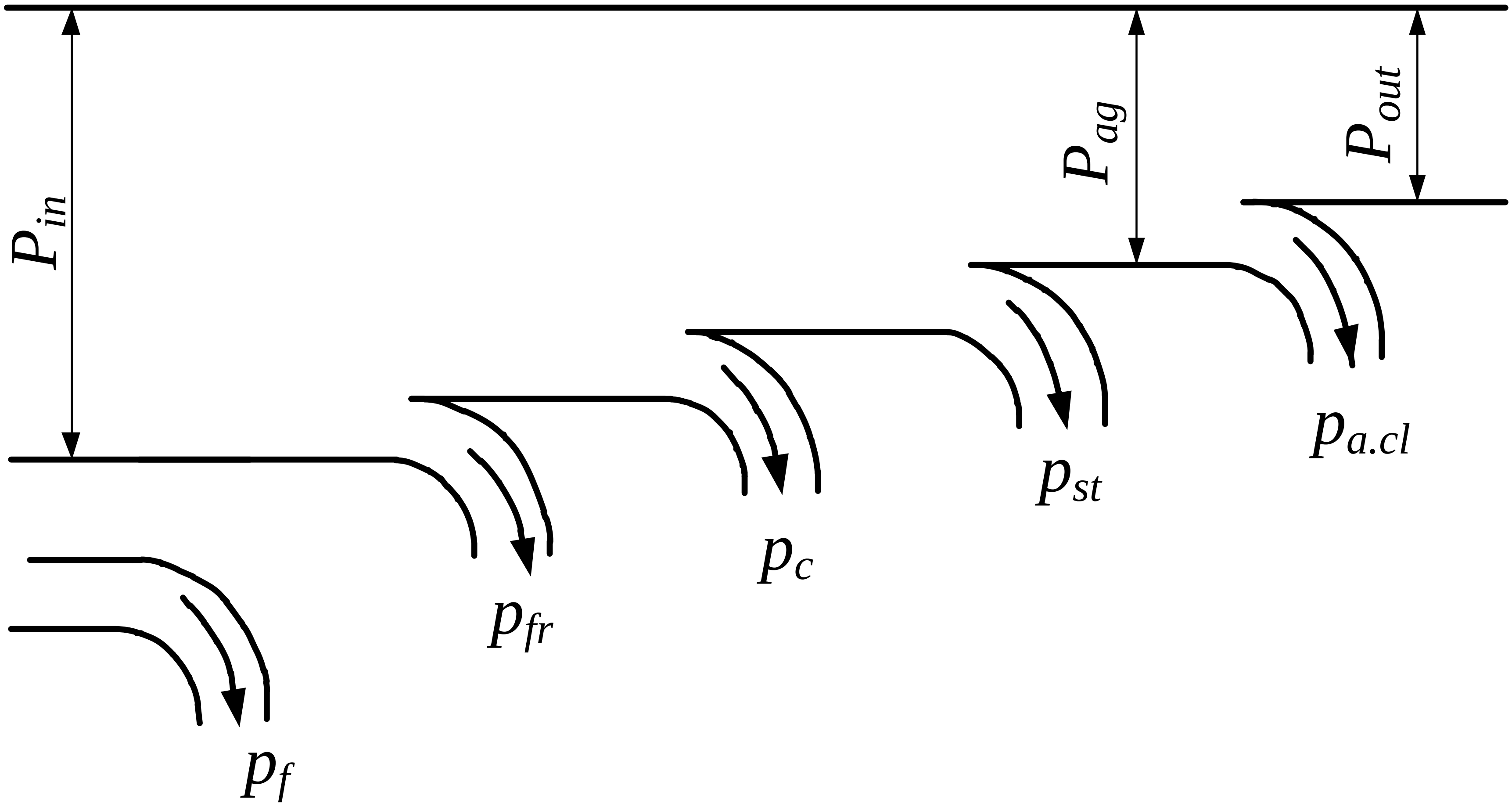
$$\eta = \frac{\mathrm{P_{in}} - \sum \mathrm{P}}{\mathrm{P_{in}}},$$

- as

$$\mathrm{P_{in}} = U_s \cdot I_s,$$

$$\eta = \frac{U_s \cdot I_s - \sum \mathrm{P}}{U_s \cdot I_s} = 1 - \frac{\sum \mathrm{P}}{U_s \cdot I_s}.$$

Energy flow diagram of DC generator



Losses and efficiency of DC generator

- The input power $\mathrm{P_{in}}$ is supplied to generator shaft, p_{fr} is the friction losses, p_c is the core losses, p_{st} stray losses, $p_{a.cl}$ copper losses in armature winding, $\mathrm{P_{out}}$ output power of the DC generator, p_f – copper losses in excitation winding.

