Ex: A 10kW DC Shunt motor connected to 200 V supply, and driving a load with the following characteristics.

$P_e = kn^2 = 3.9 \cdot 10^{-3} n^2$ (speed in rpm)

Friction losses is constant = 250kW

$R_f = 40\Omega$

a) Calculate the motor speed if the motor is supplying rated power from its shaft at steady-state.

a) $P_{out} = 10kW$ (rated power of motor ⇒ output shaft motor power

steady state ⇒ $P_{out} = P_{mech}$

$$10.000 = 3.9 \cdot 10^{-3} \cdot n^2$$

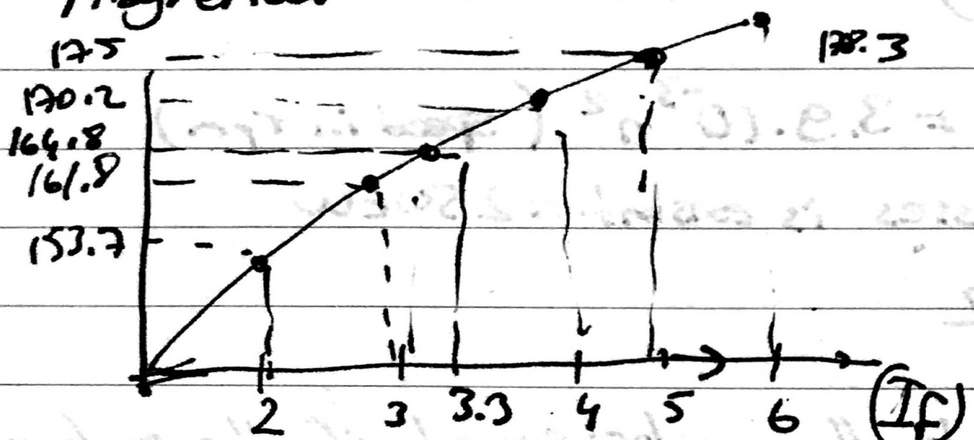
$$\underline{n = 1601 \text{ rpm}}$$

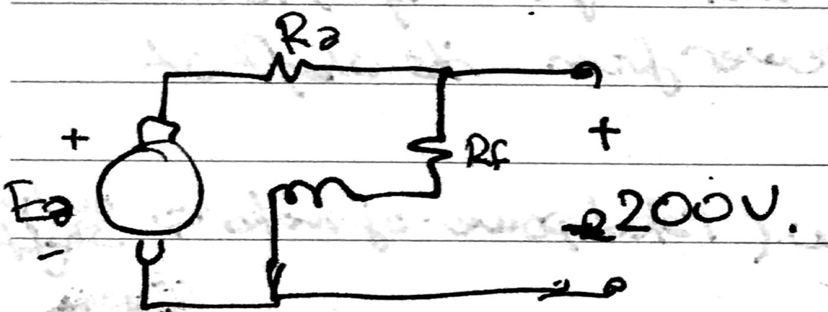
$$w = 2\pi \cdot \frac{1600}{\underset{Hz}{60}} = 168 \text{ rad/s}$$

$$T_l = \frac{P_o}{w_m} = \frac{10.000}{168} = 59.6 \text{ Nm}$$

b) Determine the armature current and armature resistance of the motor at rated load.

Magnetization characteristics.





$Rf = 40\Omega \Rightarrow If = \frac{200}{40} = 5A$

$If = 5A \Rightarrow n_r = 1500rpm \Rightarrow E_a = 175V$

$n = 1601rpm \Rightarrow If = 5A \Rightarrow E_a = 175 . \frac{1601}{1500}$

$E_a = 187V$

$Pe = Pout + Pfriction$

$Pe = 10.000 + 250 = 10.250W$

$Pe = E_a . I_a = 10.250W$

$I_a = \frac{10.250}{187} = 54.8A$

$$R_a = \frac{V_t - E_a}{I_a} = \frac{200-187}{54.8} = \underline{0.24\,\Omega}$$

c) Calculate the total current drawn from the power source.

