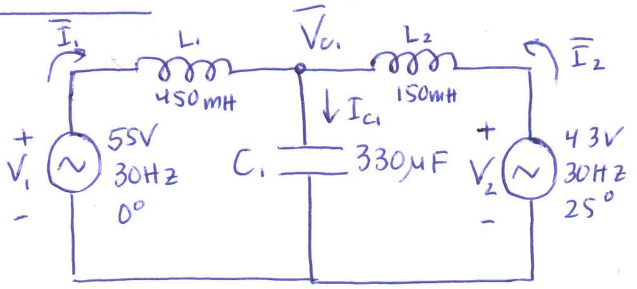
MIDTERM EXAM 2017

SECTION A



$f = 30Hz$

$L_1 = 450mH$

$L_2 = 150mH$

$C_1 = 330\mu F$

$\bar{V}_1 = 55\angle 0°$

$\bar{V}_2 = 43\angle 25°$

$\omega = 2\pi f$

(1)

$$X_{L1} = \omega L_1 = 2\pi f L_1 = 450 \cdot 10^{-3} \cdot 2\pi \cdot 30 = \underline{\underline{84,8\,\Omega}}$$

$$X_{L2} = \omega L_2 = 2\pi f L_2 = 150 \cdot 10^{-3} \cdot 2\pi \cdot 30 = \underline{\underline{28,3\,\Omega}}$$

$$X_{C_1} = \frac{1}{\omega C_1} = \frac{1}{2\pi f C_1} = \frac{1}{330 \cdot 10^{-6} \cdot 2\pi \cdot 30} = 16,1\,\Omega$$

(2) KLC: $I_{L1} + I_{L2} - I_{C1} = 0$ for node 2

where: $I_{L1} = \dfrac{V_1 - V_C}{jX_{L1}}$ (*) $\quad I_{L2} = \dfrac{V_2 - V_C}{jX_{L2}}$ (✱) $\quad I_C = \dfrac{V_C}{(-jX_{C1})}$

so:

$$\frac{V_1 - V_C}{jX_{L1}} + \frac{V_2 - V_C}{jX_{L2}} - \frac{V_C}{-jX_{C1}} = 0$$

$$\frac{V_1}{jX_{L1}} + \frac{V_2}{jX_{L2}} = V_C\left(\frac{1}{jX_{L1}} + \frac{1}{jX_{L2}} - \frac{1}{jX_C}\right)$$

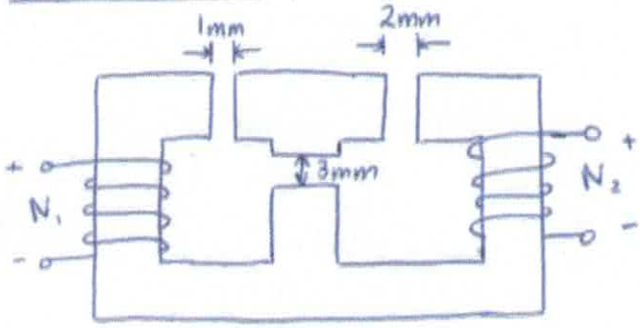
solve for V_C:

$$V_C = \frac{\dfrac{V_1}{jX_{L1}} + \dfrac{V_2}{jX_{L2}}}{\dfrac{1}{jX_{L1}} + \dfrac{1}{jX_{L2}} - \dfrac{1}{jX_C}} = \underline{\underline{141,8\angle 162,4°V}}$$

From (*) $\underline{\underline{I_{L1} = 2,29\angle -77,3°A}}$

From (✱) $\underline{\underline{I_{L2} = 6,5\angle -70,68°A}}$

SECTION B



The iron core has a permenility $\mu \to \infty \Rightarrow$ ignore core losses.

There are three air gaps ($\mu_0 = 4\pi \cdot 10^{-7}$)

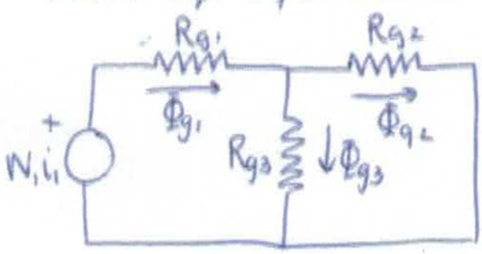
$l_{g1} = 1mm$, $l_{g2} = 2mm$ & $l_{g3} = 3mm$

$A_c = 10 cm^2 = 10 \cdot 10^{-4} m^2$

$N_1 = 200$ & $N_2 = 100$

(3) If $i_1 = 10A$ and $i_2 = 0A$, determine $\Phi_{g1}, \Phi_{g2}, \Phi_{g3}$.

