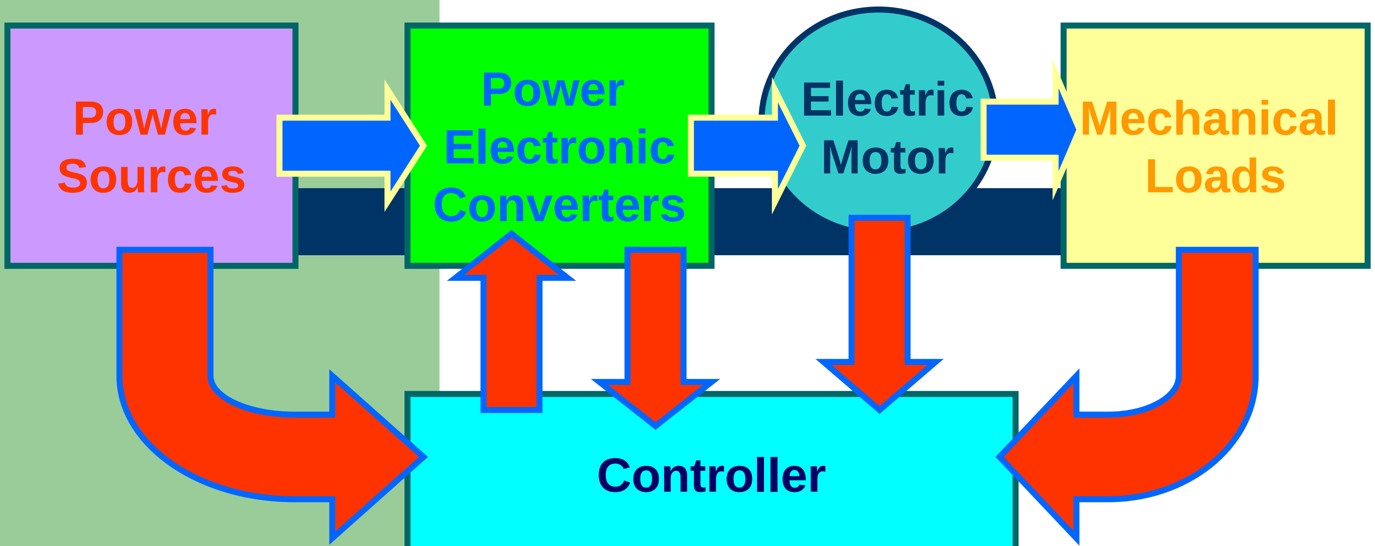
Basic Components Of An Electric Drives System

A modern electric drives system has five functional basic component :

1. Mechanical Loads
2. Electrical Motors
3. Static Converters (Power Electronic)
4. Power Sources
5. Controller



The basic criterion in selecting an electric motor for a given drives application :

1. **Power level and performance required by the loads during steady-state and dynamic operation.**

   Ex: In application for which a high starting torque is needed a dc series motor might be a better choice than an ac induction motor.

   In Constant speed applications, synchronous motor be more suitable than induction or dc motors

2. **Environmental factors** (determine the motor type)

   Ex: In food processing, chemical industries, aviation, where the environment must be clean and free from arcs, dc motor can not be used unless they are encapsulated.

3. **The cost of the electric motors.**

   In general, brushless dc motors are more expensive, whereas squirrel cage induction motors are the choppers

4. **The function of converters** (wave forms)

   Ex: If the power source is an ac type and the motor is a dc machine. The converter transforms the ac waveform to dc. (stability, efficiency and performance of motor that using this converter.

1. Mechanical Loads

Mechanical loads exhibit wide variations of speed-torque characteristics, Generally can be expressed as :

$$T = CT_r \left(\frac{n}{n_r} \right)^k \qquad \ldots\ldots\ldots.1$$

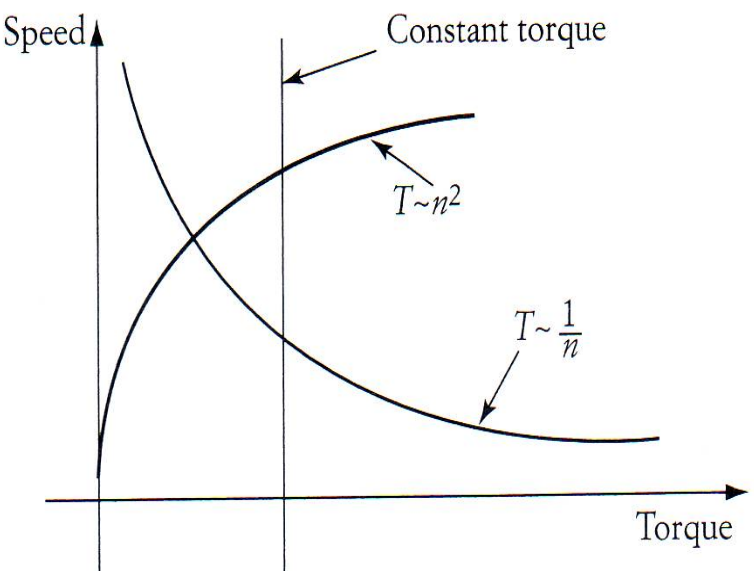
Where : *C is proportionality constant*

T_r is the loads torque

n_r is speed of load

n is operating speed

Typical speed–torque characteristics of mechanical loads



The mechanical power P of the load torque T is given by :

$$P = T\omega$$

$$\omega = 2\pi f = \frac{2\pi n}{60}$$

Type of the Mechanical Loads:

1. Torque Independent of Speed (torque constant)

The power linear dependent of speed, Ex: Hoist or the pumping of water or gas against constant pressure.