$$I_t = I_a + I_f$$
$$= 54.8 + 5 = 59.8\,A$$

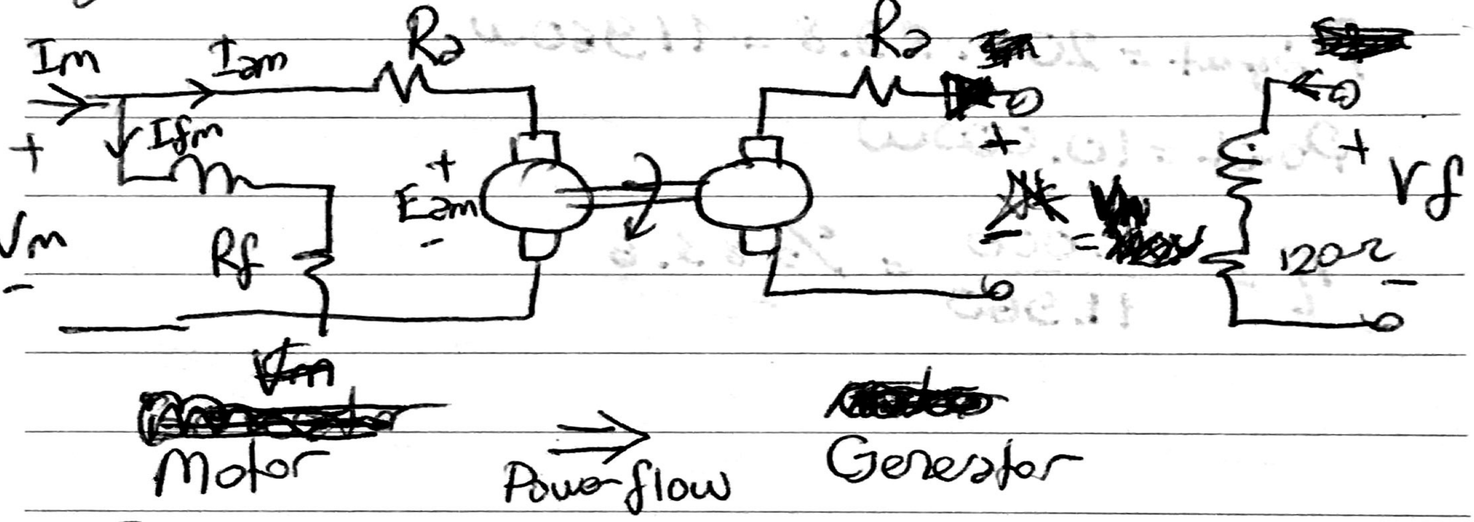
$$P_{input} = 200 \cdot 59.8 = 11960\,W$$

$$P_{out} = 10.000\,W$$

$$\eta = \frac{10.000}{11.960} = \underline{\%\,83.6}$$

Ex: Consider two identical DC machines having an armature resistance $R_a = 0.2\,\Omega$ and a field winding resistance of $R_f = 120\,\Omega$

One of the machines is used as a shunt motor to drive the other as a seperately excited generator.



The shunt motor draws 6kW from a constant voltage source of $V_t = 120V$, The excitation currents of both machines are equal and the rotational loss is constant $P_{rot} = 200W$ per machine

a) Draw the complete circuit diagram

b) Calculate the induced voltage and efficiency of the motor

$P_{im} = 6kW$ $\quad I_m = \frac{6000}{120} = 50A$

$V_m = 120V.$

$I_{fm} = \frac{120\,V}{120\,\Omega} = 1A$

$I_{am} = 50 - 1 = 49A.$

$R_a = 0.2\,\Omega$

$E_{am} = V_m - R_a . I_{am} =$
$= 120 - 0.2 . 49 = 110.2V$

$P_{elec}(m) = E_a . I_a = 110.2 . 49 = 5400W$

$P_{out}(m) = P_{elec} - P_{friction} = 5400 - 200 = 5200W$

$\eta = \frac{P_{out}}{P_{in}} = \frac{5200}{6000} = 86.67\%$

c) Assuming the induced voltage of the generator is 110.2V. Find the armature current, output power and efficiency of the generator.

