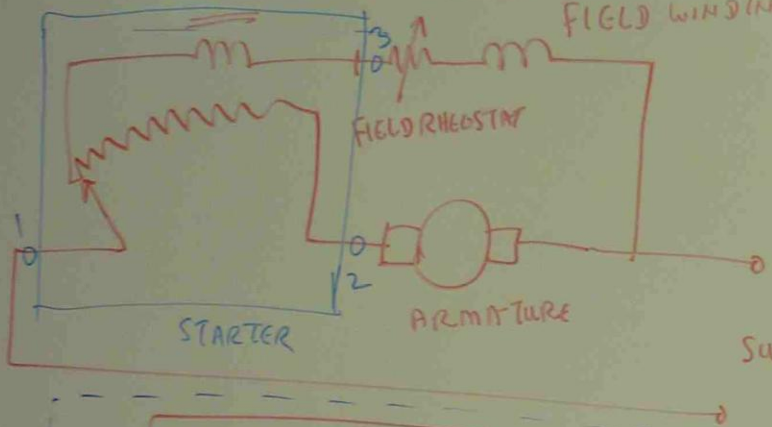
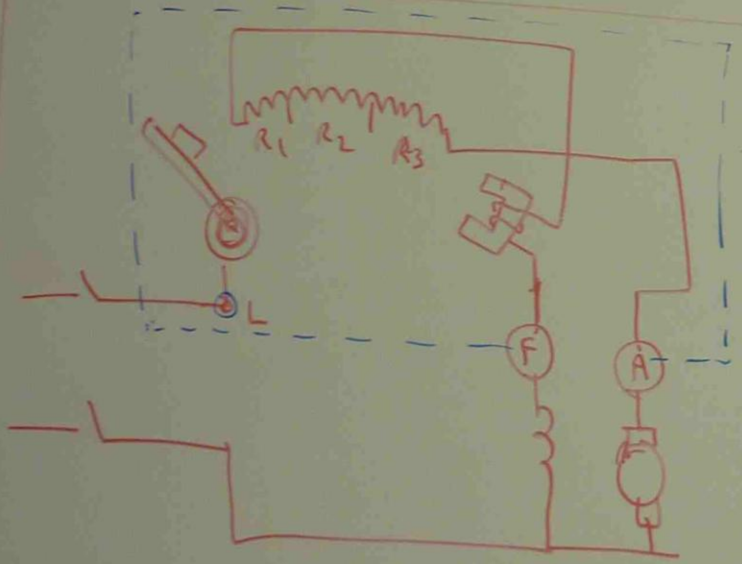
DC MOTOR STARTERS





3 POINTS STARTER

$$\left(\frac{I_{max}}{I_{min}}\right)^{n+1} = \frac{V_t}{I_r R_a}$$

n = NUMBERS OF STEPS

R_a = ARMATURE RESISTANCE

I_r = FULL LOAD CURRENT

$$\frac{I_s}{I_r} = \frac{R_K}{R_{K+1}}$$

I_s = INITIAL RESISTANCE STEP CURRENT (R_K)

I_r = FINAL RESISTANCE STEP CURRENT (R_{K+1})

Pb — THE RESISTANCE OF THE ARMATURE OF A 240V DC SHUNT MOTOR IS 0.5 Ω. IT IS REQUIRED THAT THE CURRENT AT STARTING BE LIMITED TO 200% OF FULL LOAD CURRENT AND FULL LOAD CURRENT IS 15 Amp.

DETERMINE (a) TOTAL RESISTANCE OF ARMATURE CIRCUIT AT STARTING

(b) THE NUMBERS OF STUDS ON THE STARTER

(c) RESISTANCE BETWEEN EACH STUD.

