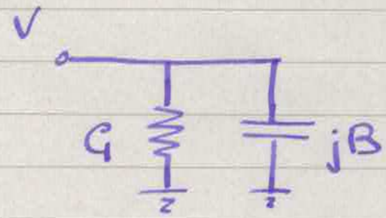
EEEN20090

Section A

1. Equivalent circuit:



$V = 20\ kV$
$Q = 200\ kVAr$
$P = 2\ kW$

$B > 0 \rightarrow$ capacitor

$\bar{Y} = G + jB$

$$B = \frac{Q}{V^2} = \frac{200 \cdot 10^3}{(20 \cdot 10^3)^2} = 5 \cdot 10^{-4}\ \Omega^{-1}$$

$$G \leq P/V^2 = \frac{2 \cdot 10^3}{(20 \cdot 10^3)^2} = 5 \cdot 10^{-6}\ \Omega^{-1}$$

2. $\bar{z} = \frac{1}{\bar{Y}} = R + jX$

$R \leq 20\ \Omega$, $X = -2000\ \Omega \rightarrow$ capacitive element.

In both cases, the element has to be implemented as a capacitor. The conductance can be assumed to be due to the losses of the capacitor. No additional element is thus required.

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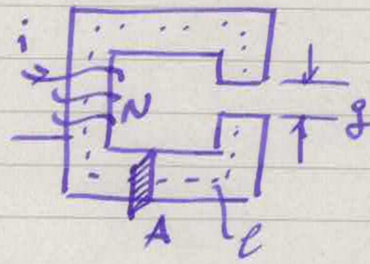
Section B.

3. Equivalent magnetic circuit



$A = 20 \cdot 10^{-4} \ m^2$

$l = 0.1 \ m$

$g = 2 \cdot 10^{-3} \ m$

$B = \frac{2H}{230 + H} \Rightarrow H = \frac{230 B}{2 - B}$ in the iron core

Equations: $\phi = \phi_g$ (no fringing effect)

$$BA = B_g A \rightarrow B = B_g$$

$B_g = \mu_0 H_g = B \Rightarrow H_g = B/\mu_0$

and, finally, from the Ampere's law: $Ni = Hl + H_g g$

Substituting and solving for B:

$$\frac{230 B}{2 - B} l + \frac{B}{\mu_0} g = Ni$$

$\rightarrow \left(230\, l + Ni + 2g/\mu_0\right) B - g/\mu_0 \cdot B^2 - 2Ni = 0$

$\rightarrow \quad a B^2 + b B + C = 0$

where:

$a = g/\mu_0 = 1591.55$

$b = -\left(230 \cdot l + Ni + \frac{2g}{\mu_0}\right) = -4206.1$

$c = 2Ni = 2000$

hence $B = \begin{cases} 2.021\ T \\ 0.622\ T \end{cases}$ → only acceptable solution (because positive H)

$$H = \frac{230\, B}{2 - B} = 103.82\ A\text{-}t$$

$$\phi = B \cdot A = 0.622 \cdot 20 \cdot 10^{-4} = 0.00124\ Wb$$

4. $\mu = \frac{B}{H} = \frac{0.622}{103.82} = 0.006\ [H/m]$

$\mu_r = \frac{\mu}{\mu_0} = 4768 \approx 5000$ → typical iron alloy for magnetic circuits

5. $L = \dfrac{N^2}{R_{TOT}}$

where $R_{TOT} = R_{Fe} + R_g$

$R_{Fe} = \dfrac{l}{\mu A} = \dfrac{0.1}{20 \cdot 10^{-4} \cdot 0.006} = 8333 \; H^{-1}$

$R_g = \dfrac{g}{\mu_0 A} = \dfrac{2 \cdot 10^{-3}}{20 \cdot 10^{-4} \cdot 4 \cdot \pi \cdot 10^{-7}} = 795\,775 \; H^{-1}$

$R_{TOT} = 804\,108 \; H^{-1}$

$L = \dfrac{500^2}{R_{TOT}} = 0.311 \; [H]$ #

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Section C

6. $K_T = \frac{2400}{240} = 10$

$$\begin{cases} R_1'' = 3/10^2 = 0.03\ \Omega \\ X_1'' = 15/10^2 = 0.15\ \Omega \end{cases}$$

$$\begin{cases} R_{sc}'' = R_1'' + R_2 = 0.06\ \Omega \\ X_{sc}'' = X_1'' + X_2 = 0,3\ \Omega \end{cases}$$

$$\bar{Z}_{sc}'' = R_{sc}'' + jX_{sc}''$$

$$I_{2N} = \frac{S_N}{V_{2N}} = \frac{10000}{240} = 41.7\ A$$

$\bar{V}_2 = V_2 \angle 0 \rightarrow$ phase reference $\rightarrow \bar{I}_2 = 41.7 \angle -36.87°$

↑

$\cos\varphi_2 = 0.8$ lagging

$\rightarrow \bar{V}_1'' = \bar{V}_2 + \bar{I}_2 \cdot \bar{Z}_{sc}'' = 250.65 \angle 1.952°\ V$

$V_1 = V_1'' \cdot K_T = 2496.5\ V$ $\quad \varepsilon_V = \frac{250.65 - 240}{250.65} 100 = 4.25\ \%$

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7. $\bar{I}_2 = 41.7 \angle 36.87^\circ$ A

↑ $\cos\varphi = 0.8$ lagging

$\bar{V}_1'' = \bar{V}_2 + \bar{I}_2 \, \bar{Z}_{sc}'' = 234.78 \angle 2.81^\circ$ V

$V_1 = k_T V_1'' = 2,347.8$ V

$$\varepsilon_V = \frac{234.78 - 240}{234.78} 100 = -2.22\,\%$$