$E_{ag} = 110.2V$

$P_{om} = 5200W$

$P_{eg} = P_{ig} - P_{friction} = 5200 - 200 = 5000W$

$$I_{ag} = \frac{P_{eg}}{E_{ag}} = \frac{5000}{110.2} = 45,37A$$

$$V_{tg} = E_{ag} - R_a I_{ag} = 110.2 - [illegible] .45,37$$
$$= 101, [illegible]$$

$$P_{ag} = R_a I_{ag}^2 = 0,2.(45,37)^2 = 411,7W$$ (Generator Armature Loss)

$R_f I_f^2 = 120W$ (given) (Same current $I_f = 1A$) to induce same voltage.

$$P_{ig} = 5200 + 120 = 5320W$$

$$P_{out} = V_{tg} . I_{ag}$$
$$= 4588$$

$$\eta = \frac{4580}{5320} = 86,25\%$$

or $P_{loss} =$

$P_{rot} + P_{field} + P_{arm}$

$= 200 + 0,2 (45,37)^2$

$+ 120.(1)^2$

$= 732W$

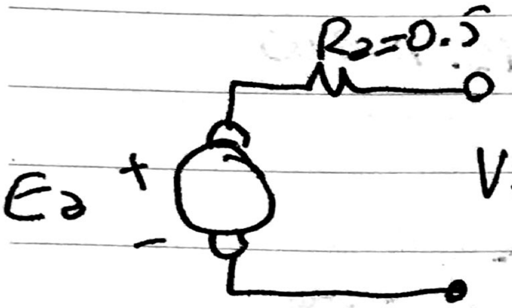
$$\eta_g = \frac{5320 - 732}{5320} = 86,25$$

d) Overall efficiency

$$\eta_s = \frac{P_{out}}{P_{in}} = \frac{4588}{6000+120} = \underline{\underline{75\%}}$$

field of the generator

(EE361-2015 Final Q4) (Muammer hoca)



$V_t = 220V$.

no load speed = 1500 rpm

↳ no load, (no friction) ⇒ $I_a = 0$

$E_a = V_t = 220V$ @1500rpm

b) $T_L = 100Nm$ (constant)

$V_t = ?$ to drive it at 1500rpm

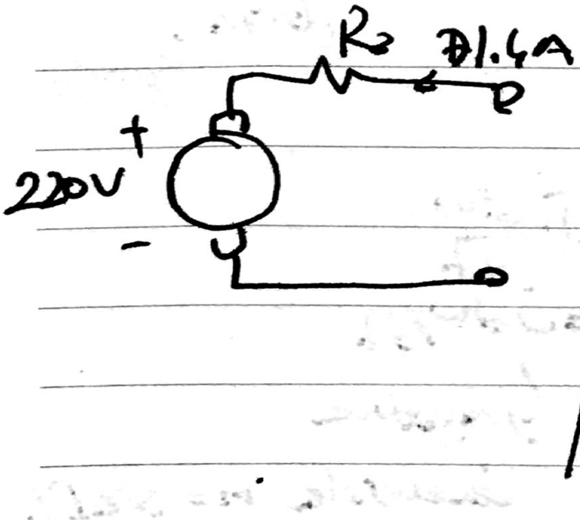
$E_a = K_a\phi . \omega = 220$.

$K_a . \phi . \frac{1500}{60} . 2\pi = 220 \Rightarrow K_a\phi = 1.4$

$T_e = T_L + T_{fric} = 100 + 0 = 100Nm$

$T_e = K_a . \phi . I_a = 100$

$1.4 . I_a = 100 \Rightarrow I_a = 71.4A$



$V_t = 220 + 71.4 . 0.5 = 255.7V$

or use the given eq.