2. Torque Linearly Dependent on Speed

Ex: Motor driving a dc generator connected to a fixed-resistance load, and the field of the generator is constant.

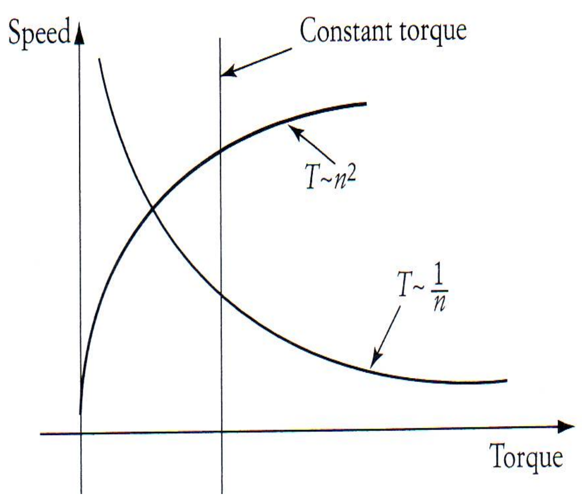
3. Torque Proportional to the Square of Speed

Ex: fans, centrifugal pumps, and propeller.

4. Torque Inversely Proportional to Speed

Ex: Milling and boring machines. The load usually requires a large torque at starting speed and at low speeds.

Typical speed–torque characteristics of mechanical loads



2. Electric Motors Speed-Torque Characteristics

Electric motors have wide variation of speed-torque characteristics

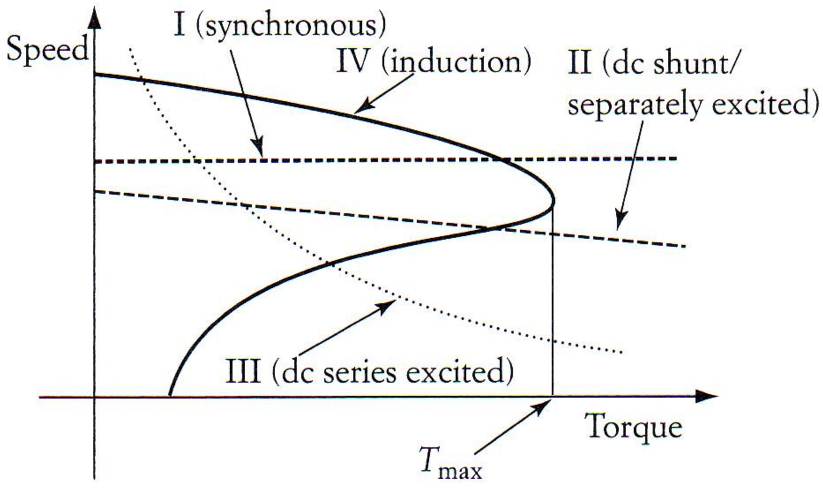
Curve I : Synchronous or reluctance motor (Constant speed)

Curve II : Shunt or separately excited dc motor (speed slightly reduced when the load torque increase)

Curve III : Series dc motor (speed is high at light loading condition and low at heavy loading)

Curve IV : Induction motor (during steady state, they operation at the linear portion of speed-torque characteristic speed is high at light loading, the maximum developed torque is limited to T_{max}

Speed–torque characteristics of electric motors



In electric drive application, electric motors should be selected to match the intended performance of loads. Ex: In constant speed application, the synchronous motor is probably the best option.

3. Power Sources

Two major type of power sources are used in industrial applications:

1. Alternating Current (ac), single phase or three-phase, 60Hz or 60 Hz, 240V/415V, 220V/380V, 120V/90V, 11kV/415V, etc.
2. Direct Current (dc)

Extensive industrial installation usually have more than one type of power sources at different voltages and frequencies, Commercial airplanes, for examples, may have a 400Hz ac sources in additional a 270 volt sources.

