PRINCIPLES OF ENERGY CONVERSION SECOND MIDTERM EXAM

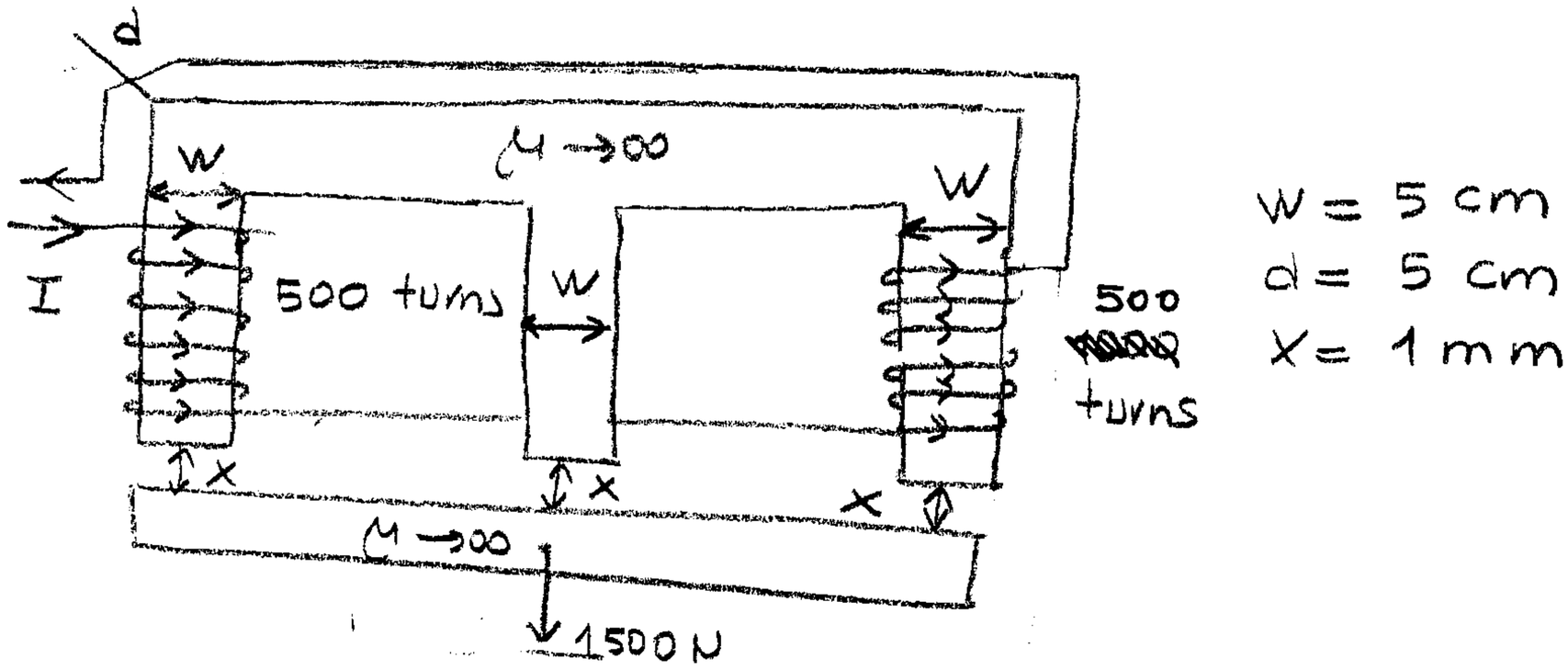
Dr. Salih FADIL **May 09, 2014**

#1) A single phase, 2400/240 V, 60 kVA transformer has the following test data.