$$\omega_r = \frac{V_t}{K_a\phi} - \frac{R_a}{(K_a\phi)^2} T_L$$

$$1500 . \frac{2\pi}{60} = \frac{V_t}{1.4} - \frac{0.5}{(1.4)^2} . 100$$

$V_t = 255.7V$

Gross AR

$P_{output} = T_e . w_r = T_L . w_r + T_{fric} . w_r$

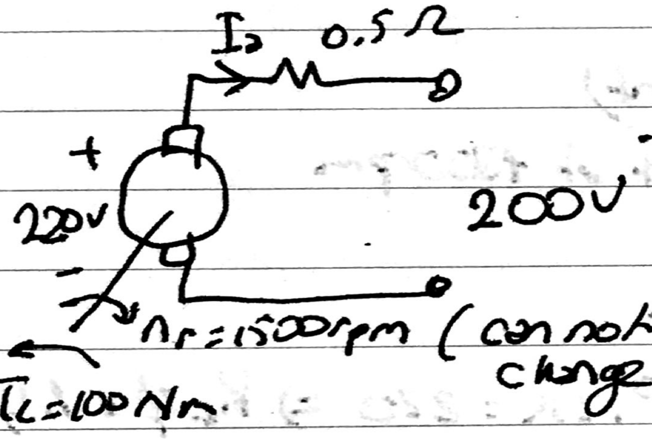
$$100 . 1500 . \frac{2\pi}{60} = \underline{15.708 \, W}$$

or since there is no friction gross mechanical power output

$P_o = E_a . I_a = 220 . 71.4 = \underline{15.708 W}$

Part III)

Vt is suddenly reduced to 200V. $K_a . \phi = 1.4$



$$I_a = \frac{220-200}{0.5} = 40A$$

$$T_e = K_a . \phi . I_a = \underline{-56 Nm}$$

Gross mechanical output power $P_m = T_e . w_r = E_a . I_a$

$$= 220 . -40 = \underline{-8800 W}$$

mechanical power converted to electrical form.

Operation mode: generator.

$$T_e - (T_{load} + T_{friction}) = J . \frac{dw}{dt}$$

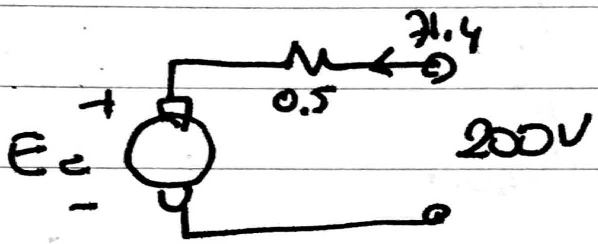
$$-56 - 100 = -156 Nm = J dw/dt$$

↳ negative

decelerates and shaft speed reaches a new Ea at steady state.

I_a is negative (generating mode) until $E_a = V_t = 200V$, from this point the machine starts in the motoring mode, but the torque is still not enough. The speed continue to decrease until $T_e = T_{mech} = 100\ Nm$.