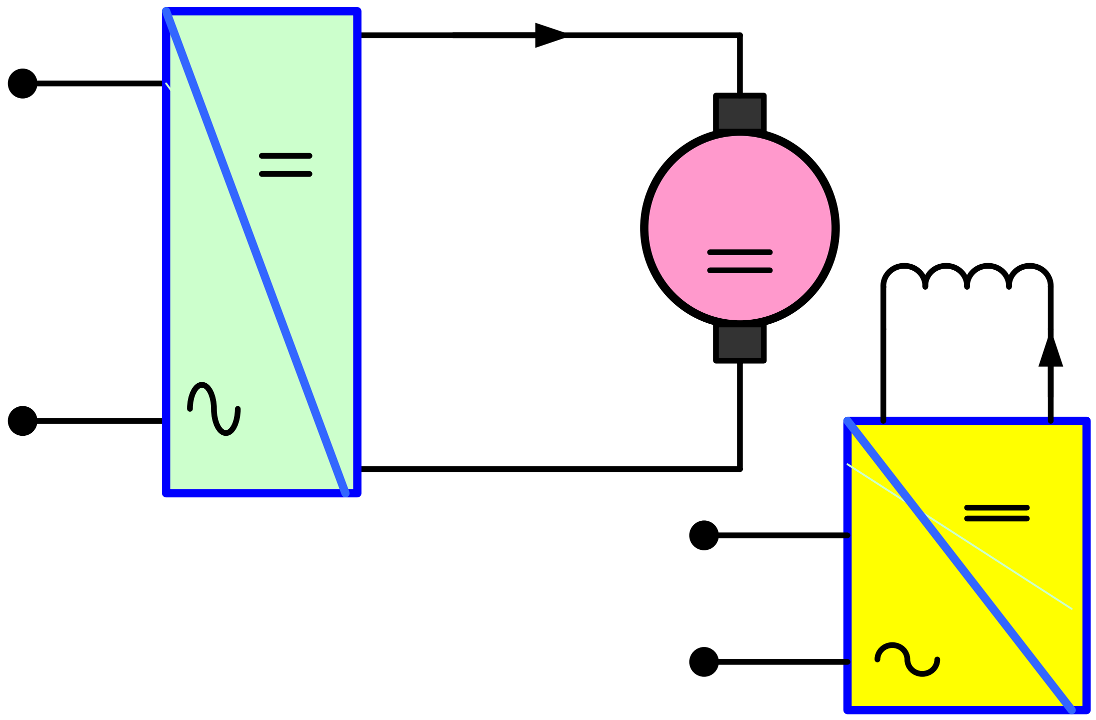
4. Converters

The main function of converters is to transform the waveform of a power sources to that the required by an electric motor in order to achieve the desired performance.

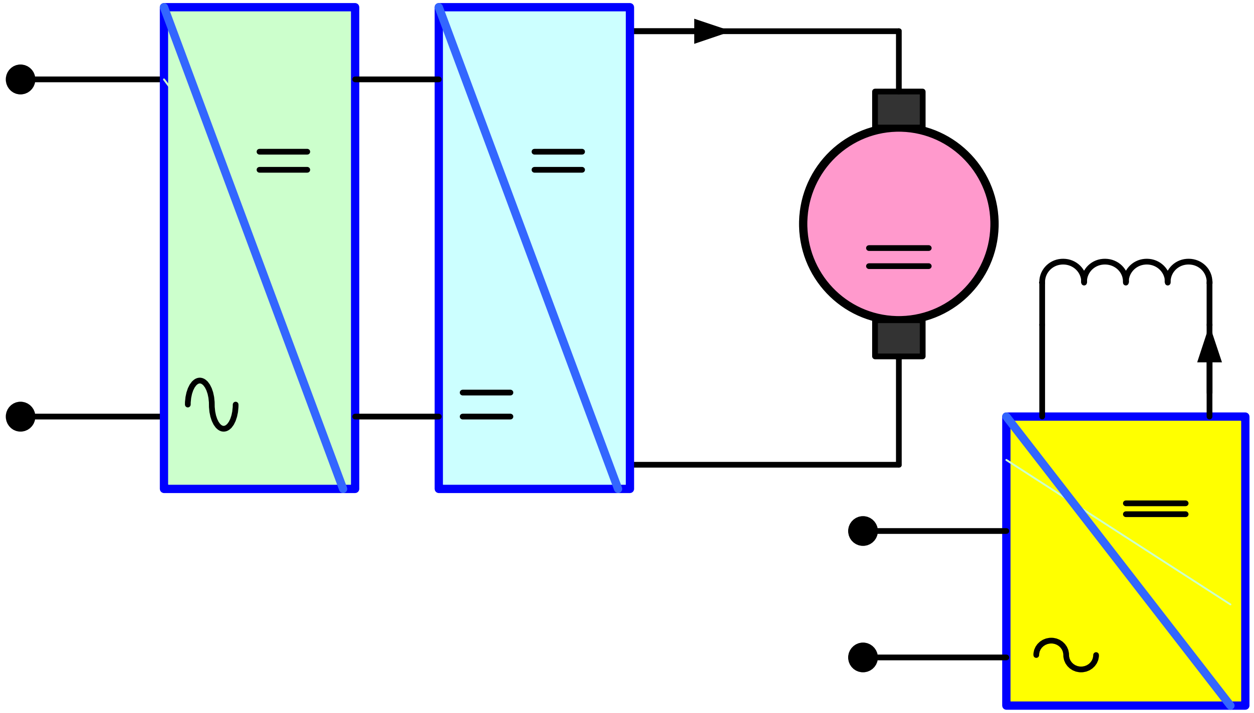
Type of Converters :

1. ***dc to ac converter*** (inverter). The output of this converter is frequency, current/voltage can be adjusted according to the application
2. ***dc to dc converter*** (dc chopper). The output of this converter is variable magnitude of voltage.
3. ***ac to dc converter*** (rectifier). The output of this converter is variable magnitude of dc voltage, input is single or three-phase ac voltage.
4. ***ac to ac converter*** (ac chopper). The output of this converter is frequency and ac variable voltage, the input is constant frequency and ac voltage.