$$\eta = \frac{\mathrm{P_{out}}}{\mathrm{P_{in}}},$$

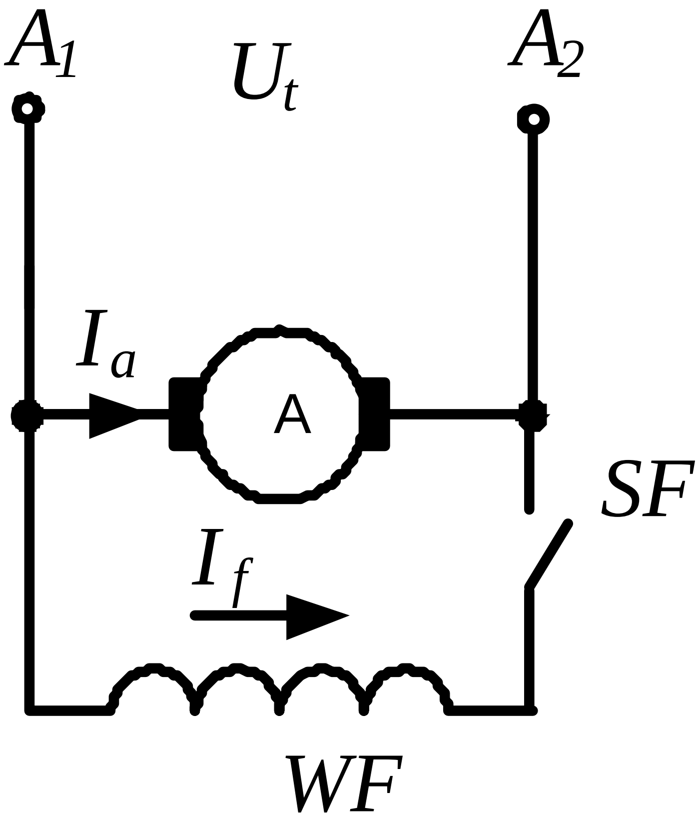
- as

$$\mathrm{P_{in}} = \mathrm{P_{out}} + \sum \mathrm{P},$$

$$\mathrm{P_{out}} = U_s \cdot I_s,$$

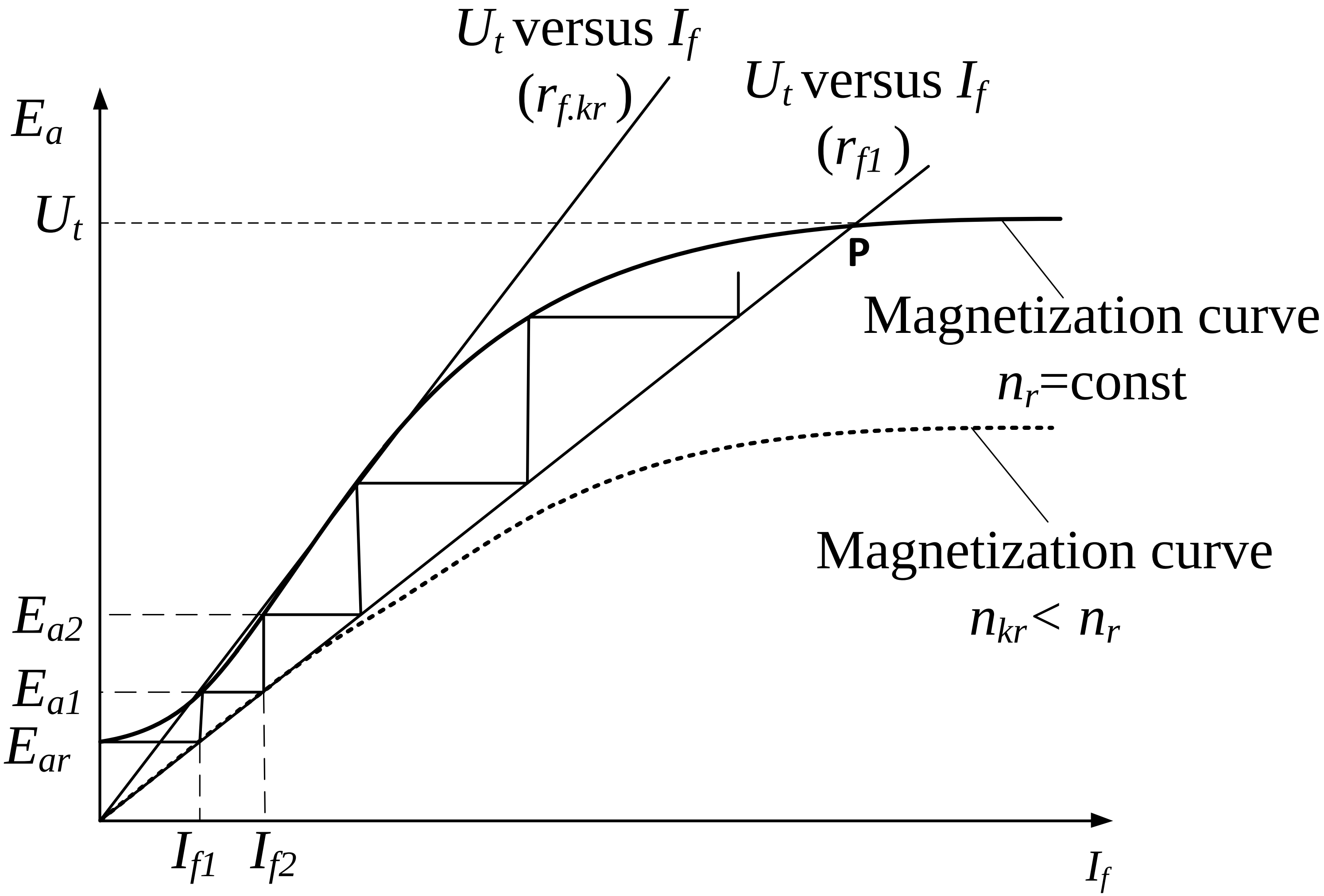
$$\eta = 1 - \frac{\sum \mathrm{P}}{U_s \cdot I_s + \sum \mathrm{P}}.$$

