EE240: Power Engineering LAB

Separately Excited and Shunt Excited DC Generator

Instructor

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Stator:

Field coil is mounted on the projected part & connected to dc

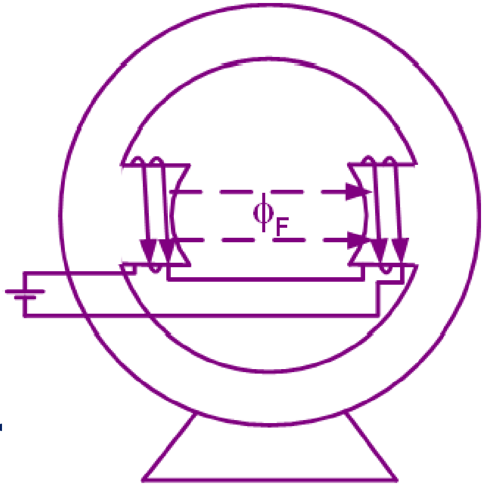
$\Rightarrow$ Coil is stationary and 'I' is dc (can be replaced by PM)

$\Rightarrow$ Time invariant field

$\therefore$ Speed of $F_s = 0$

$\Rightarrow$ Either the conductor is rotated or external 'I' should be supplied.

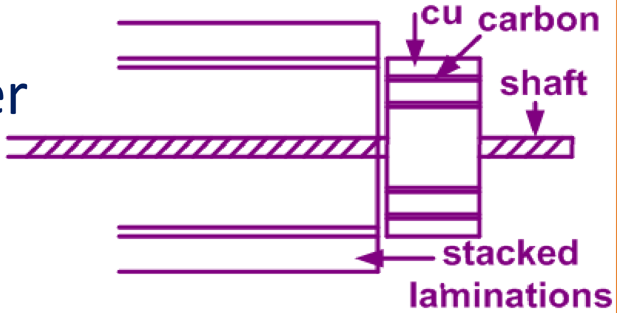
$\Rightarrow$ Rotor sees non-uniform air-gap. There is saliency!!



Rotor:

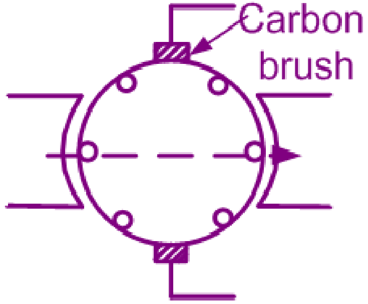
$\Rightarrow$ Laminations having slots at the outer periphery are stacked together

$\Rightarrow$ In addition, there is a commutator $\rightarrow$ has large number of cu. segments & these segments are insulated by mica



$\Rightarrow$ coils having desired number of turns are placed in these slots and two ends of the coil are connected to the cu. strips

$\Rightarrow$ two(?) carbon brushes are placed at 90^0(electrical) to the field axis on the Cu commutator. $\rightarrow$ carbon brushes are mounted on the commutator but fixed to the stator