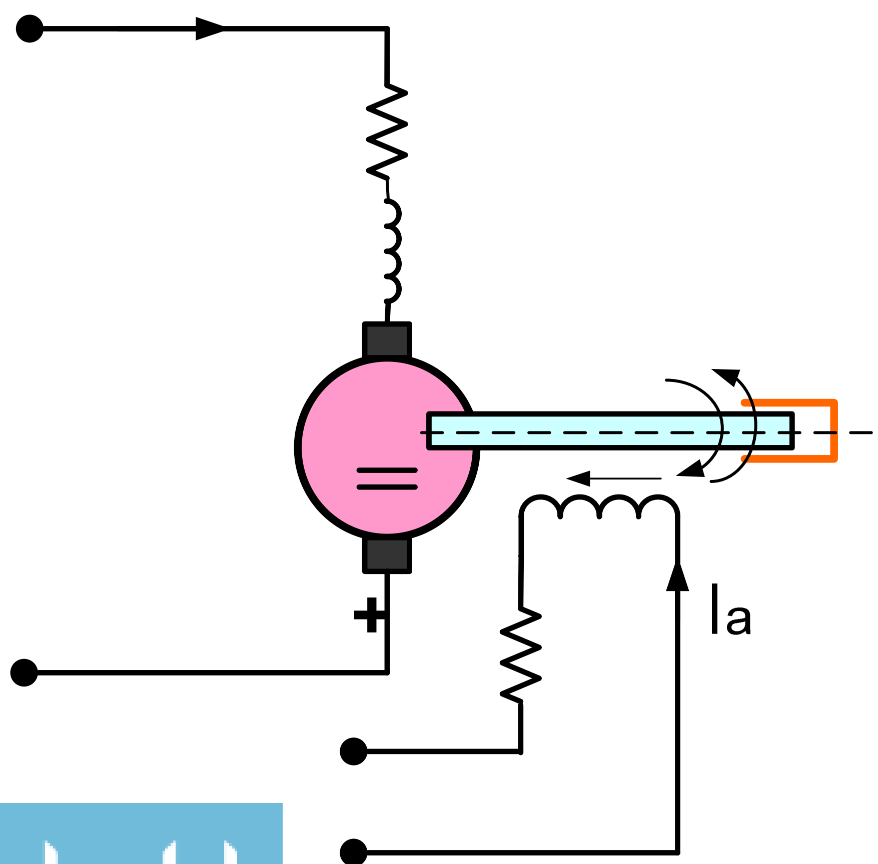
Motor DC drives System by Using Two Static Converters (Rectifiers)



Motor DC drives System by Using Three Static Converters (Two Rectifiers and one DC Chopper)



Equivalent Circuit of Separately DC Motor



$$V_f = R_f I_f$$

$$V_a = R_a I_a + E_g$$

$$= R_a I_a + K_v \omega I_f$$

$$T_d = K_v I_f I_a$$

$$= B\omega + T_L$$

$$\omega = \frac{V_a - R_a I_a}{K_v I_f} = \frac{V_a - R_a I_a}{K_v (V_f / R_f)}$$