Self-excitation of shunt DC generator



- If the machine is to operate as a self-excited generator, some residual magnetism must exits Φ_r in the magnetic circuit of the generator.

Self-excitation of shunt DC generator



Self-excitation of shunt DC generator

- conditions are to be satisfied for voltage buildup in a self-excited DC generator:
- **Residual magnetism must be present in the magnetic system.**
- **Field winding MMF should aid the residual magnetism.**
- **Field circuit resistance should be less than the critical field circuit resistance.**
- **Speed of shaft rotation should be greater than the critical speed of rotation.**

DIRECT CURRENT MACHINES 6

Starting of DC Motor

- Starting methods of DC motor:
  - **Direct-on-line.**
  - **Lower supply voltage.**
  - **Starter resistance (resistance series connected to armature winding).**

Starting of DC Motor

- The basic operational voltage equation of the dc motor given by,

$$U = E_a + I_a \cdot R_a$$

- Where U is the supply voltage, I_a is the armature current, R_a is the armature resistance. And the back EMF is given by E_a. Armature current is:

$$I_a = \frac{U - E_a}{R_a},$$

- where $E_a = C \cdot \Phi \cdot n$.

Starting of DC Motor

- Now the back EMF, in case of a DC motor, is very similar to the generated EMF of a DC generator as it's produced by the rotational motion of the electric current carrying armature conductor in presence of the field. This back emf of DC motor is given by:

$$E_a = C \cdot \Phi \cdot n,$$

- and has a major role to play in case of the starting of DC motor.

Starting of DC Motor

- From this equation we can see that E_a is directly proportional to the speed n of the motor. Now since at starting $\mathrm{n} = 0$, $\mathrm{E_a}$ is also zero, and under this circumstance the voltage equation is modified to:

$$U = I_a \cdot R_a,$$

- therefore

$$\mathrm{I_a} = \frac{\mathrm{U}}{\mathrm{R_a}}.$$

Starting of DC Motor

- armature resistance - $0.5\ \Omega$
- supply voltage being $220\ \mathrm{V}$.
- the starting current, $\mathrm{I_a} = \frac{220}{0.5} = 440\ \mathrm{A}$.

Such high starting current of DC motor creates two major problems:

- **High starting current has the potential of damaging the internal circuit of the armature winding of DC motor at the very onset.**
- **Secondly, very high electromagnetic starting torque of DC motor is produced by virtue of the high starting current, which has the potential of producing huge centrifugal force capable of flying off the rotor winding from the slots.**

Starting of DC Motor

- The main principal of this being the addition of external electrical resistance $\mathrm{R_{ext}}$ to the armature winding, so as to increase the effective resistance to $\mathrm{R_a + R_{ext}}$, thus limiting the armature current to the rated value. The new value of starting armature current is desirably low and is given by:

$$I_a = \frac{U}{R_a + R_{ext}}.$$

- Now as the motor continues to run and gather speed, the back EMF successively develops and increases, countering the supply voltage, resulting in the decrease of the net working voltage. Thus now:

$$I_a = \frac{U - E_a}{R_a + R_{ext}}.$$

Speed control of DC Motor

- Armature current is:

$$I_a = \frac{U - E_a}{R_a}, E_a = C \cdot \Phi \cdot n,$$

- so

$$n = \frac{U - I_a \cdot R_a}{C \cdot \Phi}.$$

Therefore speed n can be controlled by changing the quantities on the expression. So speed can be varied by changing:

- terminal voltage of the armature U,
- external resistance in armature circuit R_a and
- flux per pole Φ.