$R_a = 0.5\,\Omega$ $\quad V_t = 240V$, $\quad I_r = 15$ Amp

$I_s = 200\%\, I_r = 2 \times 15 = 30$ Amp.

$$\left(\frac{I_{max}}{I_{min}}\right)^{n+1} = \frac{V_t}{I_r R_a}$$

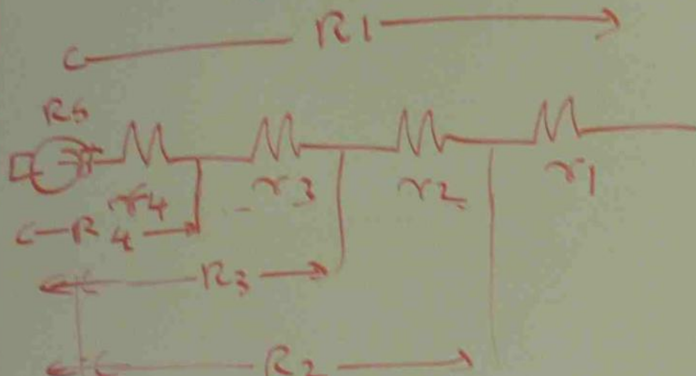
$$\left(\frac{30}{15}\right)^{n+1} = \frac{240}{15 \times 0.5} \rightarrow$$

$$2^{n+1} = 32$$

$$\log 2^{n+1} = \log 32$$

$$(n+1)\log 2 = \log 32$$

$$n = \frac{\log 32}{\log 2} - 1 = 4$$



$$r_1 = R_1 - R_2$$

$$r_2 = R_2 - R_3$$

$$r_3 = R_3 - R_4$$

$$r_4 = R_4$$

$$\frac{I_s}{I_r} = \frac{R_K}{R_{K+1}}$$

$$\frac{30}{15} = \frac{R_K}{R_{K+1}}$$

$$2 = \frac{R_K}{R_{K+1}}$$

$$\boxed{R_1 = \frac{V_t}{I_s}}$$

$$= \frac{240}{30} = 8\,\Omega$$

$$\frac{R_K}{R_{K+1}} = 2$$

$$K = 1 \rightarrow \frac{R_1}{R_{1+1}} = 2$$

$$\frac{R_1}{R_2} = 2$$

$$\frac{8}{R_2} = 2$$

$$R_2 = 8/2 = 4\,\Omega$$

$$\frac{I_s}{I_r} = \frac{R_K}{R_{K+1}}$$

$$\frac{30}{I_s} = \frac{R_K}{R_{K+1}}$$

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$$\rightarrow \frac{R_1}{R_{1+1}} = 2$$

$$\frac{R_1}{R_2} = 2$$

$$\frac{8}{R_2} = 2$$

$$R_2 = 8/2 = 4\,\Omega$$

$$K = 2 \quad \frac{R_2}{R_{2+1}} = 2$$

$$\frac{R_2}{R_3} = 2$$

$$\frac{4}{R_3} = 2$$

$$R_3 = \frac{4}{2} = 2\,\Omega$$

$$K = 3 \quad \frac{R_3}{R_{3+1}} = 2$$

$$\frac{R_3}{R_4} = 2$$

$$\frac{2}{R_4} = 2$$

$$R_4 = \frac{2}{2} = 1\,\Omega$$

$$K = 4 = \frac{R_4}{R_5} = 2 \rightarrow R_5 = \frac{R_4}{2} = \frac{1}{2} = 0.5$$

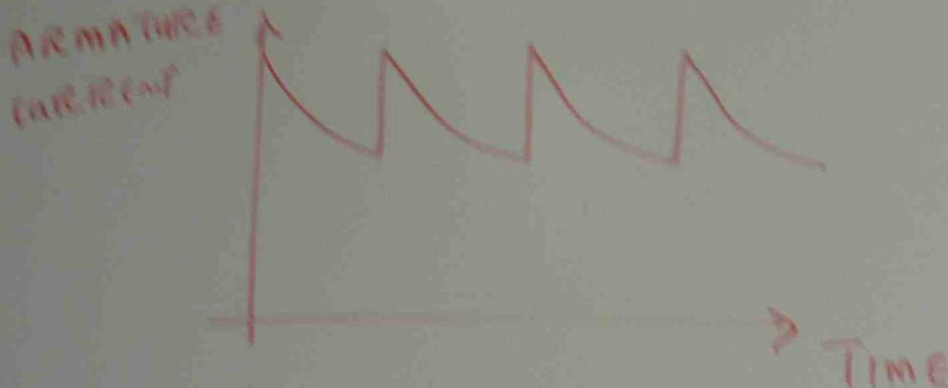
$$r_1 = R_1 - R_2$$
$$= 8 - 4 = 4\,\Omega$$