$$P = T_d \omega$$

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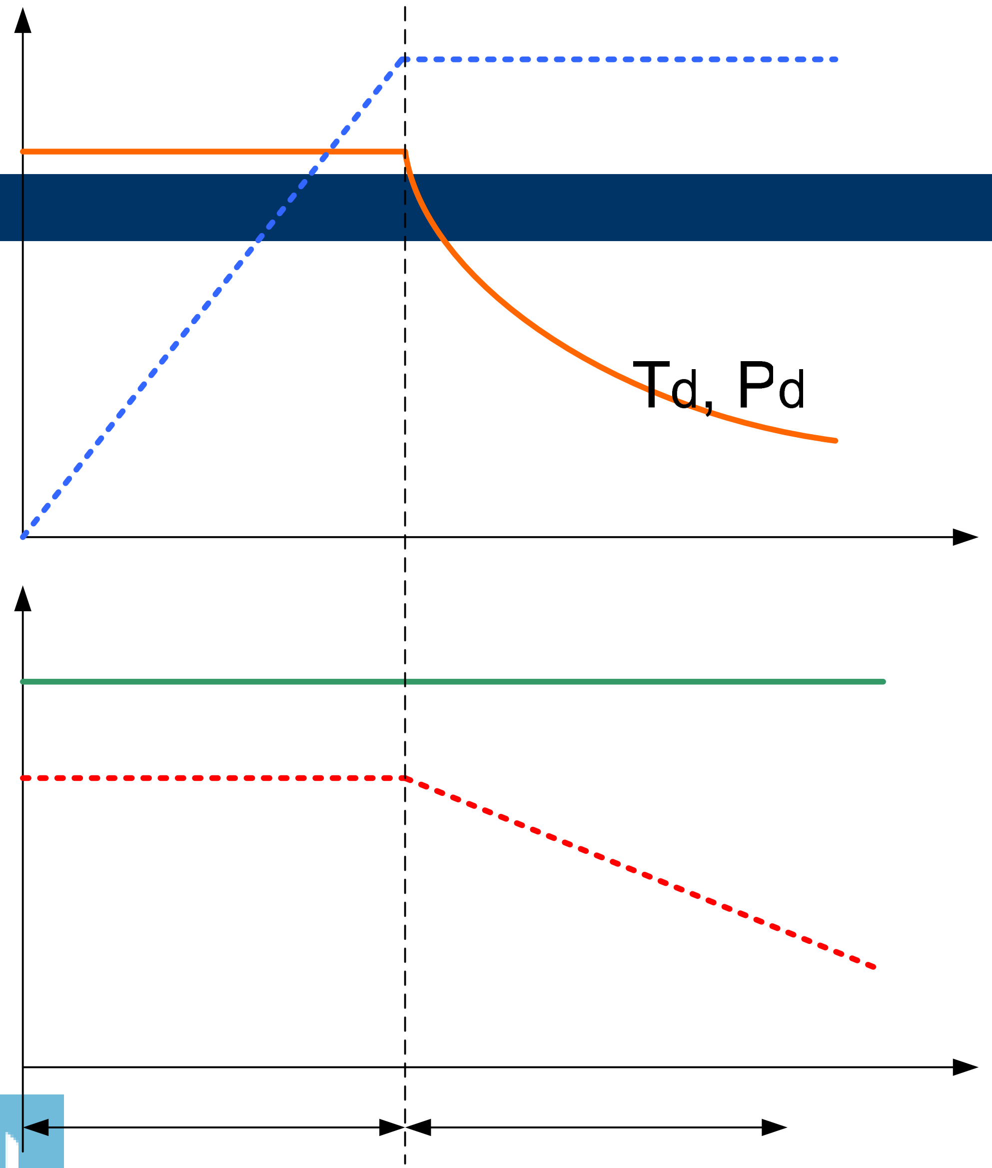
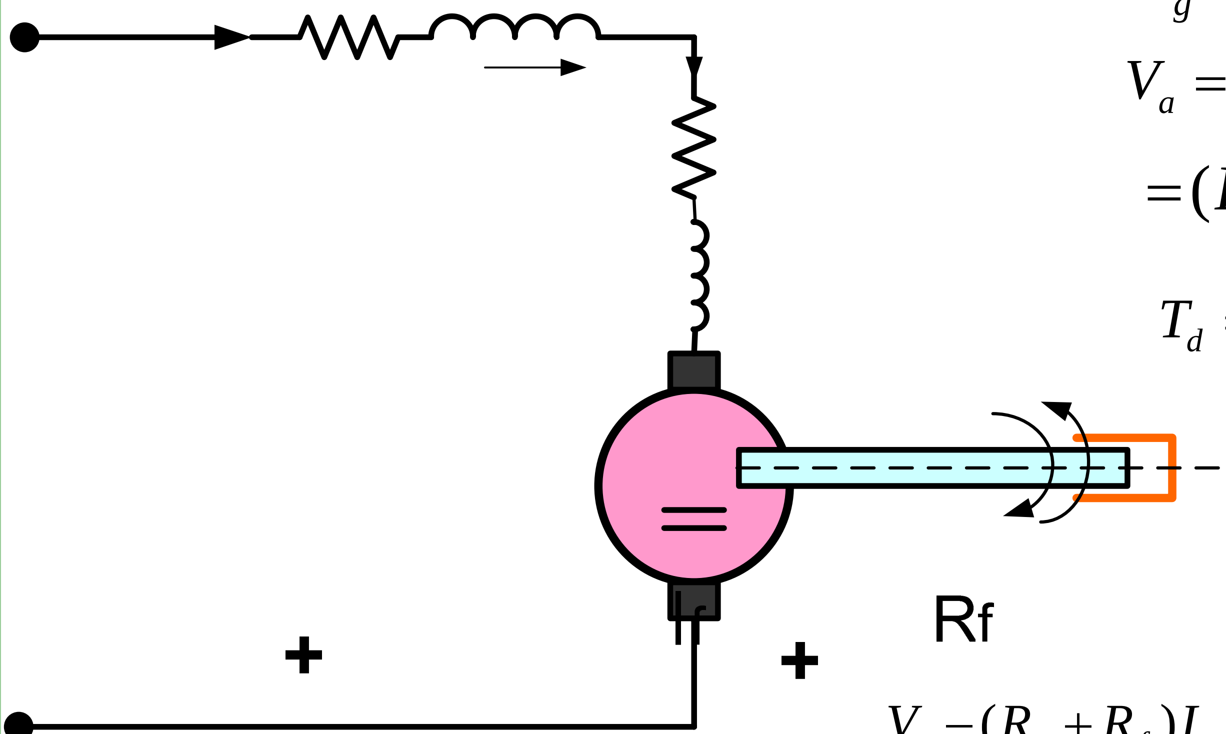
Characteristic of Separately Excited DC Motor