Speed control of DC Motor

The first two cases involve change that affects armature circuit and the third one involves change in magnetic field. Therefore speed control of DC motor is classified as

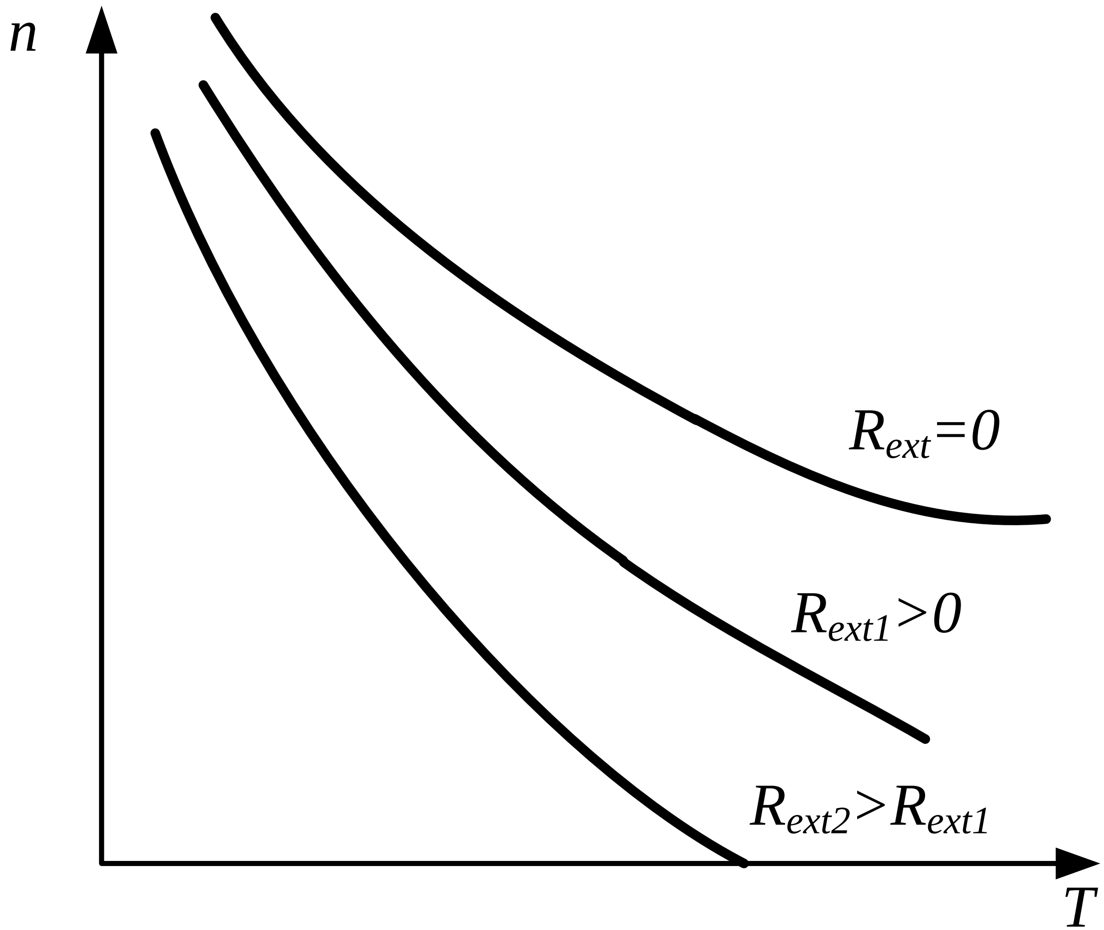
- **armature control methods and**