$$r_2 = R_2 - R_3$$
$$= 4 - 2 = 2\,\Omega$$

$$r_3 = R_3 - R_4$$
$$= 2 - 1 = 1\,\Omega$$

$$r_4 = R_4 - R_5$$
$$= 1 - 0.5 = 0.5\,\Omega$$

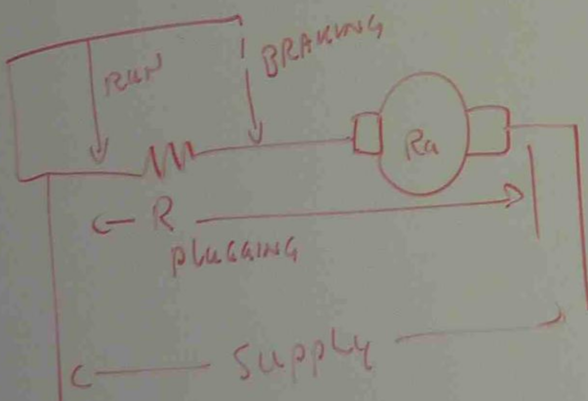
ACCERELATION OF DC MOTORS



STARTERS

- BACK EMF STARTER
- CURRENT DEPENDENT STARTER
- TIME LIMIT STARTER

Pb A 240V MOTOR IS REQUIRED TO BE BRAKED BY PLUGGING. IF THE ARMATURE CURRENT AT FULL LOAD IS 100 Amp AND THE ARMATURE RESISTANCE IS 0.1Ω, CALCULATE THE RESISTANCE OF BRAKING RESISTOR IF THE INITIAL BRAKING CURRENT IS LIMITED TO 150% OF FULL LOAD CURRENT AND BRUSH DROP IS 5 VOLT.



$$R_{PLUGGING} = \frac{V_t - (V_b + E_b)}{I_{br}}$$

V_t = TERMINAL VOLTAGE

I_{br} = BRAKING CURRENT

V_b = BRUSH VOLTAGE DROP

E_b = BACK EMF

$$E_b = V_t - (I_a R_a + V_b)$$

$$= 240 - (100 \times 0.1 + 5)$$

$$= 225 \text{ V}$$

$$I_{br} = 150\% \, I_a$$

$$= 1.5 \times 100 = 150 \text{ Amp}$$

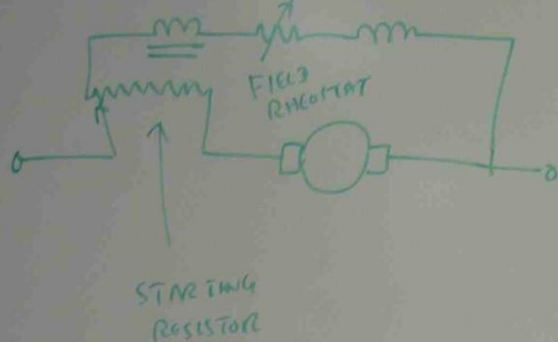
$$R_{PLUGGING} = \frac{V_t - (V_b + E_b)}{I_{br}}$$

