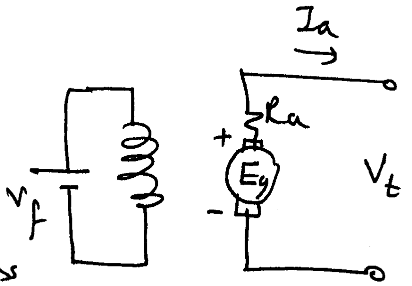
DC Machines

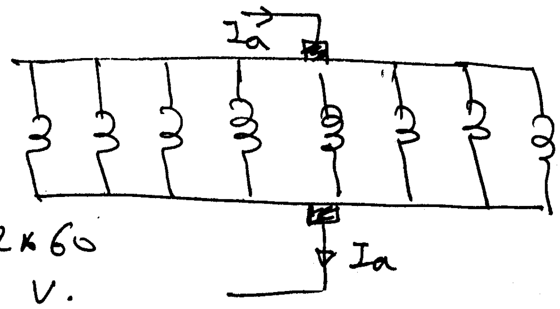
[1] I- Lap Connection:

$P = 8$, $Z = 480$, $E_g = 2.2\ V/Cond.$

$I_{cond} = 100\ A$



(a) $P = a = 8 =$ # of parallel paths



cond/path $= \frac{Z}{a} = \frac{480}{8} = 60$

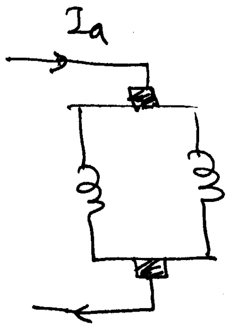
induced emf/path $= 2.2 \times 60 = 132\ V.$

$E_g = 132 =$ no load terminal voltage

(b) $I_{a_{F.L}} = a \times$ current/path $= 8 \times 100 = 800\ A.$

(c) $P_d = E_g \times I_a = 132 \times 800 = \underline{\underline{105.6\ kW}}$

II- Wave Connected



$P = 8$, $a = 2$

conductor/path $= \frac{480}{2} = 240$

(a) induced emf/path $= 2.2 \times 240 = 528$ = no load terminal voltage.

(b) $I_{a_{f.l}} = a \times$ current/path $= 2 \times 100 = 200\ Ap.$

(c) $P_d = E_g \times I_a = 528 \times 200 = \underline{105.6}\ kW$

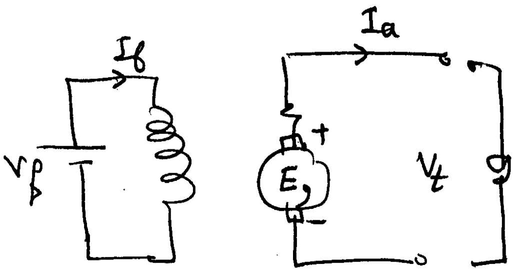
Note $P_{d_1} = P_{d_2}$ & $I_{a_1} > I_{a_2}$ & $E_{g_1} < E_{g_2}$

2. 500 V, 450 r.p.m, 750 KW

$P_{rotational} = 12.18$ KW

$R_a = 0.007\ \Omega$

$R_f = 35\ \Omega$.



(a) $E_g = V_t + I_a R_a$

$$I_{a_{f.L}} = \frac{750 * 10^3}{500} = 1500\ A$$

$\rightarrow E_g = 500 + 1500 * 0.007 = 510.5\ V$

(b) $P_{i/p_m} = P_o + P_{cu} + P_{rotational}$.

$P_{cu} = I_a^2 R_a = (1500)^2 * 0.007 = 15.75$ KW.

$\rightarrow P_{i/p_m} = 750 + 15.75 + 12.18 = 777.93$ KW $=$ mechanical input Power

(c) $$T_{i/p} = \frac{P_{i/p}}{\omega_m} = \frac{777.93 * 10^3}{2\pi * \frac{450}{60}} = 16.51\ K\ N.m.$$

(d) $$\eta = \frac{P_o}{P_{i/p}} = \frac{P_o}{P_{i/p_m} + P_{cu_{field}}}$$

$P_{cu_{field}} = I_f^2 R_f = (15)^2 * 35 = 6.86$ KW

$$\eta = \frac{750}{777.93 + 6.86} * 100$$

$= 95.57\ \%$.