- **field control methods.**

Armature Control of DC Series Motor

- **1. Armature resistance control method**
- **2. Shunted armature control**
- **3. Armature terminal voltage control**

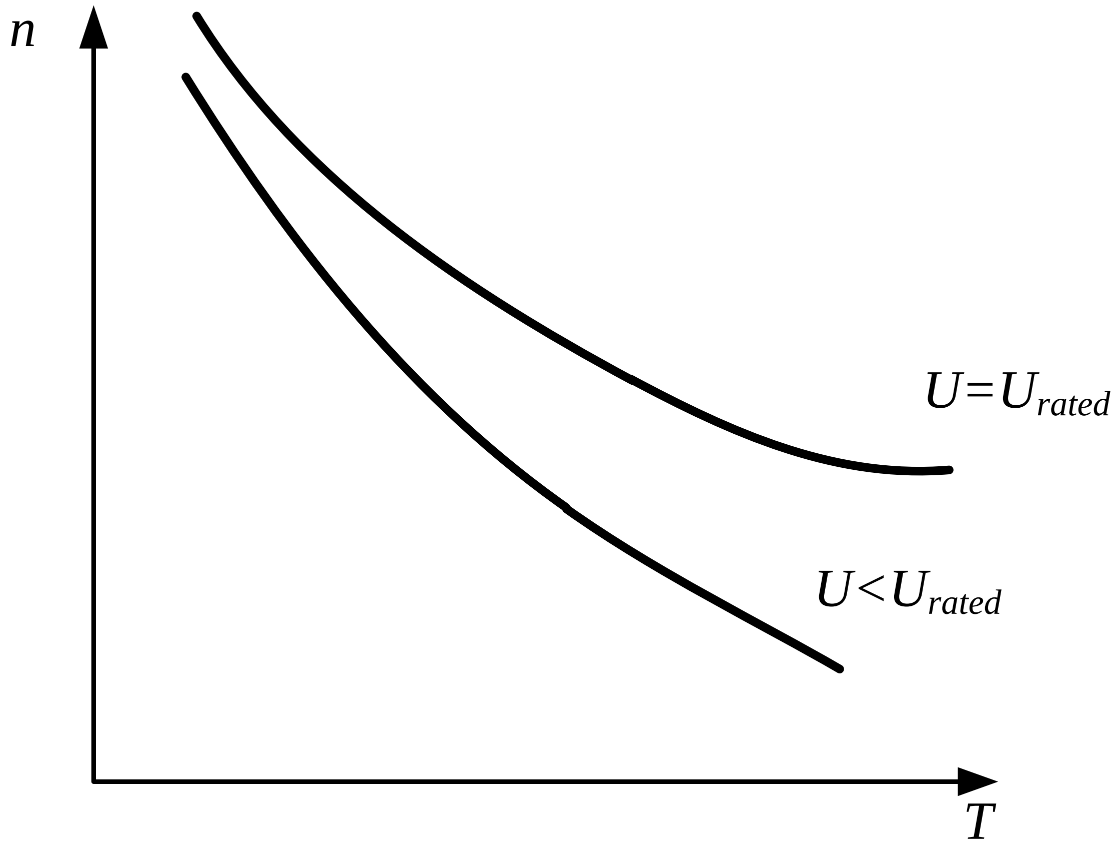
Armature resistance control method of DC Series Motor