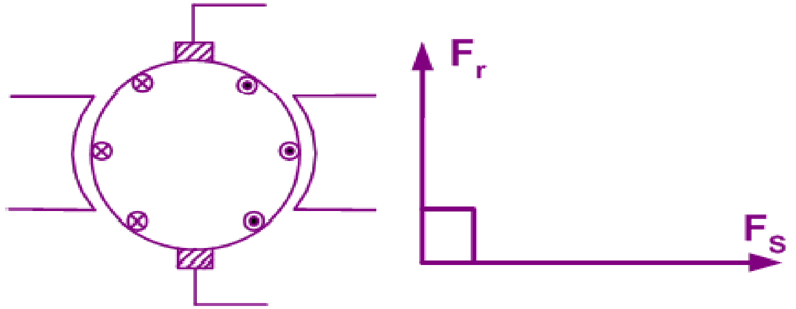


⇒ carbon brushes are stationary

⇒ direction of ‘I’ reverses when the coil crosses the brush

⇒ conductors under one pole carry ‘I’ in one direction

⇒ armature mmf axis is fixed and it is along brush (q) axis

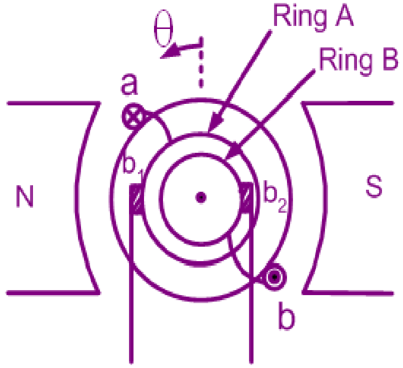


⇒ angle between F_s and F_r is 90^0 and is fixed. this angle is independent of load

⇒If F_s is held constant, F_r will change with load.

⇒ ‘I’ flowing into/out of the carbon brush is dc

⇒ mmf w.r.t. carbon brush is stationary



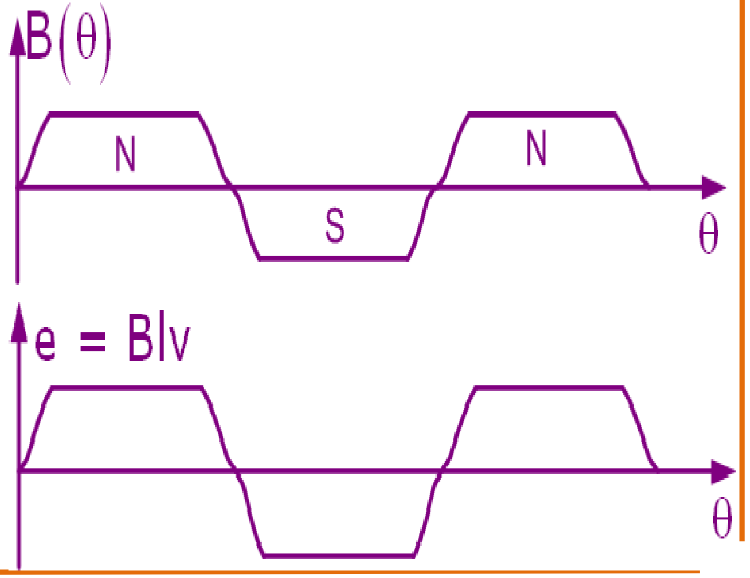
<u>Commutation</u>:

⇒ coil a-b placed in diametrically opposite slots on the rotor

⇒ two ends are connected to two slip rings (rotating)