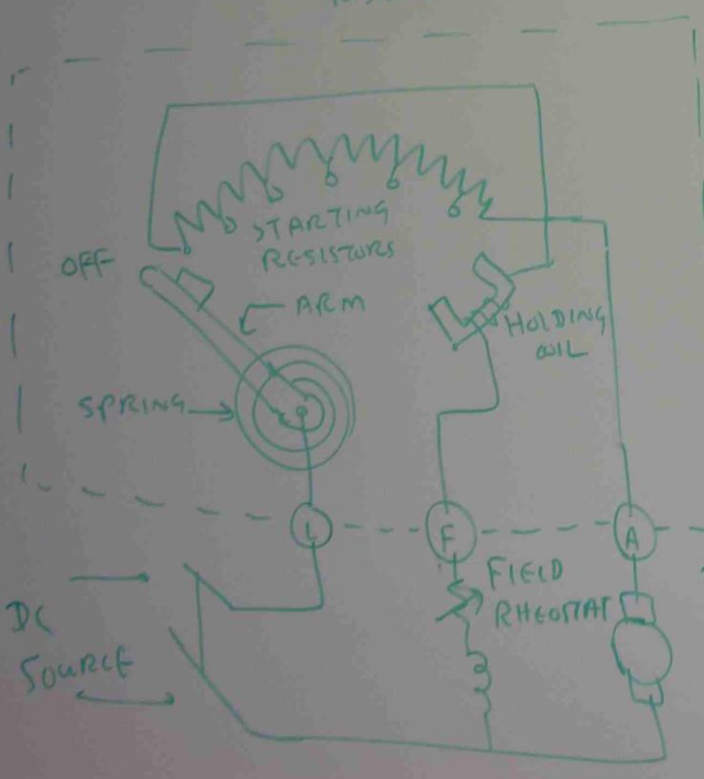
$$= \frac{240 - (5 + 225)}{150}$$

$$= 3.05\Omega$$

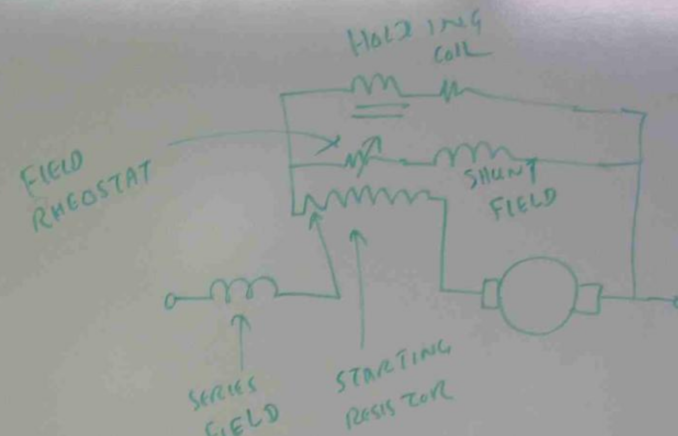
ADDITIONAL RESISTANCE $= 3.05 - 1 = 2.95\Omega$

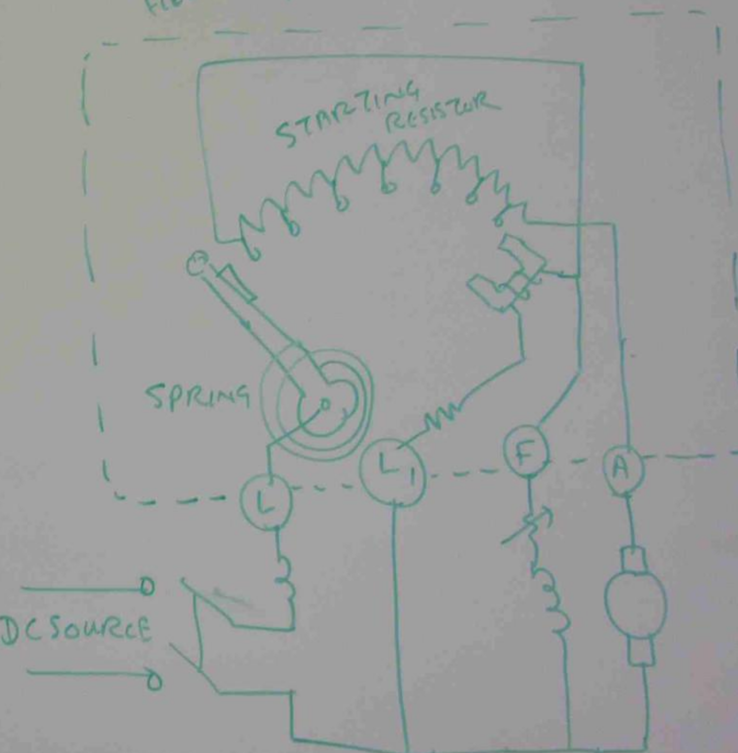
DC MOTOR STARTERS





3 POINTS STARTER





pb/ A 100 kW 500V DC SHUNT MOTOR HAS AN ARMATURE RESISTANCE 0.2 Ω AND FULL LOAD SPEED 920 RPM. IF THE LOAD HAS A TORQUE SPEED CURVE WHICH MAY BE DEFINED BY THE EXPRESSION.

$$T = 100 + 9.2 \times 10^{-4} N^2$$

AND THE MOTOR ARMATURE PARTICULARS ARE

$Z = 756$ CONDUCTORS, $p = 4$ poles PAIRS, $a = 8$ PARALLEL PATHS

$\phi = 0.04$ WEBERS.