$$U = const, i_f = const, R_{ext} = var$$



Armature terminal voltage control method of DC Series Motor

$$U = var, i_f = const$$

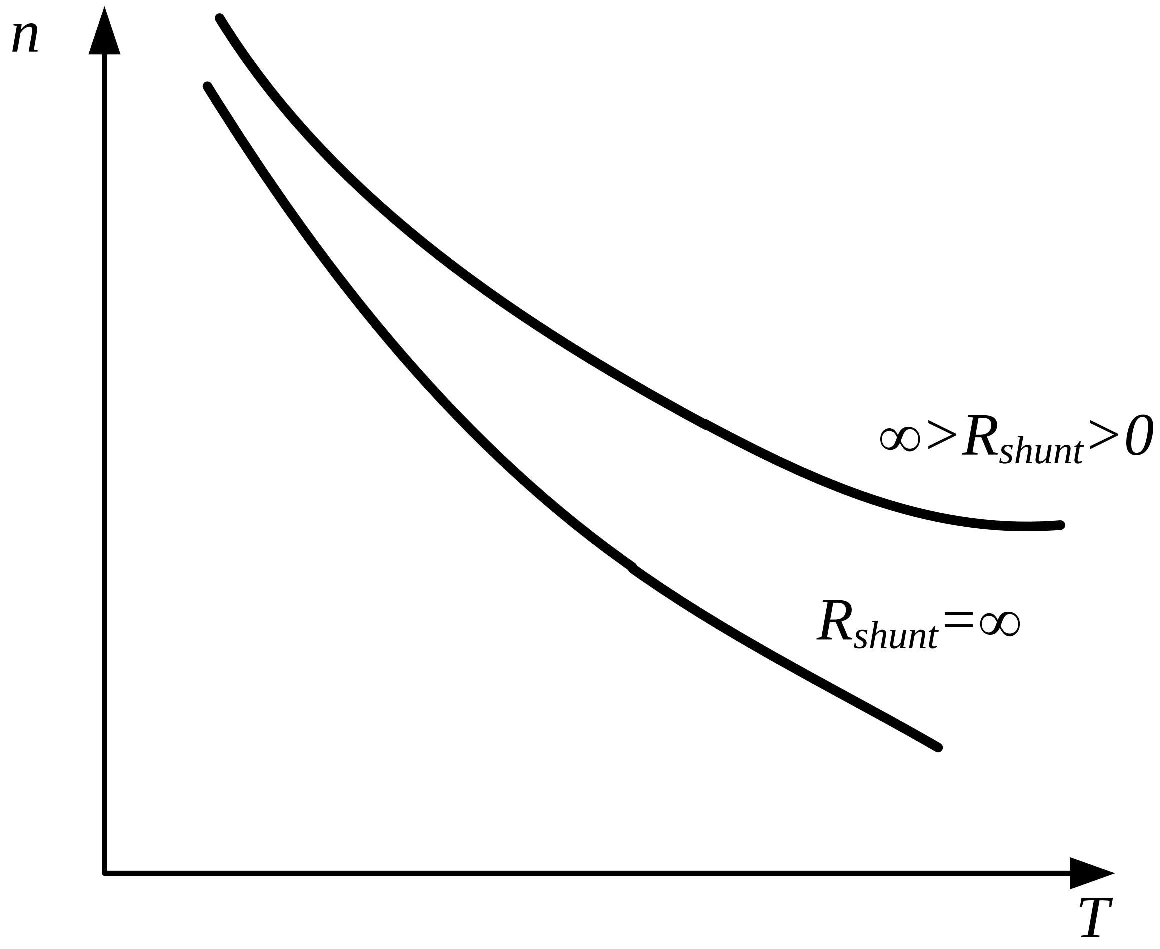


Field Control of DC Series Motor

- **1. Field diverter method**
- **2. Tapped Field control**

Field diverter method of DC Series Motor

$$U = const, i_f = var$$

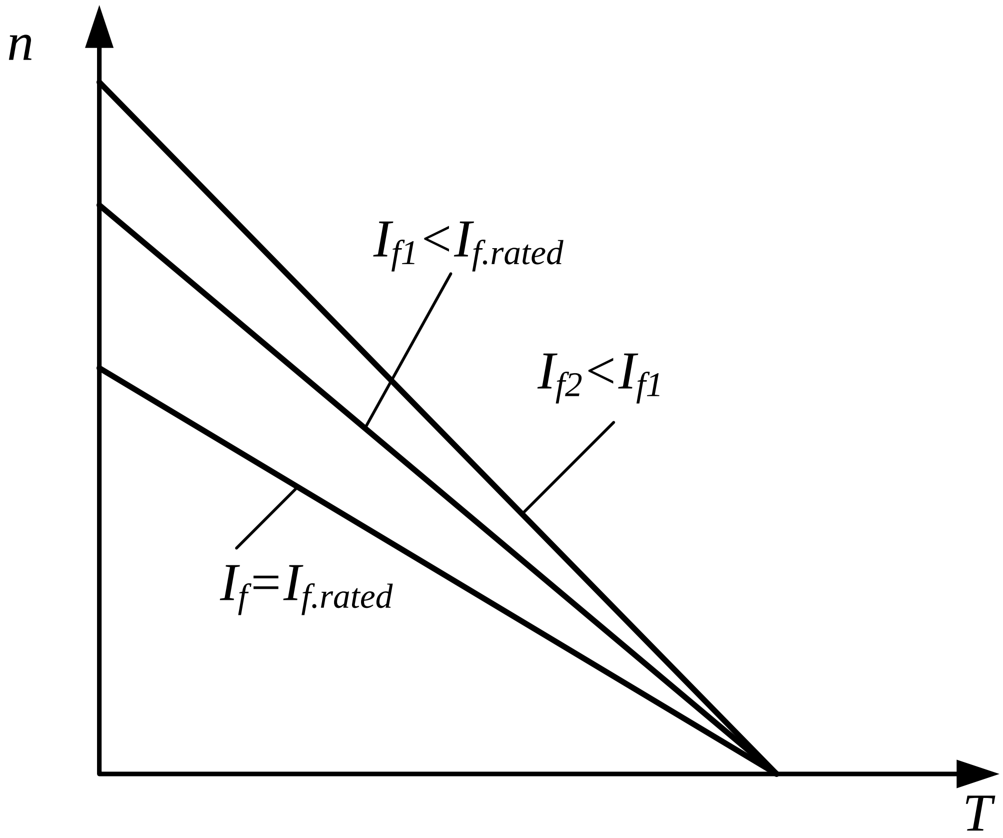


Field Control of DC Shunt and separately excited motor

- **1. Field rheostat control of DC Shunt and separately excited Motor**
- **2. Field voltage control**