Draw up equivalent circuit.



$$R_{g1} = \frac{l_{g1}}{\mu_0 A_c} = \frac{1 \cdot 10^{-3}}{4\pi \cdot 10^{-7} \cdot 10 \cdot 10^{-4}} = 795,8 \cdot 10^3 \, H^{-1}$$

$$R_{g2} = \frac{l_{g2}}{\mu_0 A_c} = 2 \cdot R_{g1} = 1591,5 \cdot 10^3 \, H^{-1}$$

$$R_{g3} = \frac{l_{g3}}{\mu_0 A_c} = 3 \cdot R_{g1} = 2387,3 \cdot 10^3 \, H^{-1}$$

Find the total resistance

$$R_{total} = R_{g1} + R_{g2} // R_{g3} = R_{g1} + \frac{R_{g2} R_{g3}}{R_{g2} + R_{g3}} = 1750,7 \cdot 10^3 \, H^{-1}$$

Now the magnetic fluxes can be computed:

$$\Phi_{g1} = \frac{N_1 i_1}{R_{total}} = \frac{200 \cdot 10}{1750,7 \cdot 10^3} = \underline{\underline{1,142 mWb}}$$

$$\Phi_{g2} = \frac{R_{g3}}{R_{g2} + R_{g3}} \cdot \Phi_{g1} = 0,6 \cdot 1,142 mWb = \underline{\underline{0,6852 mWb}}$$

$$\Phi_{g3} = \frac{R_{g2}}{R_{g2} + R_{g3}} \cdot \Phi_{g1} = 0,4 \cdot 1,142 mWb = \underline{\underline{0,4570 mWb}}$$

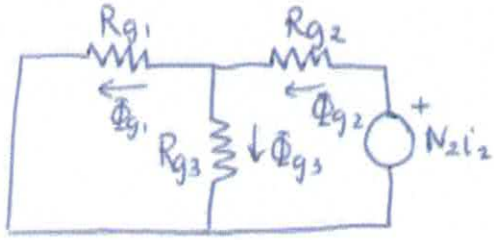
(4) Determine the self-induction coefficient (L_{11}) and the mutual inductaion (M_{12}).

$$L_{11} = \frac{\lambda}{i} = \frac{N_1 \Phi_1}{i_1} = \underline{\underline{22,84 mH}}$$

$$M_{12} = \frac{N_2 \Phi_2}{i_1} = \underline{\underline{6,852 mH}}$$

SECTION B

(5) If $i_1 = 0A$ and $i_2 = 20A$ the equivalent circuit can be redrawn



In this case

$$R_{total} = R_{g2} + R_{g1} // R_{g3} = R_{g2} + \frac{R_{g1} R_{g3}}{R_{g1} + R_{g3}}$$

$$= 2188{,}3 \cdot 10^3 \; H^{-1}$$

Determine $\Phi_{g2} = \dfrac{N_2 i_2}{R_{total}} = \underline{\underline{0{,}914 \, mWb}}$

and $\Phi_{g1} = \underline{\underline{0{,}685 \, mWb}}$ & $\Phi_{g3} = \underline{\underline{0{,}2285 \, mWb}}$

(6) $L_{22} = \dfrac{\lambda}{i_2} = \dfrac{N_2 \Phi_{g2}}{i_2} = \underline{\underline{4{,}57 \, mH}}$

$M_{21} = \dfrac{N_1 \cdot \Phi_{g1}}{i_2} = \underline{\underline{6{,}85 \, mH}}$

SECTION C

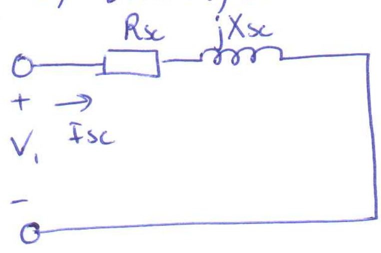
$S_n = 75\,kVA$
$V_{1n} = 3000\,V$
$V_{2n} = 220\,V$
$f_n = 50\,Hz$

Short circuit test: primary voltage (200v)
consumed power (2kW)
Current (Inominal)

Open circuit test: power consumed (1,5kW)

(7) Short-circuit impedance of transformer?

short-circuit test: second winding shorted



$I_{sc} = \frac{S_n}{V_{1n}} = 25A$ (~~The~~ The nominal current)

The short-circuit resistance:

$R_{sc} = \frac{V}{I} = \frac{P}{I^2} = \frac{2000}{25^2} = \underline{3{,}2\Omega}$

The active power consumed during short circuit test:

$P_{sc} = VI\cos(\theta) \Rightarrow \cos(\theta) = \frac{P_{sc}}{V_1 I_{sc}} = \frac{2000}{200 \cdot 25} = 0{,}4$
(powerfactor)

$\Rightarrow \theta = 66{,}42°$ ($=\arccos(0{,}4)$)

$I_p X_{sc} = V_p \sin(\theta) \Rightarrow X_{sc} = \underline{7{,}332\Omega}$

(8) Voltage drop ~~on secondary voltage~~ under full load conditions for
p.f: 0,8 lagging $\Rightarrow \cos(\theta) = 0{,}8$
$\sin(\theta) = 0{,}6$

$I_{full\,load} = I_{sc} = 25A$

The voltage drop in the short circuit impedances

$V_{loss} = I_p(R_{sc}\cos(\theta) + X_{sc}\sin(\theta)) = 25(3{,}2 \cdot 0{,}8 + 7{,}332 \cdot 0{,}6)$
$= 174\,V$

$\Delta V = \frac{V_{loss}}{V_{1n}} = 0{,}058 \simeq \underline{5{,}8\%}$

(9) pf: 0,8 leading $\Rightarrow \cos(\theta) = 0{,}8$
$\sin(\theta) = -0{,}6$

$V_{loss} = 25(3{,}2 \cdot 0{,}8 + 7{,}332(-0{,}6)) = -45{,}98\,V$

$\Delta V = \frac{-45{,}98}{3000} = \underline{-1{,}53\%}$

(10) $\eta = \frac{S_n\cos(\theta)}{S_n\cos(\theta) + \underbrace{2kW}_{\text{sc losses}} + \underbrace{1{,}5kW}_{\text{oc losses}}} = 0{,}945 \simeq \underline{94{,}5\%}$