$T = K_a . \Phi . I_a \Rightarrow I_a = 71.4A$

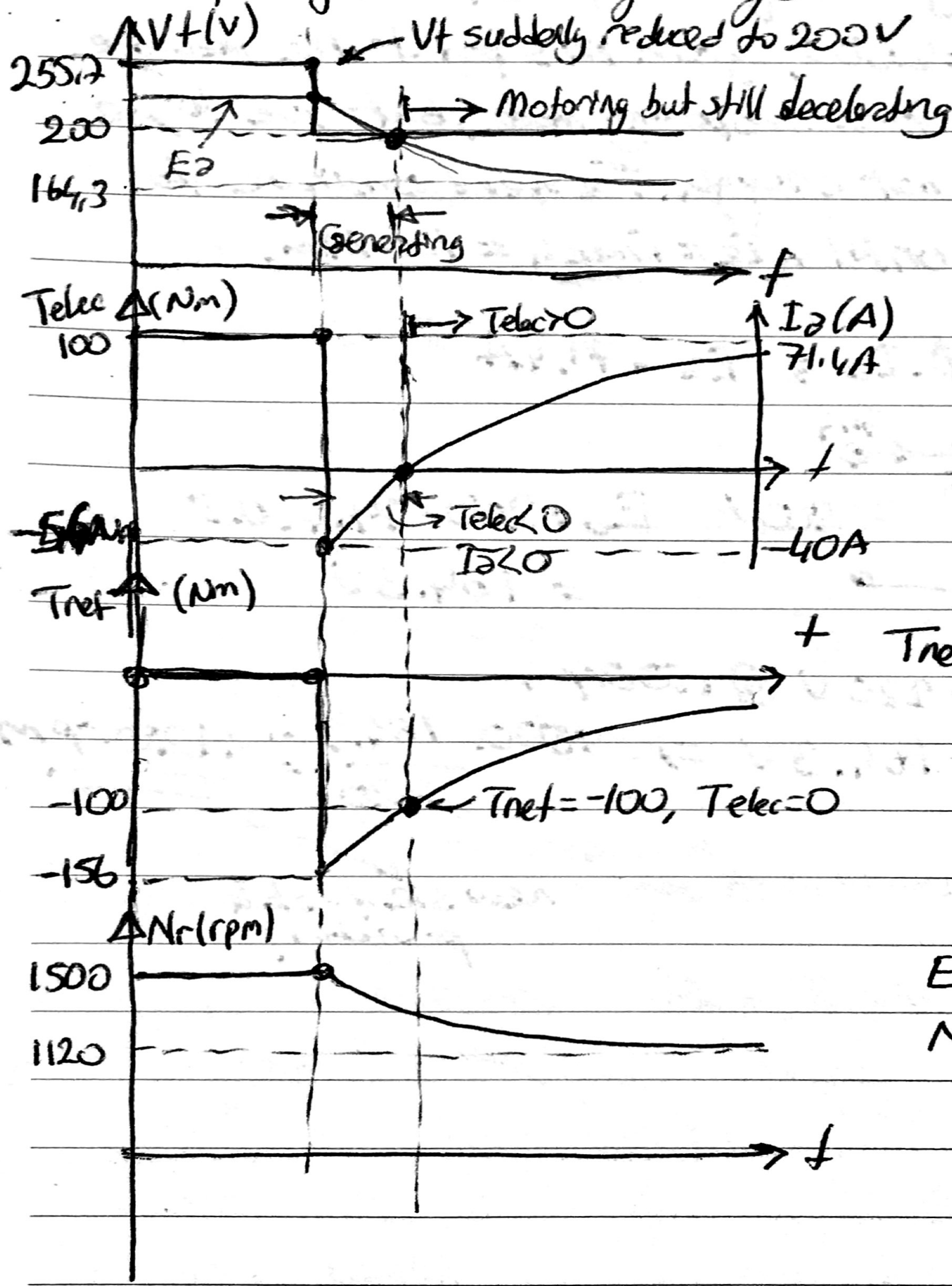


$E_a = 200 - 71.4 . 0.5$
$= 164.3V$

if $E_a = 220V$ @ 1500rpm
$E_a = 164.3V \Rightarrow 1500 . \frac{164.3}{220} \approx \underline{\underline{1120rpm}}$

new steady stable position.