Field rheostat control of DC Shunt and separately excited Motor

$$\boldsymbol{U = const, i_f = var}$$

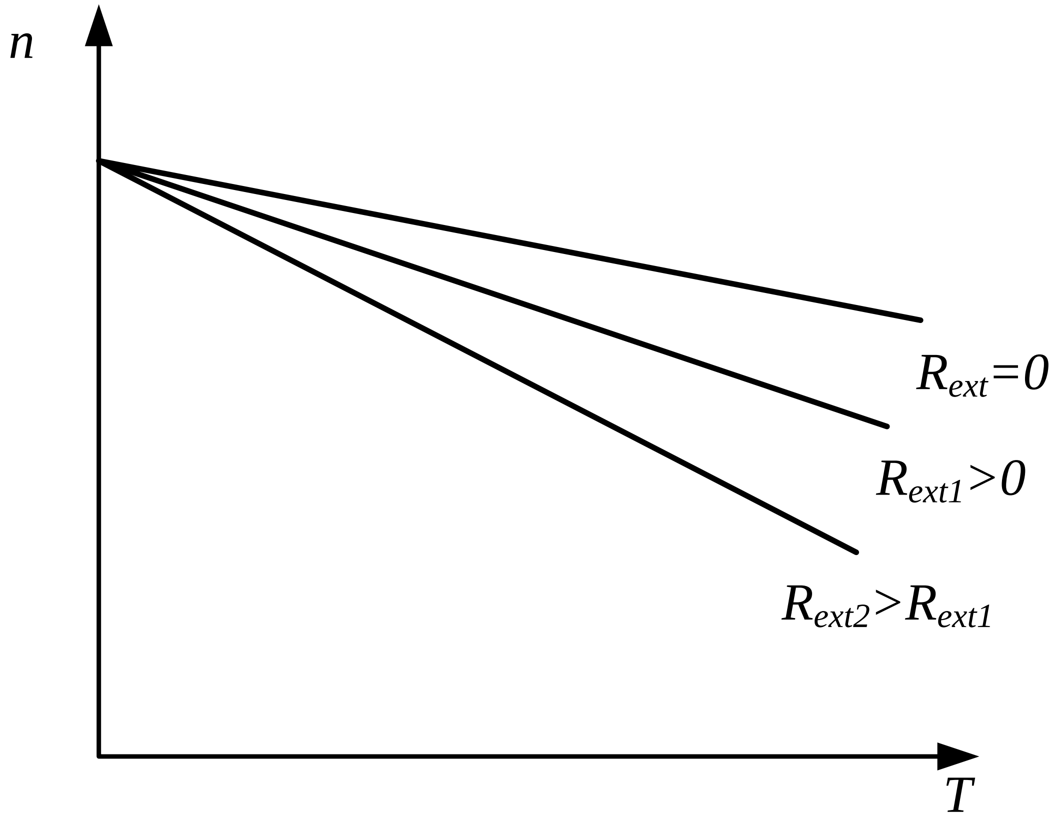


Armature Control of DC Shunt and separately excited Motor

- **1. Armature resistance control**
- **2. Armature voltage control**

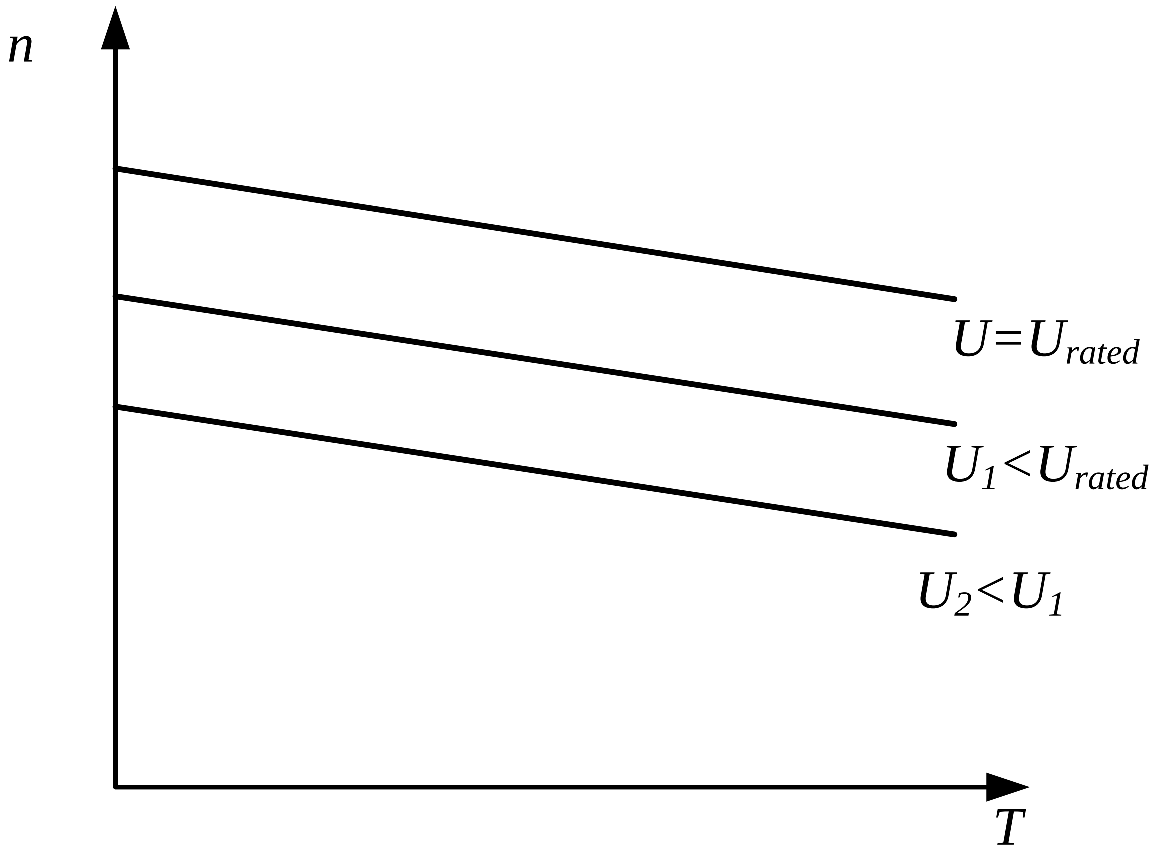
Armature resistance control of DC Shunt and separately excited Motor

$U = const, i_f = const, R_{ext} = var$



Armature resistance control of DC Shunt and separately excited Motor

$$U = var, i_f = const$$



DIRECT CURRENT MACHINES 7

TESTING OF SHUNT WOUND DIRECT CURRENT MOTOR

- **Purpose of laboratory session**
- The purpose of the given work is to study construction and working principle of the shunt wound direct current motor, to carry out experiments under load and obtain working performance, speed torque characteristics while armature resistance and field current vary.