⇒ two brushes are pressing against the slip rings

⇒ air gap flux density



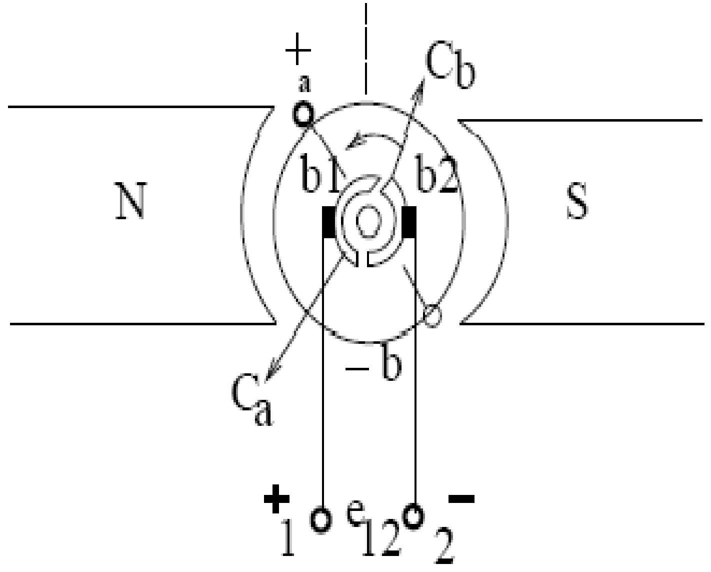
⇒ ‘e’ is AC

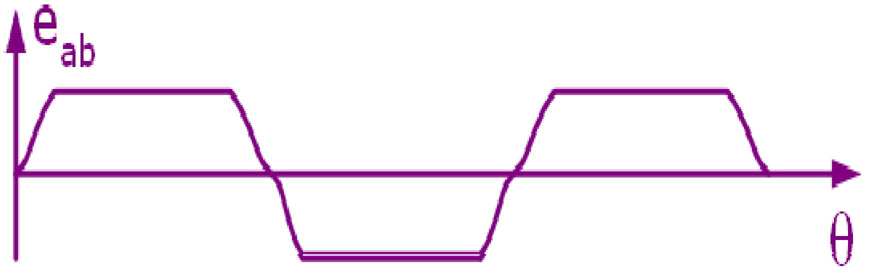
$\Rightarrow$replace slip rings by commutator segment

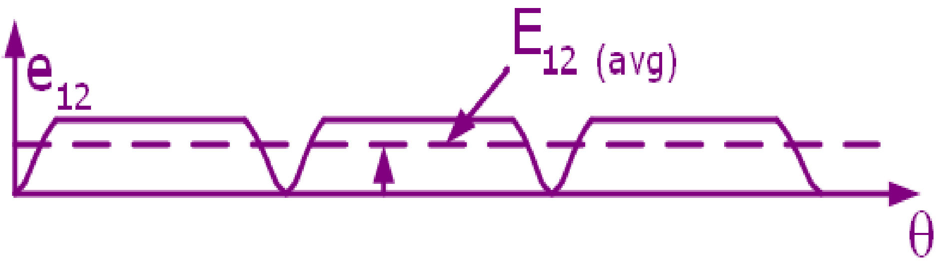
$\Rightarrow$ b_1 is +ve ($\because$ under north pole)

$\Rightarrow$ 'V' induced in the conductor is ac

$\Rightarrow$'V' across the brush is dc $\rightarrow$ has a ripple







$\Rightarrow$ (commutator + brush arrangement) converts ac to dc $\Rightarrow$ mechanical commutator

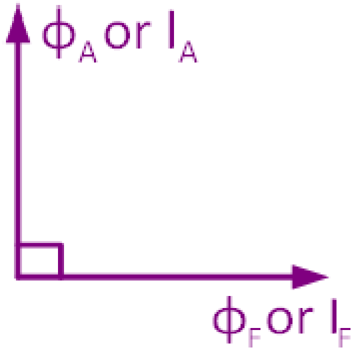
$\Rightarrow$ for constant dc, have large number of slots and place the conductor

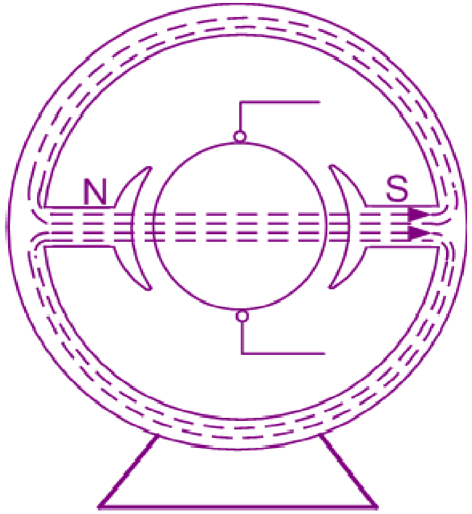
Magnetization characteristics:

$\Rightarrow$ variation of ϕ with I_F

$\Rightarrow$ dc machine has two distinct circuits

$\rightarrow$ field ckt & armature ckt





$\Rightarrow$ two mmf sources can be controlled independently $\angle_{F_s}^{F_r} = 90^0$ (not possible in IM, $\because$ there is no access to rotor terminals)