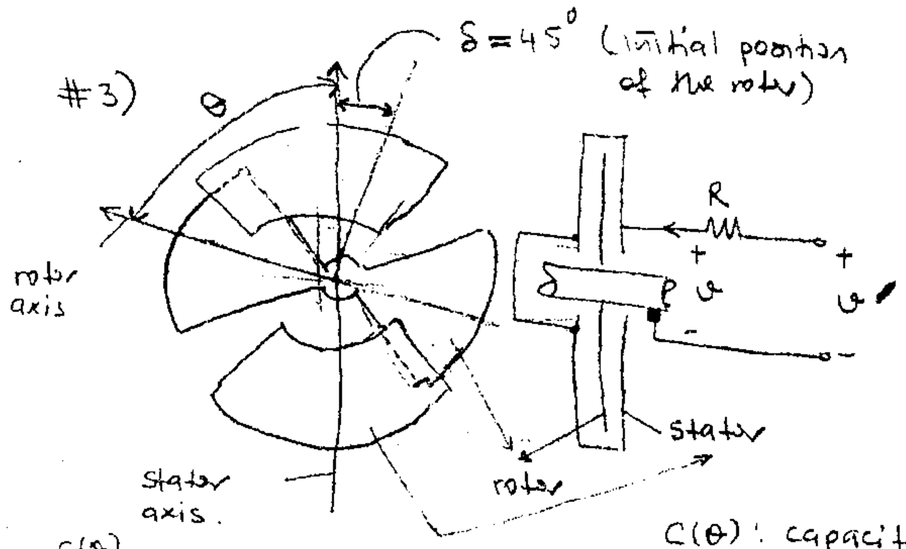
Experiment	Current (A)	Voltage (V)	Active power (W)	Comment
Open circuit	6.0	240	190	2400 V winding is open circuited and measurements are done at the low voltage winding
Short circuit	25	50	600	240 V winding is short circuited and measurements are done at the high voltage winding.

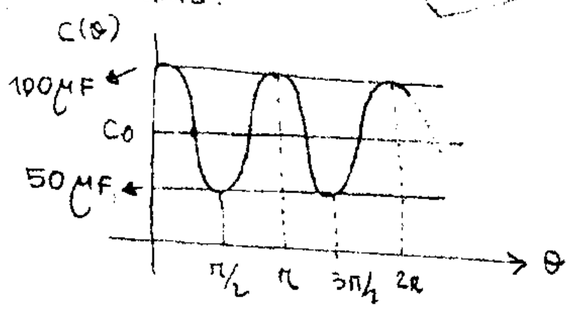
Draw the equivalent circuit of the transformer referred to high voltage side.

#2) If the electromagnet shown in the figure is capable of carrying 1500 N, find the required current value.



#3)





C(θ): capacitance between stator and rotor.

$C(\theta) = C_0 + C_2 \cos 2\theta$

$v(t) = v'(t) = V_{max} \sin(150\pi t)$ volt

Consider the electrostatic motor given in the above.

a) Calculate the continuous angular velocity and number of rotation per second of the rotor.

b) If the induced average torque is 0.7 Nm, calculate V_{max} value.

c) Calculate average mechanical power.

PRINCIPLES OF ENERGY CONVERSION SECOND MIDTERM EXAM SOLUTION MANUAL

Dr. Salih FADIL

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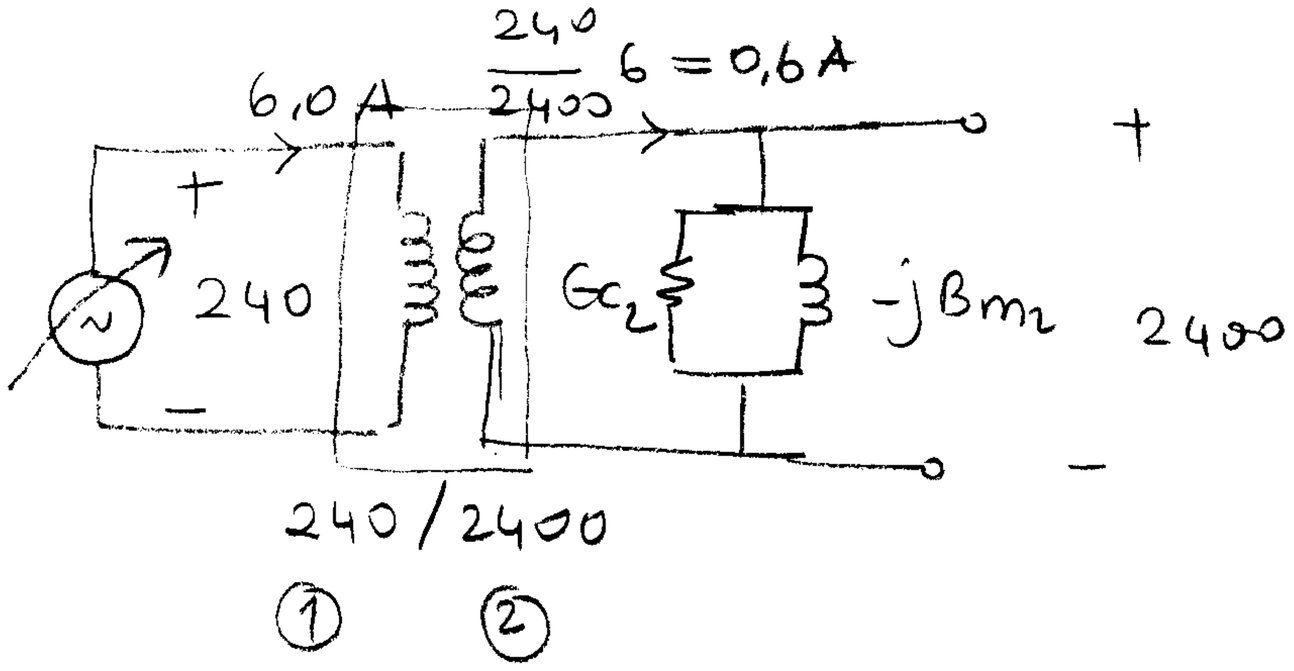
#1) From open circuit test