(e) $N_2 = \frac{450}{2} = 225$ r.p.m

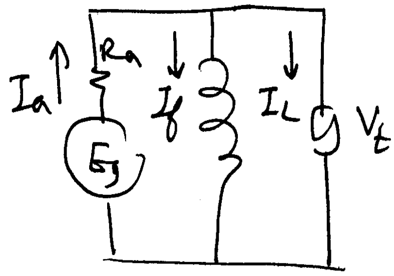
$$\frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2} \quad (\phi = Const) \rightarrow E_{g_2} = \frac{E_{g_1}}{2} = \frac{510.5}{2}$$

$$\rightarrow P_{d_{max.}} = E_{g_2} * I_{a_{f.L}} = \frac{510.5}{2} * 1500 = 382.875$$

$P_{o_{max.}} = P_d - I_a^2 R_a = 382.875 - 15.75$

$= 367.125$ KW

3. $P=8$, shunt gen, $Z = 778$ (3)
wave, 500 r.p.m
5 kW, 250 V load
$R_a = 0.24\ \Omega$, $R_f = 250\ \Omega$



(a) $I_L = \frac{P_L}{V_t} = \frac{5000}{250} = 20\ A.$

$I_f = \frac{V_t}{R_f} = \frac{250}{250} = 1\ A.$

$I_a = I_L + I_f = 20 + 1 = 21\ A.$

(b) $E_g = V_t + I_a R_a = 250 + 21 * 0.24 = 255.04$

(c) $E_g = \frac{Z N \phi}{60}\left(\frac{P}{a}\right)$ for wave $\underline{a=2}$

$255.04 = \frac{778 * 500 * \phi}{60}\left(\frac{8}{2}\right)$

$\rightarrow \phi = 9.834$ mwb.

(d) $P_d = E_g I_a = 255.04 * 21 = 5.3558$ kW.

$T_d = \frac{P_d}{2\pi \frac{N}{60}} = \frac{5.3558 * 10^3}{2\pi * \frac{500}{60}} = 102.29$ N.m

(e) $\eta = \frac{P_o}{P_{i/p}} = \frac{P_o}{P_o + P_{cu} + P_{rotational}}$

$P_{cu} = I_a^2 R_a + I_f^2 R_f = (21)^2 * 0.24 + (1)^2 * 250$
$= 355.84$ W

$\eta = \frac{5000}{5000 + 355.84 + 645} = 83.32\%$

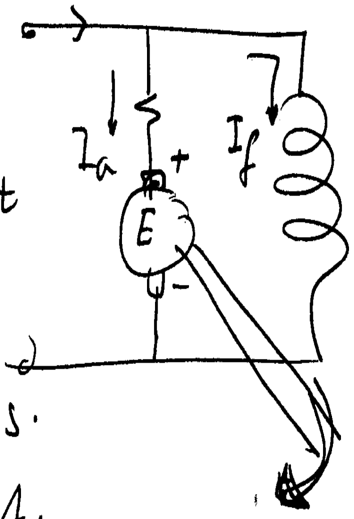
$P_{i/p_{mech}} = 5000 + 355.84 + 645 = 6000.96$ W.

4. 220 V, Shunt motor

$R_a = 0.2\ \Omega$, $R_f = 110\ \Omega$

$I_L = 4A$ at no-load

$I_L = 42A$ at 1000 r.p.m



$$I_f = \frac{220}{110} = 2A$$

= constant at all conditions.

$\rightarrow I_{a_1} = I_{L_1} - I_f = 4 - 2 = 2A.$

$I_{a_2} = I_{L_2} - I_f = 42 - 2 = 40A.$

$E_1 = V_t - I_{a_1} R_a \rightarrow E_1 = 220 - 2 \times 0.2 = 219.6\ V$

$E_2 = V_t - I_{a_2} R_a \rightarrow E_2 = 220 - 40 \times 0.2 = 212\ V.$

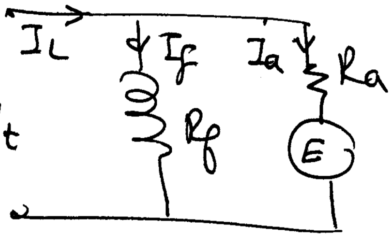
$\rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2}$ (ϕ = Const, where I_f = const.)