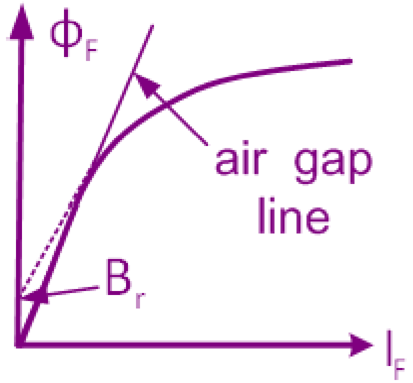
Assume armature terminals are open,

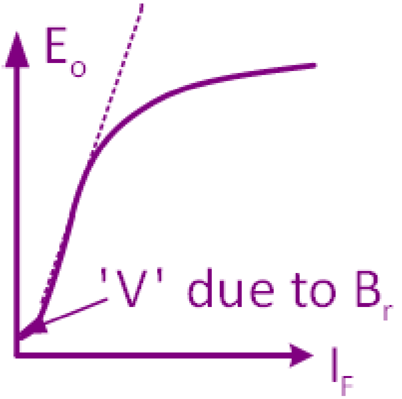
Assuming μ_r of iron is very high, all ATs are used to establish 'ϕ' in air gap

$\therefore \phi = \dfrac{NI}{\Re} \rightarrow$ per pole

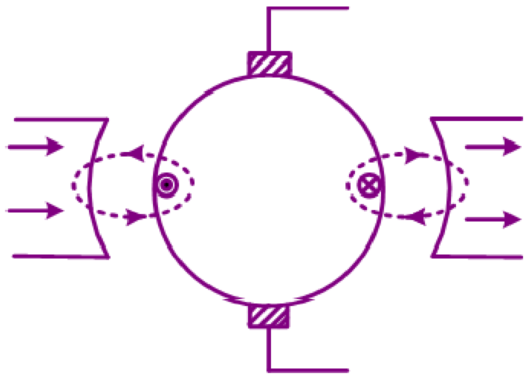
OCC(open circuit characteristics):

$\rightarrow$ variation of E_o with I_F at constant 'ω'

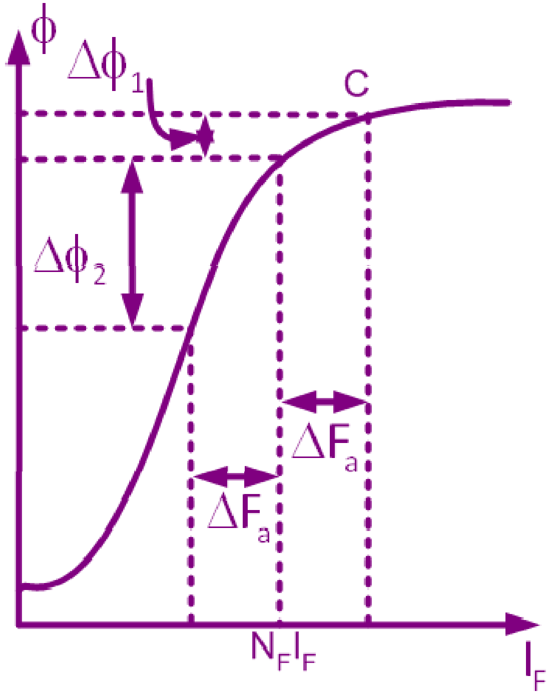




Armature reaction:



$\Rightarrow$ If $i_a = 0$, air gap flux = flux due to field current alone
$\Rightarrow$ when i_a is flowing in the armature it produces its own flux
$\Rightarrow$ 'ϕ' produced by current in armature coil opposes 'ϕ' under one half of the pole & it aids under the other half
$\Rightarrow$ region where 'ϕ' due to i_a aids field flux
$\rightarrow$ net mmf = $N_F I_F + \Delta F_a$
$\rightarrow \uparrow$ in 'ϕ' is $\Delta\phi_1$
$\Rightarrow$ region where 'ϕ' due i_a opposes
$\rightarrow$ net mmf = $N_F I_F - \Delta F_a$
$\rightarrow \downarrow$ in 'ϕ' is $\Delta\phi_2$
$\because$ magnetic circuit is operated at 'C'
$\uparrow$ in 'ϕ' due to $\Delta F_a < \downarrow$ in 'ϕ' due to ΔF_a
$\Rightarrow$ net result $\rightarrow$ air gap flux $\downarrow$
$\Rightarrow$ it can be compensated