THE COMBINED INTERIA OF LOAD AND ARMATURE IS $100\ N\text{-}m^2$

CALCULATE (a) STARTER RESISTANCES (b) SPEED AT EACH RESISTANCE STEP (c) TORQUE

EFFICIENCY = 90% (CURRENT LIMIT 150%, 90%)

$$I_{FL} = \frac{100 \times 1000}{500 \times \frac{90}{100}} = 220 \text{ Amp}$$

$$I_{MAX} = 1.5 \times I_{FL} = 1.5 \times 220 = 330 \text{ Amp}$$

$$I_{MIN} = 0.9 \times I_{FL} = 0.9 \times 220 = 200 \text{ Amp.}$$

$$R_1 = \frac{V_t}{I_{MAX}} = \frac{500}{330} = 1.51 \Omega$$

$$\left(\frac{I_{MAX}}{I_{MIN}}\right)^n = \frac{R_1}{R_a}$$

$$\left(\frac{330}{200}\right)^n = \frac{1.51}{0.2}$$

$$1.65^n = 7.4$$

$$n \log 1.65 = \log 7.4$$

$$n = \frac{\log 7.4}{\log 1.65} = 4$$

LOAD

Y

$$R_2 = R_1 \times \left(\frac{I_{MIN}}{I_{MAX}}\right)$$

$$= 1.51 \times \left(\frac{200}{330}\right) = 0.92\Omega$$

$$R_3 = R_2 \times \frac{I_{MIN}}{I_{MAX}}$$

$$= 0.92 \times \frac{200}{330} = 0.555\Omega$$

$$R_4 = R_3 \times \frac{I_{MIN}}{I_{MAX}}$$

$$= 0.555 \times \frac{200}{330} = 0.336\Omega$$

$$R_5 = R_4 \times \frac{I_{MIN}}{I_{MAX}}$$

$$= 0.336 \times \frac{200}{330} = 0.2\Omega$$

$$\frac{Eb_1}{Eb_2} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

FULL LOAD

$$Eb = V_t - I_a R_a$$

$$= 500 - 220 \times 0.2$$

$$= 455.4V$$

REF

$$N = 920\,RPM$$

$$R_1 = 1.51\Omega$$

$$Eb_1 = V_t - I_1 \times R_1$$

$$= 500 - 200 \times 1.51 = 198V$$

$$\frac{Eb}{Eb_1} = \frac{\phi N}{\phi N_1} \rightarrow \frac{455.4}{198} = \frac{920}{N_1}$$

$$N_1 = \frac{920 \times 198}{455.4}$$

$$= 400\,RPM$$

R_2

E

$R_2 = 0.92\Omega$

$E_{b_2} = V_t - I_1 \times R_2$

$= 500 - 200 \times 0.92$

$= 316\,V$

$$\frac{E_b}{E_{b_2}} = \frac{\phi N}{\phi N_2}$$

$$\frac{455.4}{316} = \frac{920}{N_2}$$

$N_2 = 625\,RPM$

$R_3 = 0.555\Omega$

$E_{b_3} = V - I_1 R_3$

$= 500 - 200 \times 0.555$

$= 389\,V$

$$\frac{E_b}{E_{b_3}} = \frac{\phi N}{\phi N_3} \rightarrow \frac{455.4}{389} = \frac{920}{N_3}$$

$N_3 = 780\,RPM$

$R_4 = 0.336\Omega$

$E_{b_4} = V_t - I_1 R_4$

$= 500 - 200 \times 0.336$

$= 455\,V$

$$\frac{E_b}{E_{b_4}} = \frac{\phi N}{\phi N_4}$$

$$\frac{455.4}{455} = \frac{920}{N_4}$$

$N_4 = 860\,RPM$

$R_5 = 0.2\Omega$

$E_{b_5} = V_t - I_1 R_5$

$= 500 - 200 \times 0.2$

$= 460\,V$

$$\frac{E_b}{E_{b_5}} = \frac{\phi N}{\phi N_5}$$

$$\frac{455.4}{460} = \frac{920}{N_s}$$

$$N_s \simeq 920 \text{ RPM}$$

$$T = \frac{K_t \phi V_t}{R_a} - \frac{K_e K_t \phi^2 N}{R_a}$$

$$K_e = \frac{PZ}{60a}, \quad K_t = \frac{PZ}{2\pi a}$$

$$K_e = \frac{8 \times 756}{60 \times 8} = 12.6$$

$$K_t = \frac{8 \times 756}{2 \times 3.1416 \times 8} = 121$$

$$T = \frac{121 \times 0.1 \times 500}{0.2} - \frac{12.6 \times 121 \times 0.1^2 \times N}{0.2}$$