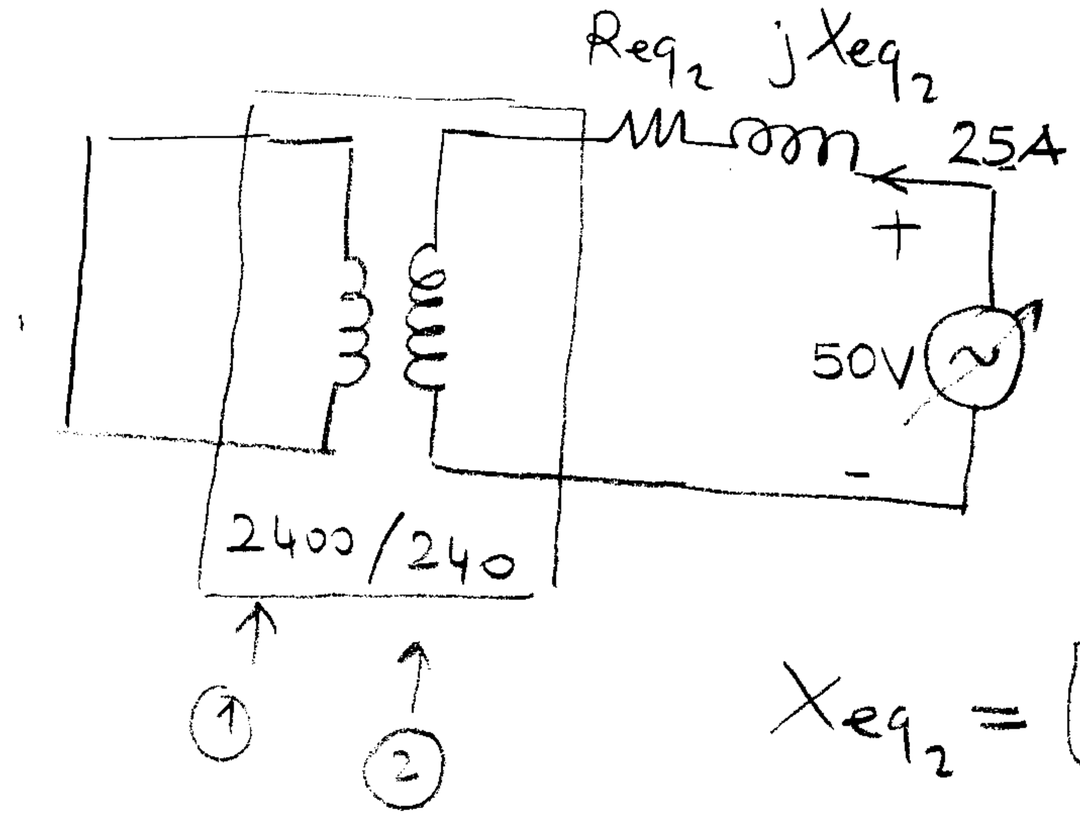


$$G_{c_2} = \frac{190}{(2400)^2} = 3,2986\ 10^{-5}\ S.$$

$$Y_{m_2} = \frac{0,6}{2400} = 2,5\ 10^{-4}\ S \qquad B_{m_2} = \left[(2,5\ 10^{-4})^2 - (3,2986\ 10^{-5})^2\right]^{1/2}$$