$\rightarrow N_1 = \frac{E_1}{E_2} N_2 = \frac{219.6}{212.0} \times 1000 = 1035.84$ r.p.m

5. 230 V, DC shunt motor

$R_a = 0.25$, $R_f = 115\,\Omega$

At F.L $I_a = 38\,A$, $N = 1050$



(a) $P_d = E I_a$

$E_1 = V_{t_1} - I_a R_a$

$= 230 - 38 * 0.25$

$= 220.5\ V.$

$P_{d_1} = 220.5 * 38 = 8379\ W.$

$T_{d_1} = \dfrac{P_d}{2\pi \frac{N}{60}} = \dfrac{8379}{2\pi \frac{1050}{60}} = 76.2\ N.m.$

(b) $R_f = 144$, Torque = Const , I_a = const

$T = K \phi I_a \rightarrow \phi_1 I_{a_1} = \phi_2 I_{a_2}$

Since $I_{a_1} = I_{a_2} \rightarrow \phi_1 = \phi_2 \rightarrow I_{f_1} = I_{f_2}$

$I_{f_1} = \dfrac{230}{115} = 2A \rightarrow I_{f_2} = 2 = \dfrac{V_t}{144}$

$\rightarrow V_{t_2} = 288.$

$\rightarrow E_2 = V_{t_2} - I_a R_a = 288 - (38)(0.25)$

$= 278.5\ V$

$\dfrac{E_1}{E_2} = \dfrac{N_1}{N_2}$ ($\phi_1 = \phi_2$)

$N_2 = \dfrac{E_2}{E_1} N_1 = \dfrac{278.5}{220.5} * 1050 = 1326.19$ r.p.m

(c) $P_o = P_{d_2} - P_{rotational} = 278.5 * 38 - 600 = 9983$

$\rightarrow \eta = \dfrac{9983}{288 * 40}$, $P_{i/p} = V_t I_L = 288 * 40$

$= 86.65\ \%$

6. A Series Motor

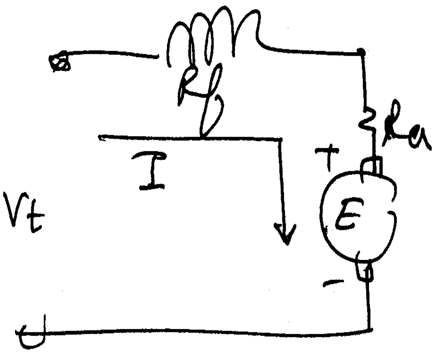
$R_a + R_f = 0.1$

$220\,V,\ 300\ r.p.m \rightarrow I = 25A$

voltage increased $\rightarrow N_2 = 400\ r.p.m$

Torque $\propto N^2$

$\phi \propto I$



$E_1 = V_t - I_{a_1} R_a$

$= 220 - 25 \times 0.1$

$= 217.5\,V$

$T = K I^2$ for Series Motor

$\rightarrow \dfrac{T_1}{T_2} = \dfrac{I_1^2}{I_2^2}$ also we have $\dfrac{T_1}{T_2} = \dfrac{N_1^2}{N_2^2}$

$\rightarrow \left(\dfrac{I_1}{I_2}\right)^2 = \left(\dfrac{N_1}{N_2}\right)^2 \rightarrow \underline{I_2} = \left(\dfrac{N_2}{N_1}\right) I_1 = \dfrac{400}{300} \times 25$

$= \underline{33.33}\ A$

$\dfrac{E_1}{E_2} = \dfrac{\phi_1 I_1}{\phi_2 I_2} = \dfrac{I_1^2}{I_2^2}$

$\rightarrow E_2 = E_1 \dfrac{I_2^2}{I_1^2} = 217.5 \times \left(\dfrac{33.33}{25}\right)^2 = 386.66\,v$

$\rightarrow \underline{V_{t_2}} = E_2 + I_a(R_a + R_f)$

$= 386.66 + 33.33\,(0.1) = \underline{389.99}\ V.$

7)

Open circuit voltage = 230 V (from the curve)
Critical field resistance = 37.5 Ω