$$T = 1600 - 1.62\,N$$

$R_4 = 0.336\Omega$

$E_{b4} = V_t - I_1 R_4$

$= 500 - 200 \times 0.336$

$= 455V$

$$\frac{E_b}{E_{b4}} = \frac{\phi N}{\phi N_4}$$

$$\frac{455.4}{455} = \frac{920}{N_4}$$

$N_4 = 860 RPM$

$R_5 = 0.2\Omega$

$E_{b5} = V_t - I_1 R_5$

$= 500 - 200 \times 0.2$

$= 460V$

$$\frac{E_b}{E_{b5}} = \frac{\phi N}{\phi N_5}$$

$$\frac{455.4}{460} = \frac{920}{N_5}$$

$N_5 \simeq 920 RPM$

$$T = \frac{K_t \phi V_t}{R_a} - \frac{K_e K_t \phi^2 N}{R_a}$$

$$K_e = \frac{PZ}{60a}, \quad K_t = \frac{PZ}{2\pi a}$$

$$K_e = \frac{8 \times 756}{60 \times 8} = 12.6$$

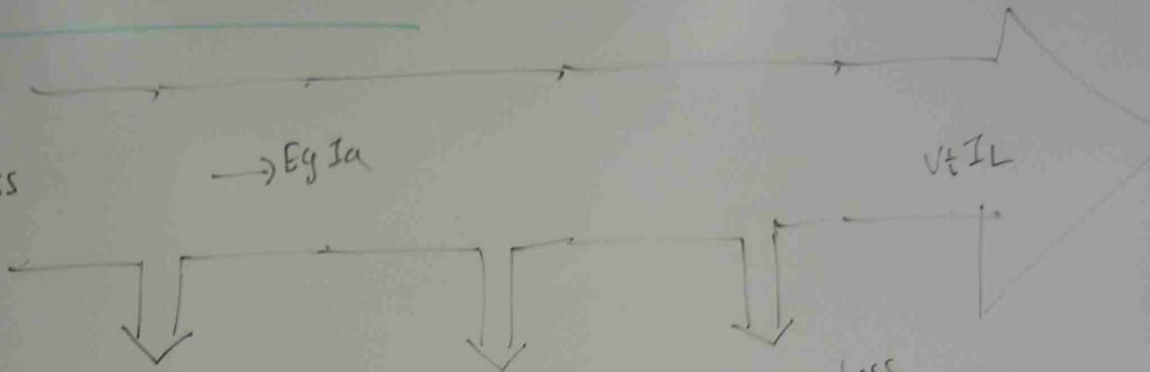
$$K_t = \frac{8 \times 756}{2 \times 3.1416 \times 8} = 121$$

$$T = \frac{121 \times 0.1 \times 500}{0.2} - \frac{12.6 \times 121 \times 0.1^2 \times N}{0.2}$$