$$B_{m_2} = 2,4781\ 10^{-4}\ S.$$

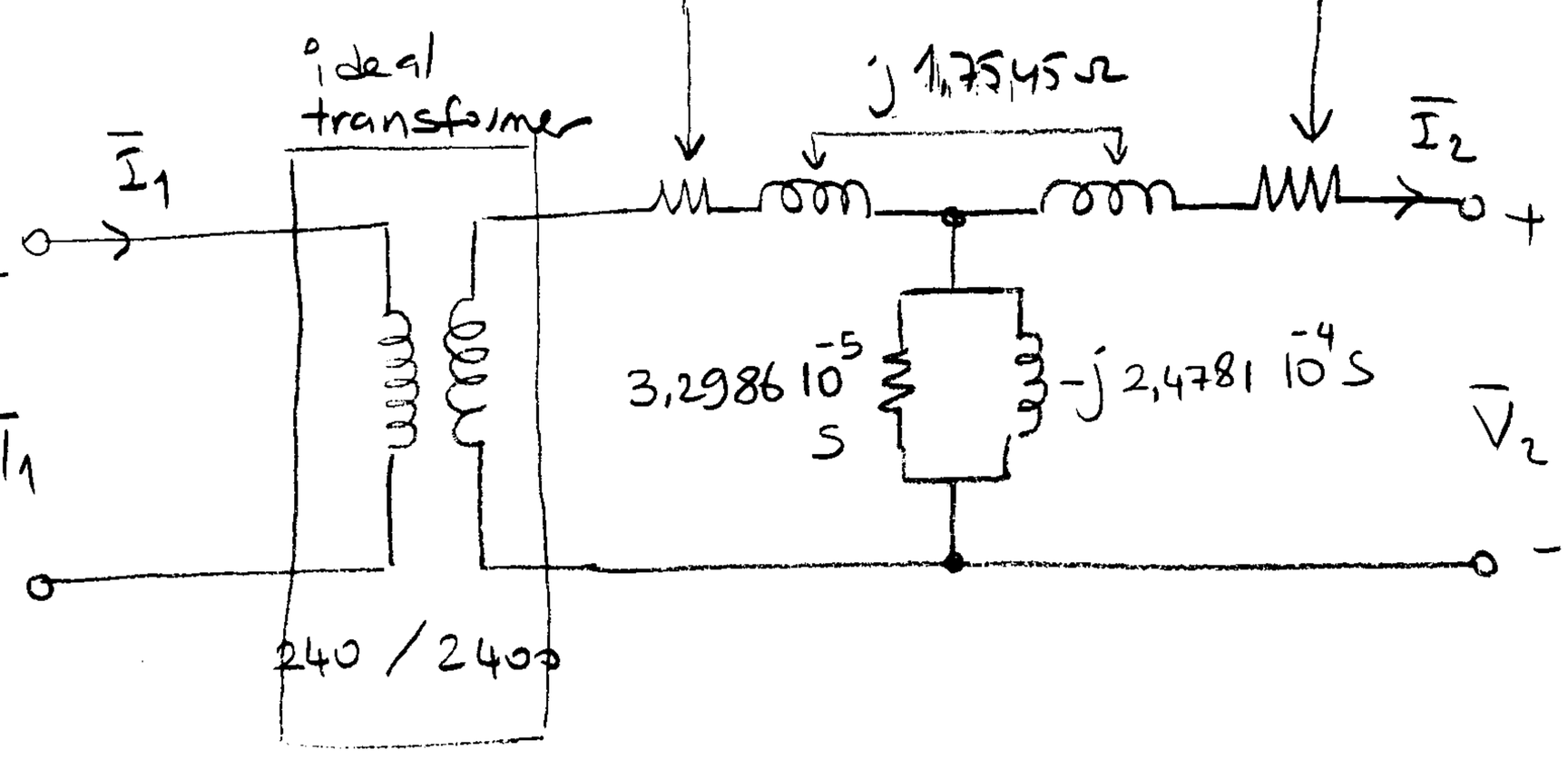
From short circuit test



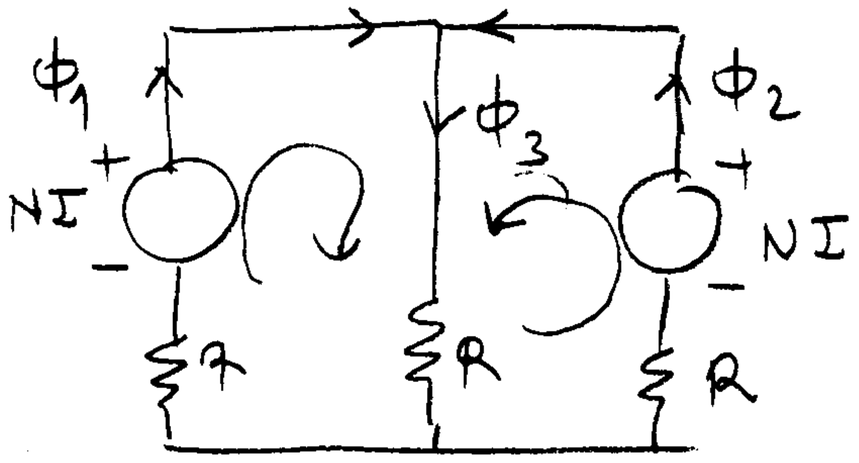
$$Req_2 = \frac{600}{(25)^2} = 0,96\ \Omega$$

