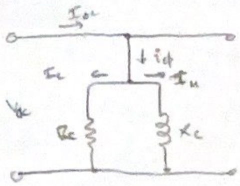
ECE385 | HW2 | CHASE LOTITO 09-15-2024

(1) 1-ϕ XF HAS 500 TURNS IN PRIMARY WINDING. WHEN CONNECTED TO 1ϕ, 120V, 60Hz PWS, THE NO-LOAD CURRENT IS 1.6A AND THE NO LOAD POWER IS 80W. NEGLECT WINDING RESISTANCE + LEAKAGE RESISTANCE.

CALCULATE:

- CORE LOSS CURRENT, I_c
- MAGNETIZING CURRENT, I_m
- PEAK VALUE OF CORE FLUX, ϕ_{max}
- R_c, X_m.

* remember these are magnitudes of phasors.



$V_{oc} = 120V$

$I_{oc} = 1.6A$

$P_{oc} = 80W$

$R_c = \frac{V_{oc}^2}{P_{oc}} = 180\Omega$

$\Rightarrow I_c = \frac{V_{oc}}{R_c} = \frac{120}{180} = 0.667A$

$\Rightarrow I_m = \sqrt{(1.6)^2 - (0.667)^2} = 1.45A$

$\Rightarrow X_m = \frac{V_{oc}}{I_m} = \frac{120}{1.45} = 82.8\Omega$

$Z_L = j\omega L$, $\omega = 2\pi f$

$\Rightarrow X_m = 2\pi f L_m = 2\pi f \frac{N\phi_{max}}{I_m} \Rightarrow \phi_{max} = \frac{X_m I_m}{2\pi f N} = \frac{(82.8)(1.45)}{2\pi(60)(500)} =$

$\therefore$ $\boxed{\begin{aligned} I_c &= 0.667A \\ I_m &= 1.45A \\ \phi_{max} &= 703\,\mu Wb \\ R_c &= 180\Omega \\ X_m &= 82.8\Omega \end{aligned}}$

$\phi_{max} = \frac{E_{rms}}{4.44Nf}$

(2) 1ϕ, 10kVA, 2400/120V, 60Hz, TRANSFORMER HAS THE FOLLOWING CIRCUIT PARAMETERS:

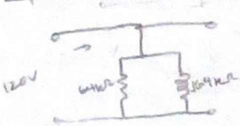
$Z_{eq,H} = 5 + j25\Omega$ → turns ratio $a = \frac{2400}{120} = 20$

$R_{c,H} = 64k\Omega$

$X_{m,H} = 64k\Omega$

DETERMINE: NO-LOAD TEST RESULTS (V_{oc}, I_{oc}, P_{oc}) + SHORT-CKT TEST RESULTS (V_{sc}, I_{sc}, P_{sc}).

NOLOAD → LOW-SIDE



$V_{oc,L} = 120V$ (rated) → $P_{oc} = \frac{120^2}{160} = 90W$

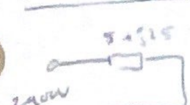
$R_{c,L} = \frac{1}{a^2} R_{c,H} = \frac{1}{20^2}(64k) = 160\Omega$

$X_{m,L} = \frac{1}{20^2}(64k) = 160\Omega$

$Q_{oc} = \frac{120^2}{160} = 90VAR \rightarrow I_{m,L} = \sqrt{\frac{90}{160}} = 0.75A$, $I_{oc} = \sqrt{0.75^2 + 0.75^2} = 1.06A$

$\Rightarrow$ $\boxed{\begin{aligned} V_{oc} &= 120V \\ I_{oc} &= 1.06A \\ P_{oc} &= 90W \end{aligned}}$

SHORT-CKT



$\Rightarrow I_{sc,H} = \frac{S_{rated}}{V_{sc}} = \frac{10k}{2400} = 4.17A$

$R_{eq} = 5\Omega = Re\{Z_{eq}\} \Rightarrow P_{sc} = I^2R = (4.17)^2(5) = 86.9W$