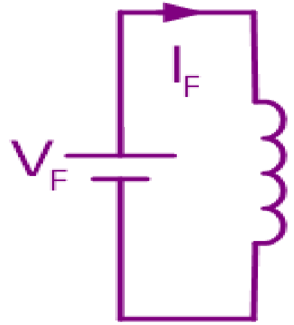
Eq.ckt of dc machine:

stator eq. ckt:

$\Rightarrow$ dc current (I_f) is flowing in the field coil

($R_F \rightarrow$ resistance & $L_F \rightarrow$ inductance)

$$V_F = R_F i_F + L\frac{di_F}{dt}$$



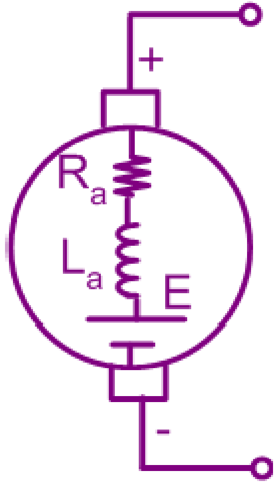
rotor eq. ckt:

$\Rightarrow$ at steady state $V_F = R_F I_F$

$\Rightarrow$ armature is rotating in the magnetic field

$\Rightarrow$ 'V' induced, $E \,\alpha\, \phi\omega$

$\Rightarrow$ can be represented by $E = K\phi\omega$



Classification of dc machines:

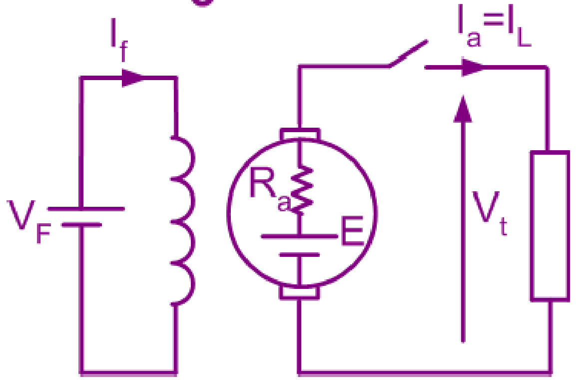
Separately excited dc generator(S.E):

$\Rightarrow$ field is connected to a separate dc source

$\Rightarrow$ for given V_F, $P_F \downarrow$ as $R_F \uparrow$

$$P_F = \frac{V_F^2}{R_F}$$

$\rightarrow$ use thin conductor & there would be large no. of turns



external characteristics:

$\rightarrow$ variation of V_t with I_L at constant ω

$$V_t = E_0 - I_a R_a \qquad I_a = I_L$$

$$E_0 = K\phi\omega$$

As $I_a \uparrow$, 'ϕ' due to I_a also $\uparrow$ & due to armature reaction, air gap flux $\downarrow$

$\rightarrow$ E α (air gap flux) ω

$\Rightarrow$ power is developed in the armature, R_a comes in the main path of power flow, so it should be small.