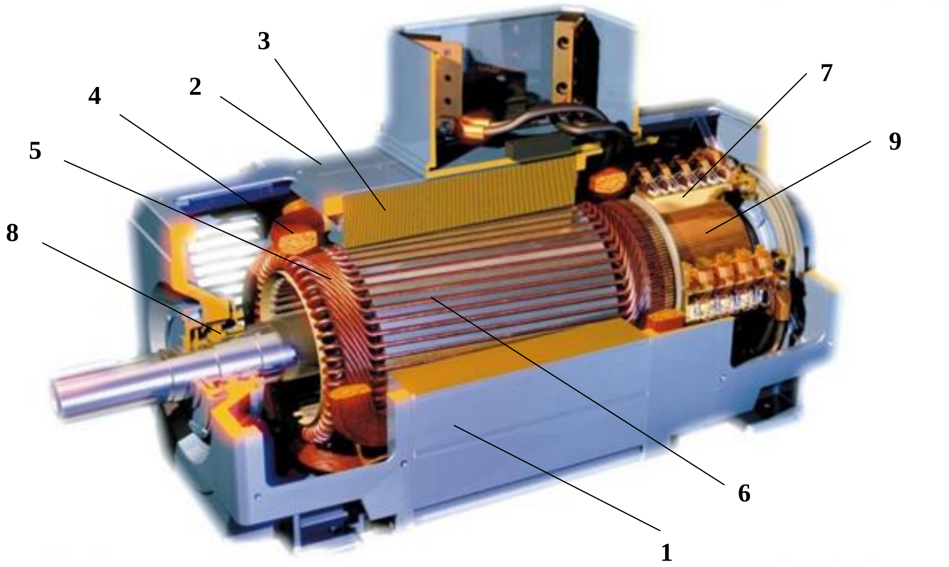
Operating program

- To examine the working principle of the shunt direct current motor and to classify the types of direct current machines.
- To define the laboratory unit.
- To start the shunt direct current motor.
- To make experiment of load test and build characteristics.
- To calculate speed torque characteristics while armature resistance vary.
- To provide experiment while field current vary and build speed current characteristics.
- To analyze the motor characteristics under load test and make conclusions.

Self-instruction

- Direct current motor – *(give the definition)*____
- Direct current motor consists of following main components (*write title, purpose and material*):
- 1.____
- 2.____
- 3.____
- 4.____
- 5.____

Self-instruction



- According to the fig. 1 name all components of direct current motor:
- 1.____________________________ ____________________
- 2.____________________________ ____________________
- 3.____________________________ ____________________
- 4.____________________________ ____________________
- 5.____________________________ ____________________
- 6.____________________________ ____________________
- 7.____________________________ ____________________
- 8.____________________________ ____________________
- 9.____________________________ ____________________

Self-instruction

- The working principle of direct current motor is based on ______________________________ ____ ____ ____ ____ ____
- The voltage equation of direct current motor:
- ____________=___________________________________ ____,
- where ____________ - ____ __________________________________,
- ____________ - ____ ____,
- ____________ - ____ ____,
- ____________ - ____ ____,
- ____________ - ____ ____,
- ____________ - ____ ____,

Self-instruction

- The main construction differences between induction motors with squirrel-cage and wound rotors are the following:
- ____
  ____
  ____
  ____
  ____
- ____
  ____
  ____
  ____
  ____
- The direct current motor starting methods are the following:
- 1.____
  ____
- 2.____
  ____
- 3.____
  ____

Self-instruction

- The induction motor speed changing methods are the following:
- 1.____
  ____
- 2.____
  ____
- 3.____
  ____
- The idle running of shunt direct current motor is ____
  ____
  _____

Self-instruction

- To idle running losses could be included following ___ ____
- The short circuit test of shunt direct current motor is _ ____ ______
- To short circuit losses could be included following ___ ____

Self-instruction

- The load test of shunt direct current motor is ________
  ____
- The armature reaction in the direct current motor is:_
  ____
  ____
  ____
  ____
  ____
  ____
  ____
  ____
  ____

Self-instruction

- To reduce the armature reaction effects and to improve the machine’s performance, following methods are used:______________________________
____
____
____
____
____
____
____
____
____
- Commutation in direct current motor is:________________________________
____
____
____
____
____
____
____
____
____

Self-instruction

- To improve the commutation in direct current motors following methods are used: ____
- Methods of direct current machines excitation are the following:
- ____

Self-instruction

- Draw the energy flow diagram of shunt direct current motor and make all necessary notes.

Self-instruction

- The efficiency of the shunt direct current motor is ____
-
-