Equivalent Circuit of Series DC Motor



$$E_g = K_v \omega I_f = K_v \omega I_a$$

$$V_a = (R_a + R_f) I_a + E_g$$

$$= (R_a + R_f) I_a + K_v \omega I_f$$

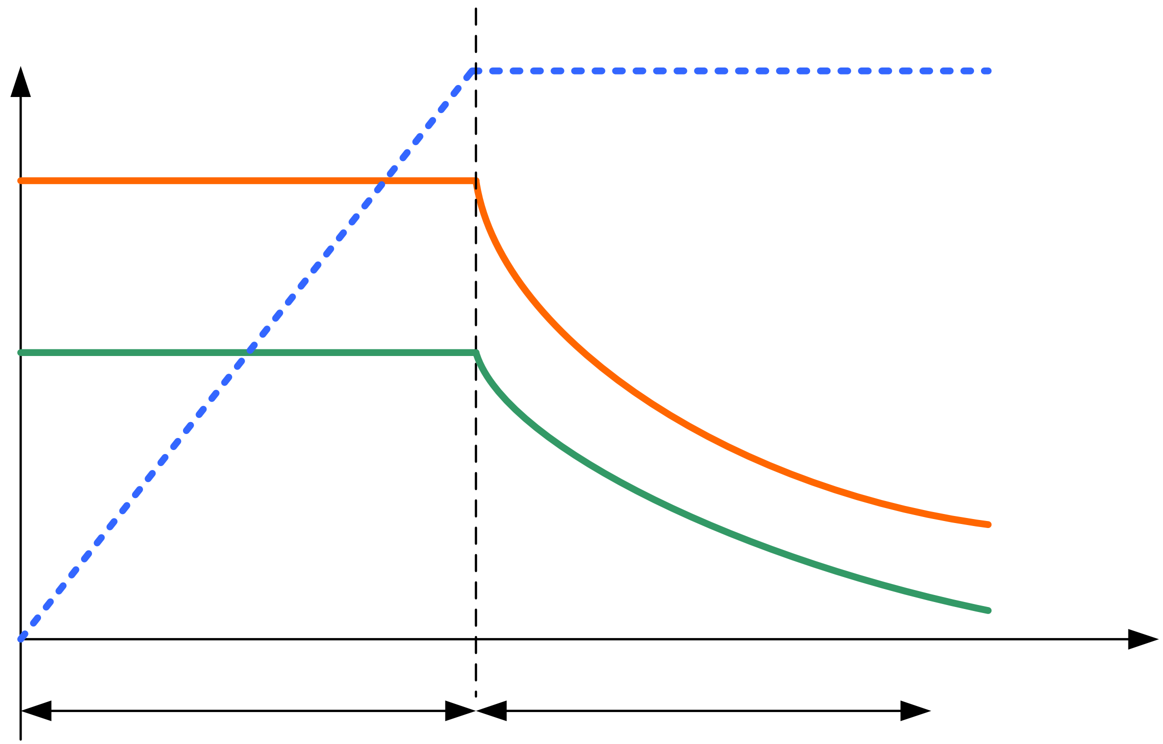
$$T_d = K_v I_f I_a = K_v I_a^2$$

$$= B\omega + T_L$$

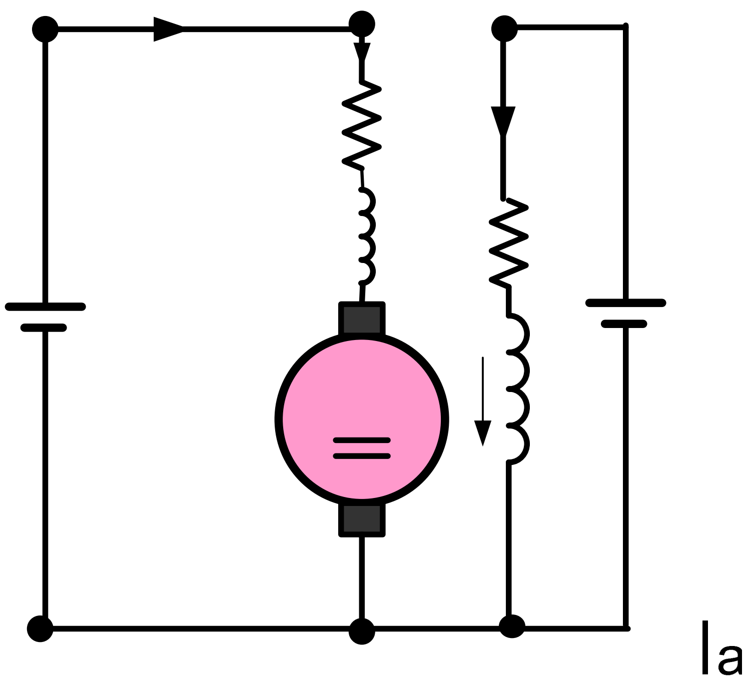
$$P = T_d \omega$$

$$\omega = \frac{V_a - (R_a + R_f) I_a}{K_v I_f} = \frac{V_a - (R_a + R_f) I_a}{K_v I_a \Phi}$$