Graphs after terminal voltage change



$T = 1.4 I_a$

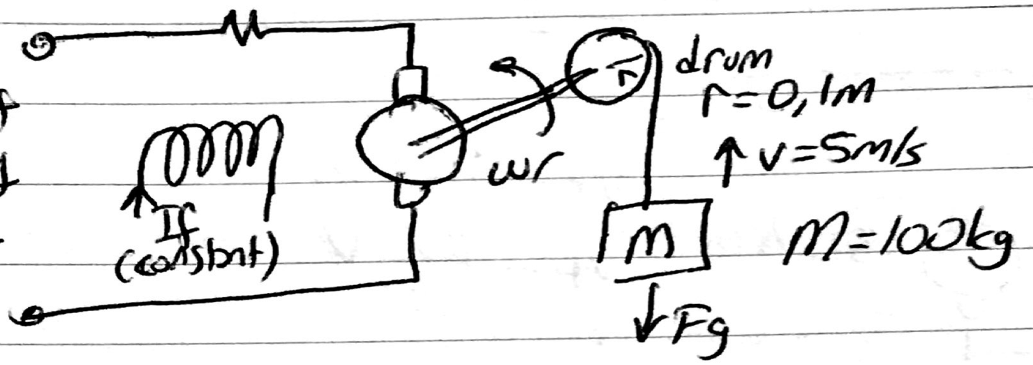
$T_{net} = T_{elec} - T_{load}$

$E_a = 1.4 \cdot \omega_r$

$N_r = \frac{\omega_r}{2\pi} \cdot 60$

Ex-3

A separately excited DC motor is operating in a crane-hoist. Its field excitation is kept constant.
$R_a = 0{,}5\,\Omega$ $\underline{I_a = 100A}$ are given.



a) Find the applied armature voltage (V_t) in order to rise (ascend) the load at a constant speed of $V = 5m/s$

$\Rightarrow$ Since speed is constant, $\Rightarrow$ no acceleration $\Rightarrow T_{net} = J.\frac{dw}{dt}$

$T_{net} = 0 \Rightarrow T_{elec} = T_{load}$

$T_{load} = \underbrace{m.g}_{Fg}.r = 100.10.0{,}1 = 100\,Nm$

$W_r.r = V$ ← linear speed
↑ rotational speed.

$w_r = \frac{5}{0{,}1} = 50\,rad/s.$

$N_r = \frac{50}{2\pi}.60 = 477{,}5\,rpm$

$T = K_a.\phi.I_a$
$100 = K_a.\phi = 100$
$\underline{K_a\phi = 1}$

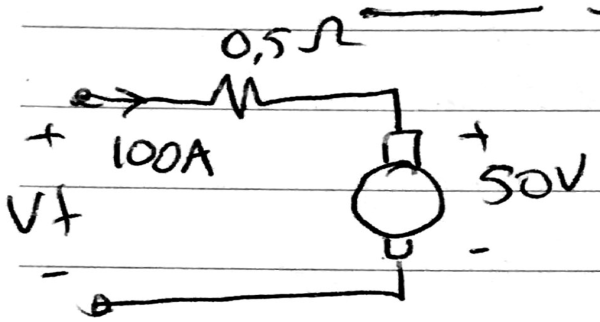
$E_a = K_a\phi.w_r$
$E_a = 50V$ (motoring mode)

Alternatively use energy conservation.

$$P_{mech} = F.v = \underbrace{100.10}_{Fg}.5 = 5kW$$

$$P_{(motor\_out)} = E_a.I_a = E_a.100 = 5kW$$

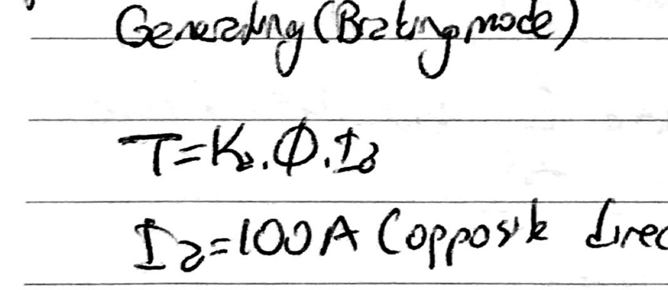
$$E_a = 50V$$



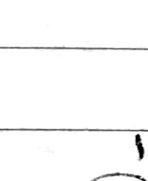
$$V_t = 50 + 0,5.100$$

$$V_t = 100V$$

b) Now, assume the motor lowers (descends) the load at constant speed. (which is called overhauling)
Find the speed at which the DC machine can overhaul the load by assuming that V_t remains same. (but note that either the direction of I_f or V_t is reversed)



Generating (Braking mode)



$T_e = T_L$
generating mode
T_e, ω have opposite directions

$$T = K_a.\Phi.I_a$$

$I_a = 100A$ (opposite direction)

$$E_a = V_t + R_a I_a$$
$$= 100 + 0,5.100$$
$$= 150V$$

$$E_a = K_a.\Phi\omega$$
$$\omega = 150 \text{ rad/sec}$$
$$n_n = 1432.5 \text{ rpm}$$

4 Quadrant Operation