$$Zeq_2 = \frac{50}{25} = 2\ \Omega$$

$$Xeq_2 = \left[4 - (0,96)^2\right)^{1/2} = 1,7545\ \Omega$$



-2)



$$-NI + \Phi_3 R + \Phi_1 R = 0$$

$$-NI + \Phi_3 R + \Phi_2 R = 0$$

$$\Phi_1 + \Phi_2 = \Phi_3$$

$$\Phi_3 + \Phi_1 = \frac{NI}{R}$$

$$\mp\Phi_3 \mp \Phi_2 = \mp\frac{NI}{R}$$

$$\Phi_1 - \Phi_2 = 0 \rightarrow \Phi_1 = \Phi_2$$

$$\Phi_3 = \Phi_1 + \Phi_2 = 2\Phi_1$$

$$2\Phi_1 + \Phi_1 = \frac{NI}{R}$$

$$\Phi_1 = \frac{NI}{3R} = \Phi_2$$

$$\Phi_3 = \frac{2NI}{3R}$$

$$R = \frac{x}{wd\mu_0} \longrightarrow \frac{dR}{dx} = \frac{1}{(wd)\mu_0}$$

$$f_{tot} = \frac{1}{2}\Phi_1^2 \frac{dR}{dx} + \frac{1}{2}\Phi_3^2 \frac{dR}{dx} + \frac{1}{2}\Phi_2^2 \frac{dR}{dx}$$

$$f_{tot} = \frac{1}{2}\left(\Phi_1^2 + 4\Phi_1^2 + \Phi_1^2\right)\frac{dR}{dx} = 3\Phi_1^2 \frac{dR}{dx}$$

$$= \cancel{3}\,\frac{N^2 I^2}{\cancel{9}R^2}\frac{dR}{dx} = \frac{N^2 I^2}{3\frac{x^2}{\cancel{(wd)^2\mu_0^2}}}\frac{1}{wd\cancel{\mu_0}} = \frac{N^2 I^2 w.d\,\mu_0}{3x^2}$$

$\cancel{3}$

$\cancel{(wd)}\,\mu_0$

$$f_{tot} = f_{load} = \frac{N^2 I^2 w d \mu_0}{3x^2}$$

$$I = \left[\frac{3x^2 f_{load}}{N^2 w d \mu_0}\right]^{1/2} = \frac{x}{N}\sqrt{\frac{3 f_{load}}{(w d)\mu_0}} \quad A$$

$$I = \frac{10^{-3}}{500}\sqrt{\frac{3 \times 1500}{25\,10^{-4} \cdot 4\pi\,10^{-7}}} = 2.39365 A$$

#3)

a) Continous angular velocity

$$\omega_m = \omega = 150\pi \text{ r/s.}$$

$$n = \frac{150\pi}{2\pi} = 75 \text{ rps (rotation per second)}$$

b) $T_{e,avg} = -\frac{1}{4} V_{max}^2 C_2 \sin 2\delta \quad , \delta = 45^\circ = \pi/4$

$$C(\theta) = C_0 + C_2 \cos 2\theta$$

$100 = C_0 + C_2 \longrightarrow$ for $\theta = 0$

$\mp 50 = \mp C_0 \pm C_2 \longrightarrow$ for $\theta = \pi/2$ please see the figure

$50 = 2C_2$

$C_2 = 25\ \mu F$

$C_0 = 100 - 25 = 75\ \mu F \quad \cdot \delta = 45^\circ$

$$\left|T_{e,avg}\right| = \frac{1}{4} V_{max}^2\ 25\,10^{-6} \underbrace{\sin \pi/2}_{1} = 0,7 \quad Nm$$

$$V_{max} = \left[\frac{4 \times 0,7}{25\,10^{-6}}\right]^{1/2} = 334,66 \quad volt$$

c) $P_{m,avg} = P_m = \omega_m T_{e,avg} = 0,7\ 150\pi = 329,86\ W$