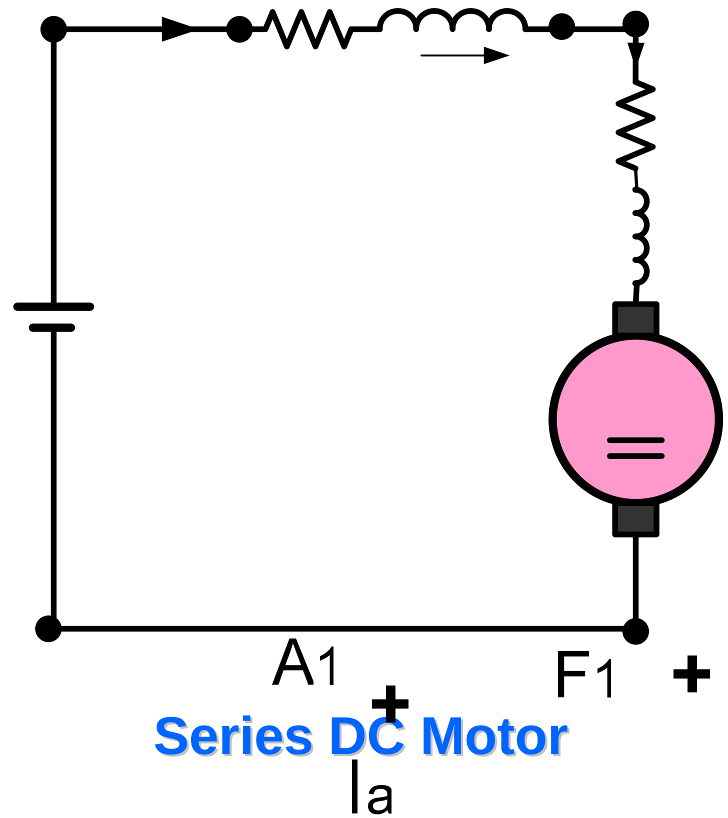
Characteristic of Series Excited DC Motor