$|Z_{eq}| = \sqrt{5^2 + 25^2} = 25.5\Omega$

Voltage needs full impedance → $\Rightarrow V_{sc} = I_{sc}Z_{eq} = (4.17)(25.5) = 106.3V$

$\Rightarrow$ $\boxed{\begin{aligned} V_{sc} &= 106.3V \\ I_{sc} &= 4.17A \\ P_{sc} &= 86.9W \end{aligned}}$

(3) 1ϕ, 1200kVA, 240/120V, 60Hz ~~Pxxx~~ TRANSFORMER HAS A NO-LOAD LOSS OF 3.2kW @ V_{rated} AND A COPPER LOSS OF 9.5kW @ I_{rated}. DETERMINE EFFICIENCY FOR THE FOLLOWING LOAD CONDITIONS.

- 1200kVA @ pf = 1.0
- 1200kVA @ pf = 0.9
- 1200kVA @ pf = 0.0

$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{cu} + P_{core}}$$

$$P_{cu} = I_1^2 R_1 + I_2^2 R_2 = I_1^2 R_{eq_1} = I_2^2 R_{eq_2}$$

$$P_{out} = V_2 I_2 \cos\theta_2$$

$$\eta = \frac{V_2 I_2 \cos\theta_2}{V_2 I_2 \cos\theta_2 + P_c + I_2^2 R_{eq_2}}$$

$\boxed{\text{PRELIMINARY INFO}}$

$S_{rated} = 1200kVA$

$V_{rated,H} = 240V$

$V_{rated,L} = 120V$

derived

$I_{rated,H} = 5kA$

$I_{rated,L} = 10kA$

$P_{core} = 3.2kW$ by definition

$P_{cu} = 9.5kW$ by definition

When pf = 1, then $P_c = P_{cu}$ $\therefore$ $P_c = P_{cu} = 3.2kW$

$$\Rightarrow P_{out} = |V_2||I_2|\cos\theta_2 = |S_{rated}|(1) = 1200kW$$

$$\Rightarrow \eta_{pf=1} = \frac{1200kW}{1200kW + 3.2kW + 7.5kW} = 0.9895 \quad \therefore \quad \boxed{\eta|_{pf=1} = 98.95\%}$$

When pf = 0.9

$$\Rightarrow P_{out} = |S_{rated}|\cos\theta_2 = (1200kVA)(0.9) = 1080kW$$

$$\Rightarrow \eta|_{pf=0.9} = \frac{1080k}{1080k + 3.2k + 7.5k} = 0.9884 \quad \therefore \quad \boxed{\eta|_{pf=0.9} = 98.84\%}$$

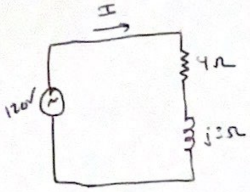
When pf = 0.0

$$\Rightarrow P_{out} = |S_{rated}|\cos\theta_2 = (1200kVA)(0) = 0,$$

$$\Rightarrow \eta|_{pf=0} = \frac{0}{0 + 3.2k + 9.5k} = 0.0 \quad \therefore \quad \boxed{\eta|_{pf=0} = 0.0\%}$$

PROBLEM 4

FIND ACTIVE, REACTIVE, & APPARENT POWER CONSUMPTION OF THE LOAD (& pf). DRAW ITS POWER TRIANGLE.