$T = 30250 - 76.23 N$

POWER FLOW DIAGRAM OF DC GENERATOR

MECHANICAL POWER INPUT $= E_g I_a +$ Loss



W = ROTATIONAL LOSS

FRICTION, BRUSH
IRON, WIND
HYSTERESIS

ARMATURE COPPER LOSS

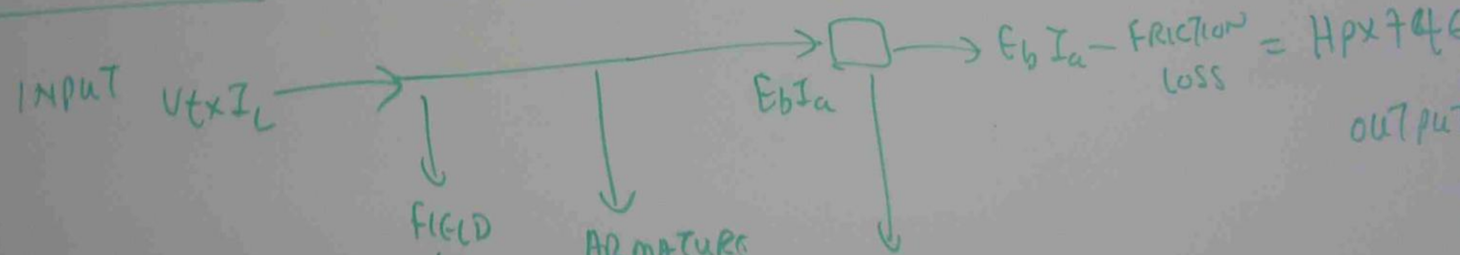
$= I_a^2 R_a$

FIELD LOSS

$V_t \times I_{FIELD}$

$$\text{GENERATOR EFFICIENCY} = \frac{V_t I_L}{E_g I_a + W} \times 100$$

DC motor



FIELD loss

$V_t I_f$

ARMATURE loss

$I_a^2 R_a$

FRICTION loss

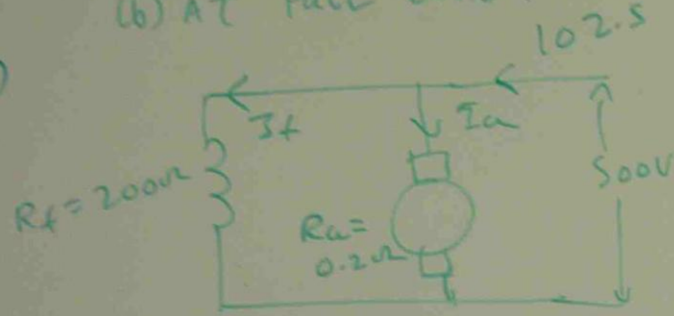
pb. THE WINDING RESISTANCE OF A 500V, 60KW DC SHUNT MOTOR ARE $R_a = 0.2\Omega$ $R_f = 200\Omega$

IF MECHANICAL LOSSES ARE 1.4 KW, DETERMINE THE EFFICIENCY OF THE MACHINE

(a) WHEN THE LINE CURRENT IS 102.5 AMP

(b) AT FULL LOAD.

(a)



$$\%\eta = \frac{P_{IN} - P_{loss}}{P_{IN}} \times 100$$

$$= \frac{51250 - 4650}{51250} \times 100$$

$$= 90.93\%$$

$$I_f = \frac{500}{200} = 2.5\ A$$

$$I_a = I_L - I_f = 102.5 - 2.5 = 100\ \text{Amp}.$$

$$P_{IN} = V_t \times I_L = 500 \times 102.5 = 51250\ \text{WATT}$$

$$P_{losses} = I_a^2 R_a + I_f^2 R_f + 1400 = 100^2 \times 0.2 + 2.5^2 \times 200 + 1400$$

$$= 4650\text{W}$$

(b) AT FULL LOAD

$$P_{out} = 60\,kW = 60{,}000\,W$$

$$P_{out} = E_g I_a - W \Rightarrow E_g I_a = P_{out} + W$$

$$E_g I_a = 60{,}000 + 1400 = 61400$$

$$E_g = V_t - I_a R_a$$

$$(V_t - I_a R_a) I_a = 61400$$

$$(500 - I_a \times 0.2) I_a = 61400$$

$$500 I_a - 0.2 I_a^2 = 61400$$

$$0.2 I_a^2 - 500 I_a + 61400 = 0$$

$$A x^2 + B x + C = 0$$

$$x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$I_a = \frac{-(-500) \pm \sqrt{(-500)^2 - 4 \times 0.2 \times 61400}}{2 \times 0.2}$$

$$= 129.5 \text{ (OR) } 2375$$

$$P_{IN} = P_{out} + \underset{\text{LOSS}}{\text{ROTATIONAL}} + I_a^2 R_a + I_f^2 R_f$$

$$= 60000 + 1400 + (129.5)^2 \times 0.2 + 2.5^2 \times 200$$

$$= 66000 \text{ WATT}$$

$$\%\eta = \frac{P_{out}}{P_{IN}} \times 100$$

$$= \frac{60000}{66000} \times 100 = 90.9\%$$