EE240: Power Engineering LAB

Characteristics of Separately Excited DC Motor

Instructor

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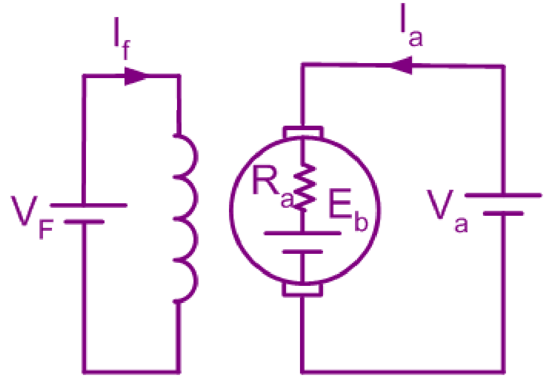
DC Motor

⇒input is electrical energy

⇒ armature is connected to the source

⇒ 'V' induced in the armature is also known as back emf

$$I_a = \frac{V_a - E_b}{R_a}$$



⇒ power input to the armature = $V_a I_a$

⇒ power input to the motor = $V_a I_a + V_f I_f$

⇒ $V_a = E_b + I_a R_a$ multiplying by I_a

$$V_a I_a = \underbrace{E_b I_a}_{\text{power developed in the armature}} + I_a^2 R_a$$

$$E_b I_a = T\omega$$

If frictional loss is neglected

$$T\omega = E_b I_a = (k\phi\omega) I_a$$

$$\therefore T = k\phi I_a$$

$$= kF_sF_r sin\delta$$

$$\Rightarrow \delta = 90 \qquad \phi \rightarrow F_s \qquad I_a \longrightarrow F_r$$

$$\Rightarrow \qquad \frac{T}{I_a} \; or \; \frac{T}{A} \; when \; \delta = 90 \quad > \quad \frac{T}{A} \; when \; \delta < 90$$

$$\therefore DC \; machine \; has \; maximum \; \frac{T}{A} \; ratio$$

In other machine to achieve this condition extra control is needed.

$\Rightarrow$ Mmf produced by the field coil and the armature coil are in quadrature hence provide wide and smooth range of speed control.

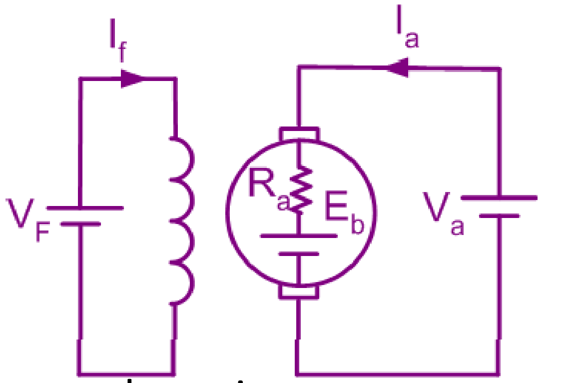
Speed Control

⇒ The basic equations governing the steady state operation of DC machine are:

$$V_a = E_b + I_a R_a \qquad E_b = k\omega\phi \qquad I_F = \frac{V_F}{R_F}$$

$$\Rightarrow E_b = V_a - I_a R_a \qquad I_a = \frac{T}{k\phi}$$

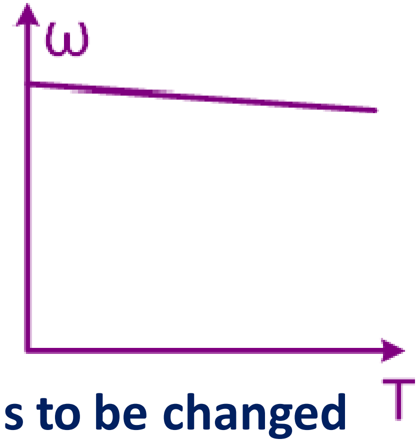
$$\Rightarrow \omega = \frac{V_a}{k\phi} - \frac{T R_a}{(k\phi)^2}$$



If armature voltage V_a and air gap flux ϕ is held constant then above equation can be written as:

$$\omega = A + BT \quad \text{where A} = \frac{V_a}{k\phi} \text{ and B} = -\frac{T R_a}{(k\phi)^2}$$

$$A \Rightarrow Y\ axis\ intercept (no\ load\ speed) \qquad and\ B \Rightarrow slope$$



R_a: armature resistance → very small

∴ for all practical purposes, S.E. dc motor is a constant speed motor

∴ ⇒ if application requires **wide variation in speed** (fan or pump), **Y-axis intercept has to be changed**

⇒ Armature reaction helps in maintain the speed constant.

⇒ For wide range of speed variation Y axis intercept has to be changed

$$A = \frac{V_a}{k\phi}$$

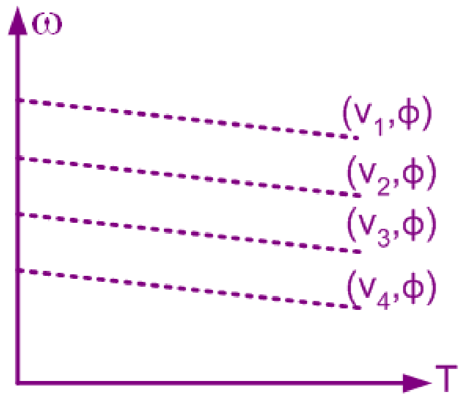
⇒ This can be achieved by

1. controlling the voltage applied to the armature terminal (V_a)
2. controlling the flux produced by the field winding (ϕ)