$\Rightarrow$ needs a separate dc source

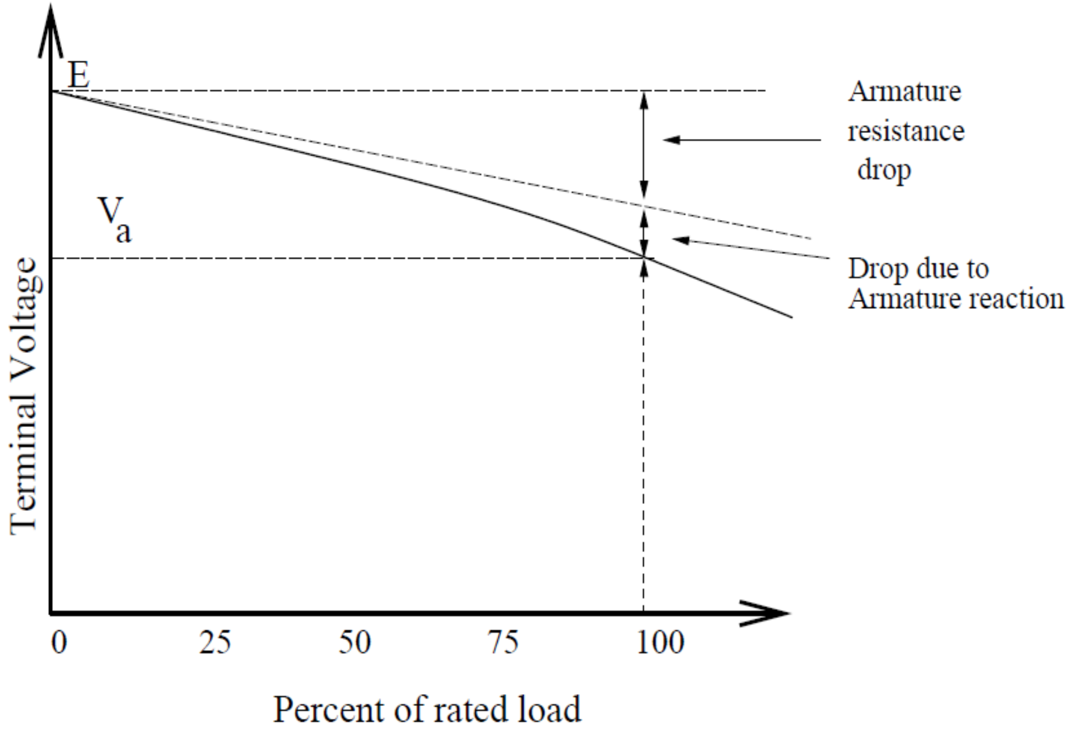
$\therefore$ If I_F is held constant, $\Rightarrow$ ϕ_F will remain constant

$\therefore$ E_0 will remain constant , if ω is held constant ($E_0 = K\phi_F\omega$)

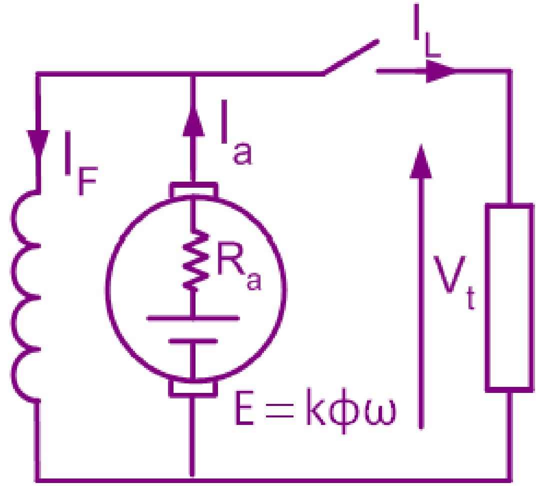
$\therefore$ $V_t \downarrow$ as I_a ($= I_L$) $\uparrow$ due to

i. $\downarrow$ in air gap flux (arm. reaction) & $\therefore$ 'V' induced in the armature

ii. $I_a R_a$ drop



Self excited dc generator:



- field is connected across the arm. terminals
- also known as shunt generator

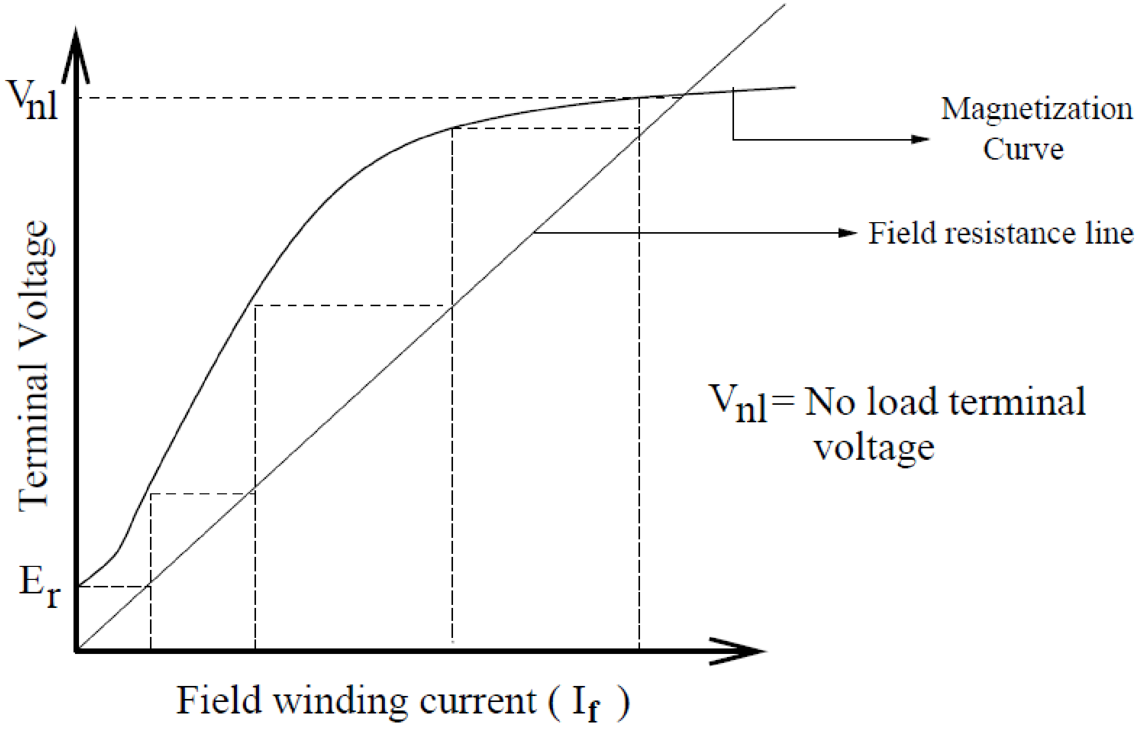
$\rightarrow$ If there is residual flux & field flux aids the residual flux, m/c builds up as $\omega \uparrow$

$\because$ magnetic ckt saturates, V_t will attain a steady value

$\rightarrow$ if it fails to develop, it could be due to

i) field 'ϕ' opposes the residual 'ϕ'

ii) total resistance is very high



External characteristics:

$I_a = I_L + I_F$ $\qquad I = \frac{V_t}{R_F}$ $\qquad E = K\phi\omega$

$\rightarrow$ power loss in the field = $\frac{V_t^2}{R_F}$ or $I_F^2 R_F$,

$\rightarrow$ connect the field across the arm. terminals

$\rightarrow$ as the rotor starts rotating

$\rightarrow$ small 'V' is induced in the armature

→ this 'V' drive a small 'I' in the field

$$\Delta i_F \cong \frac{V_r}{R_a + R_F}$$

→ this Δi_F flows in N_F (field winding)