Mode : Motoring

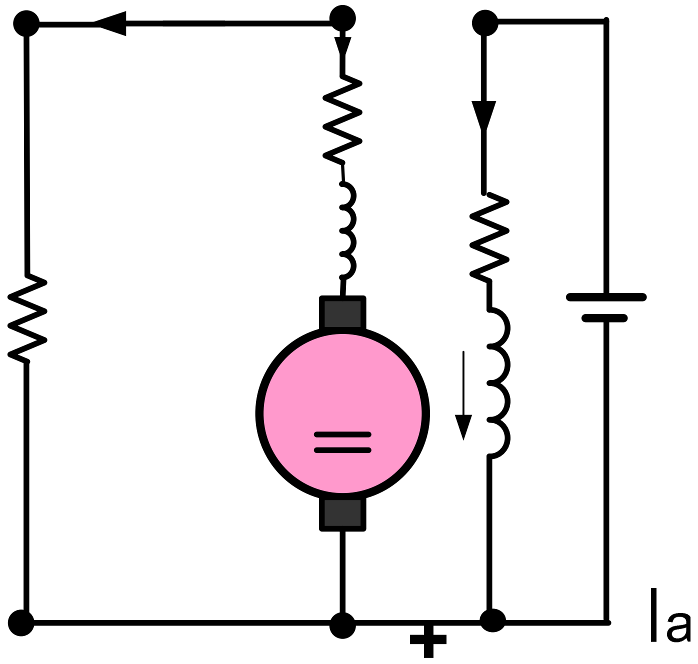


Separately DC Motor

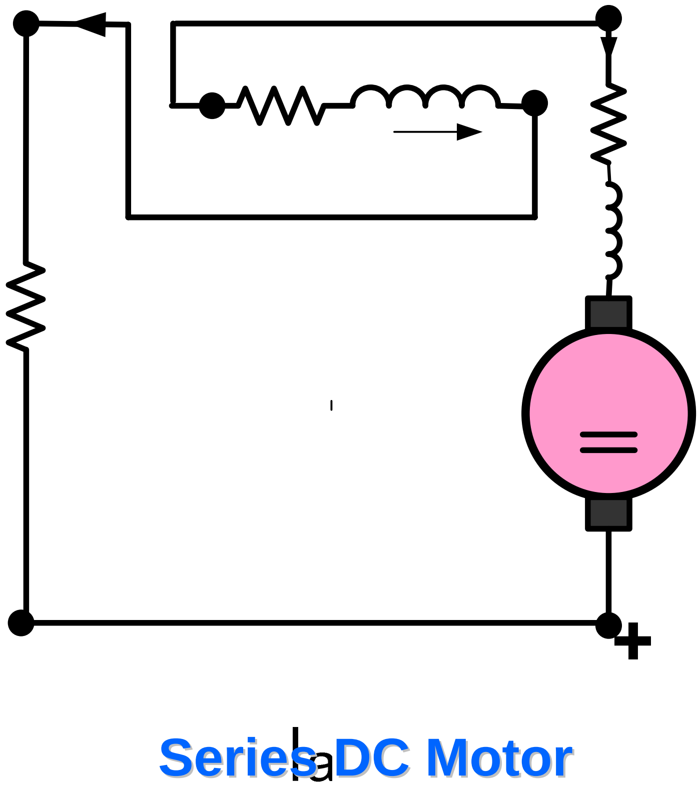


Series DC Motor

Mode : Regenerative Braking

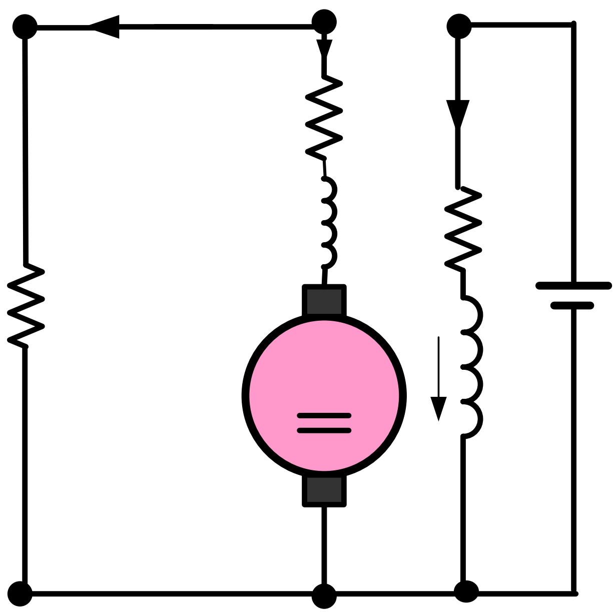


Separately DC Motor

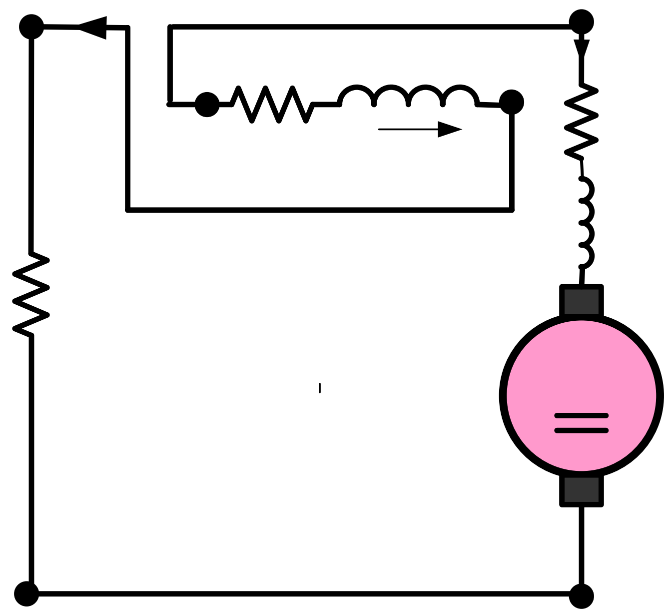


Series DC Motor

Mode : Dynamic Braking

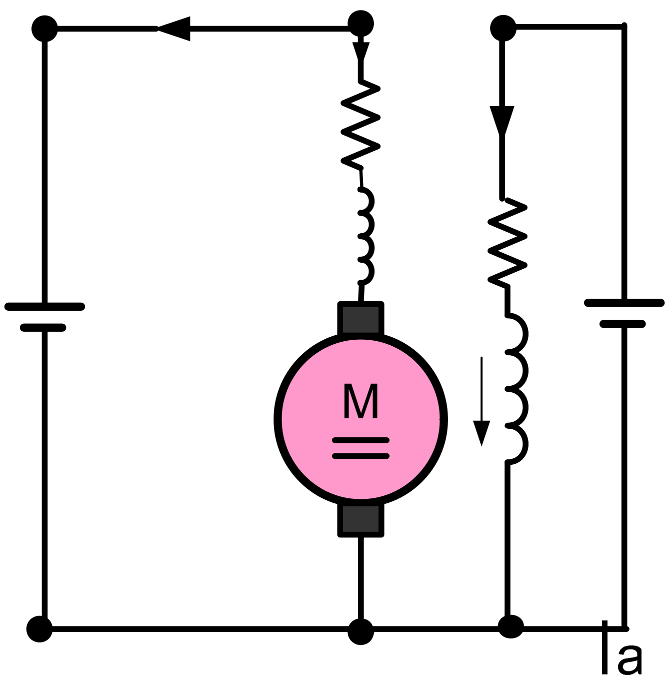


Separately DC Motor

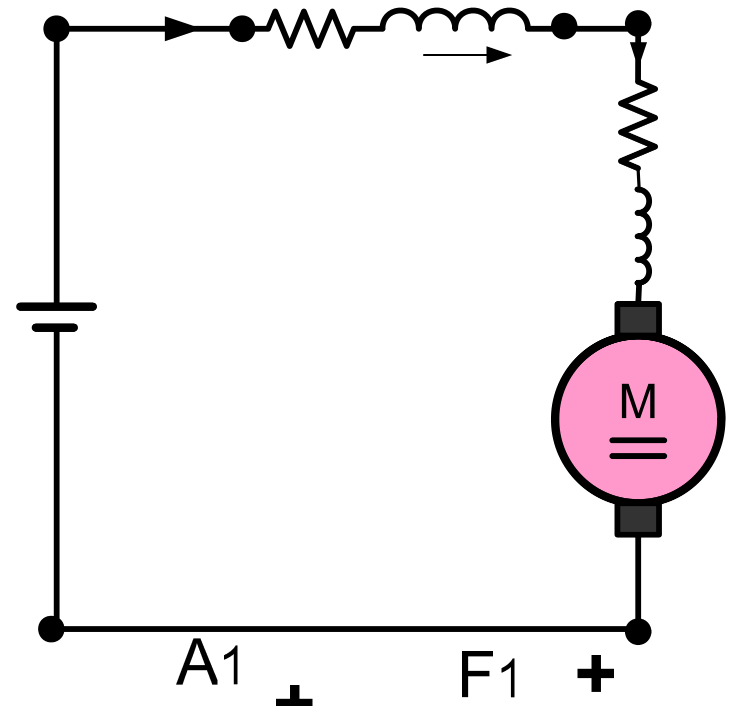


Series DC Motor

Mode : Plugging Braking



Separately DC Motor



Series DC Motor

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