⇒ Speed can be controlled in two range

1. below the rated speed ($0 < \omega < \omega_{rated}$)
2. above the rated speed ($\omega > \omega_{rated}$)

⇒ **Controlling speed below base speed ($0 < \omega < \omega_{rated}$):**



either ↑ ϕ or ↓ V_a

'ϕ' can not be ↑(saturation)

∴ as V_a↓, 'A' will ↓

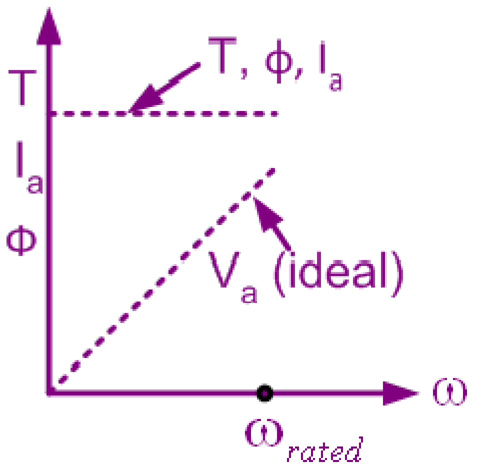
∴ For $0 < \omega < \omega_{rated}$, 'ϕ' held constant at its rated value & V_a is ↓, $A \propto V_t$

⇒ 'ϕ' is held constant → constant flux operation

⇒ If I_a is held constant → T remains constant

(at low speeds 'T' required is high, eg., train, scooter.....)

→ **constant torque region**

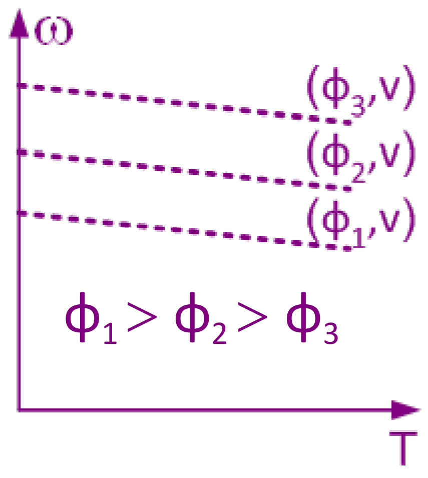


⇒ By varying the armature voltage from 0 to rated value speed can be varied from upto rated speed.

⇒ This method is known as "***Armature Voltage Control***"

⇒ **Controlling speed above base speed ($\omega > \omega_{rated}$):**

$$A = \frac{V_a}{k\phi}$$



→ either ↑ V_a & ↓ϕ

⇒ not a good engineering practice to ↑ V_a beyond V_{rated}

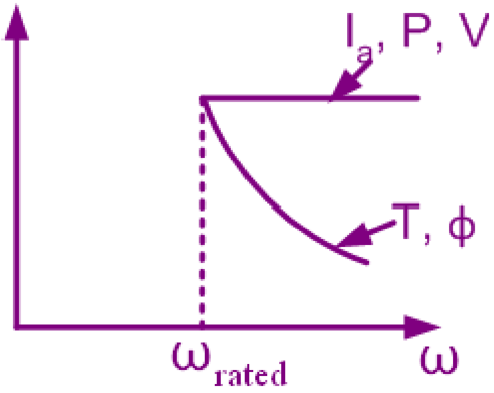
→ keep $V_a = V_{rated}$ & ↓ϕ

$\Rightarrow$ field is weakened $\rightarrow$ ***field weakening mode***

$\Rightarrow$ as $\phi \downarrow$, A$\uparrow$

$\Rightarrow$ If 'I' is held constant, power input to the armature remains constant

$V_a I_a$



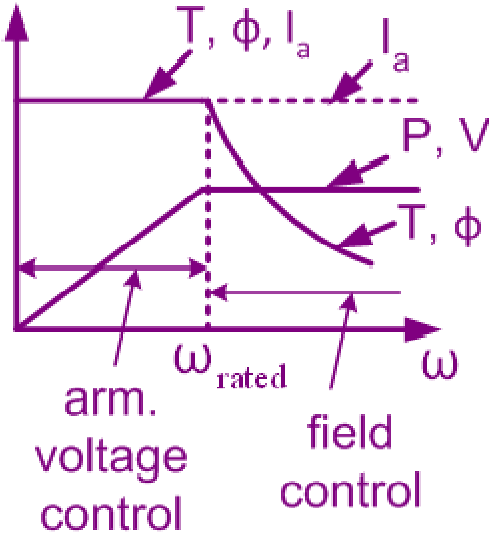
$\Rightarrow$ power o/p = $V_a I_a - I_a^2 R_a$ - friction loss

as I_a is constant $\rightarrow I_a^2 R_a$ remains constant

$\Rightarrow$ loss due to friction varies with speed

$\Rightarrow$ If this change is neglected $\rightarrow$ power o/p remains constant

$\rightarrow$ constant HP mode



Starting of DC Motor

$$I_a = \frac{V_a - k\phi\omega}{R_a} \qquad T = k\phi I_a$$

- Starting torque is utilised to
  - Overcome friction
  - Accelerating the armature
  - Accelerating the load
- At standstill E_b = 0, hence small armature voltage is required to flow full rated current
- The starting current can be limited by two methods:
  - Add external resistance in the armature circuit (helps in developing necessary starting torque but should be cut off once back emf has developed)
  - Applying low voltage by using variable DC power supply. This voltage can be increased if machine accelerates
- The developed torque and rate at which back emf is generated depends on air gap flux.