→ generates its own flux

→ this ϕ can either aid or oppose the residual flux

→ if it aids, then there is ↑ in air gap flux

→ this ↑ the 'V' induced in the armature & ∴ Δi_F

→ 'V' builds up & attain a steady value

→ m/c develops 'V' at its own & it is due to residual magnetism

→ hence the name self excited dc generator

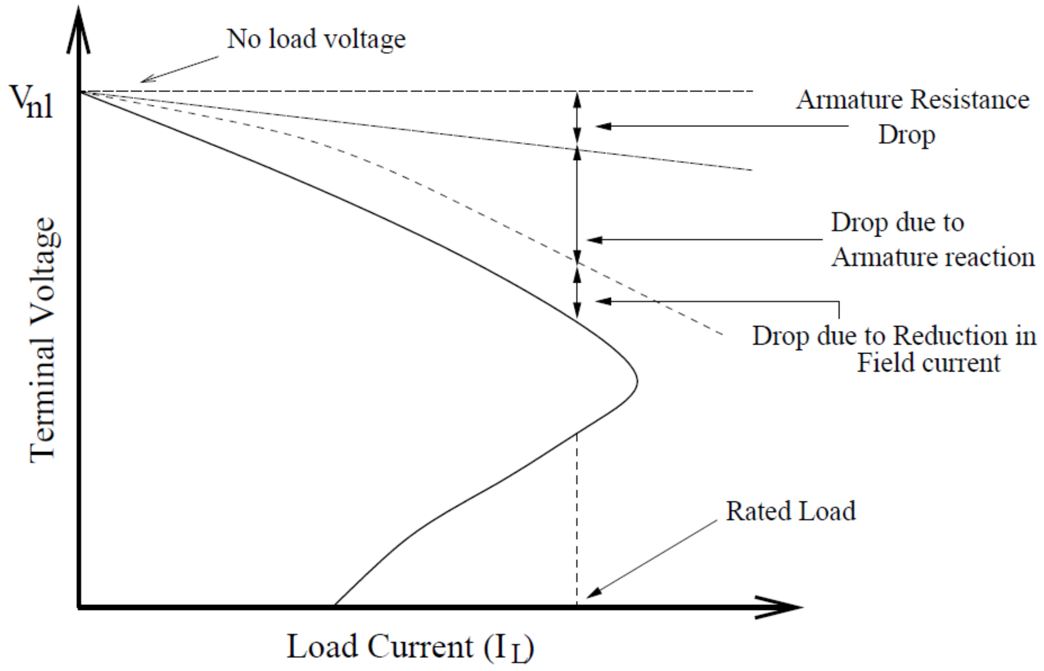
⇒ drop in terminal Voltage due to :

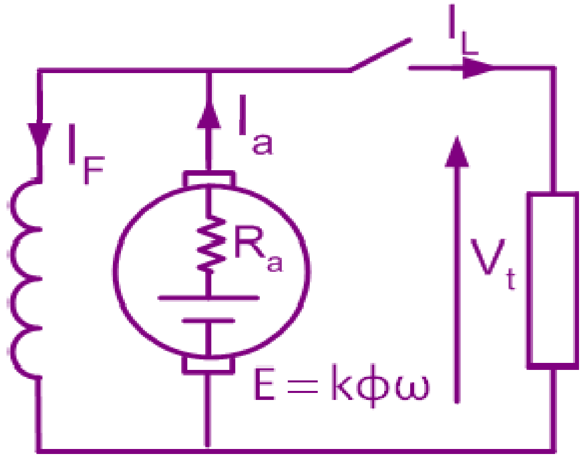
i) $I_a R_a$ drop ii) arm. reaction iii) reduction in field flux.

In S.E dc machine, $I_F = (V_F/R_F)$ remains constant

∵ V_F is held constant

while in this case $I_F = V_t/R_F$ where V_t decreases with load





Efficiency:

$$\eta = \frac{\text{o/p power}}{\text{i/p power}}$$

Output Power = $V_t I_L$

Input = $V_t I_L$ + $\underbrace{\text{Arm. Cu. Loss}}_{I_a^2 R_a}$ + $\underbrace{\text{Field Cu. Loss}}_{I_F^2 R_F}$ + Friction Loss

$\Rightarrow$ power developed = $E I_a$

$= (V_t + I_a R_a)\, I_a$