CURRENT

$$I = \frac{V}{Z} = \frac{120}{4+j3} = 24\angle -36.9^\circ A \quad \therefore |I| = 24A$$

ACTIVE

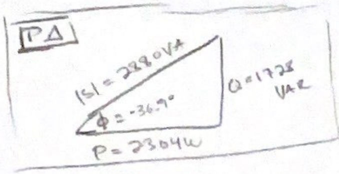
$$P = |I|^2 R = (24)^2(4) = \boxed{2304W}$$

REACTIVE

$$Q = |I|^2 X = (24)^2(3) = \boxed{1728 \text{ VAR}}$$

APPARENT

$$|S| = \sqrt{P^2 + Q^2} = \sqrt{2304^2 + 1728^2} = \boxed{2880VA} \Rightarrow pf = \frac{P}{S} = \frac{2304}{2880} = 0.8 \rightarrow \boxed{pf = 0.8 \text{ lag}}$$

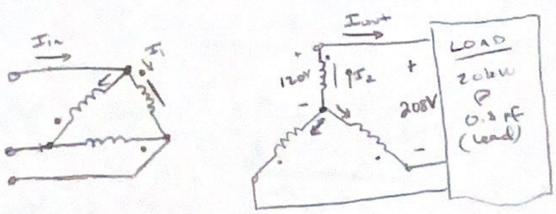


PROBLEM 5

THREE 1ϕ, 10kVA, 460/120V XFs FORM A 3ϕ 460/208V XF. ZEQ FOR EACH XF ON THE HIGH SIDE IS 1.0+j2.0Ω. THE 3ϕ XF ~~SUPPLY~~ SERVES A 20kW LOAD @ 0.8 pf leading.

SCHEMATIC

SINCE PRIMARY VOLTAGE FROM 1ϕ ↦ 3ϕ IS THE SAME AND THE SECONDARY VOLTAGE FROM 1ϕ ↦ 3ϕ INCREASES, IT IS A Δ-Y CONFIG.



WINDING CURRENT

$$\underline{S_{LOAD}} = \frac{P_{LOAD}}{pf} = \frac{20kW}{0.8} = \frac{20kW}{4/5} = \underline{25kVA}$$

THE SECONDARY COIL CURRENT SERVES THE LOAD $\therefore I_2 = I_{out}$.

FOR 3ϕ SYSTEMS $\tilde{S} = \sqrt{3}\tilde{V}\tilde{I}$. $\therefore |I| = \frac{|S|}{\sqrt{3}V} = \frac{25k}{\sqrt{3}\,208} = 69.4A \quad \therefore \boxed{I_2 = 69.4A}$

FOR THE PRIMARY COIL,

$$I_1 = \frac{1}{a} I_2 = \left(\frac{460}{120}\right)^{-1}(69.4) = 18.1A \rightarrow \boxed{I_1 = 18.1A}$$

CONTINUED

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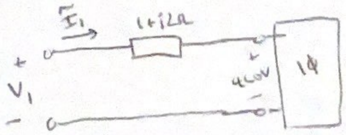
PRIMARY VOLTAGE

TO FIND THE PRIMARY VOLTAGE, WE HAVE TO ANALYZE A SINGLE ϕ ON THE HIGH SIDE, WHERE $Z_{EQ,H} = 1+j2\Omega$.



FIRST, WE NEED THE PHASE ON THE CURRENT

$\rightarrow \phi = \cos^{-1}(0.8) = 36.9°$, but $\phi < 0$ b/c LEADING.

$\phi = \phi_V - \phi_I = -36.9°$ $\nearrow$ $\tilde{I}_1 = 18.1\angle 36.9° A$

$\phi_V = 0 \Rightarrow \phi_I = +36.9°$

KVL

$-V_1 + \tilde{I}_1(1+j2) + 460 = 0 \Rightarrow V_1 = (18.1\angle 36.9)(1+j2) + 460 = 454.5\angle 5.03° V$

$\therefore \boxed{|V_1| = 454.5V}$ ← b/c of leading pf, we don't need to drive the XF as hard to see 460V across the primary wdg.

VOLTAGE REGULATION

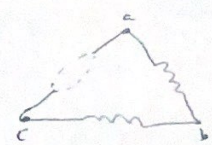
$$V.R. = \frac{454.5 - 460}{460} \times 100\% = \boxed{-1.196\%}$$

PROBLEM 6

TWO 250kVA, 230/460V TRANSFORMERS ARE CONNECTED IN AN OPEN DELTA TO SUPPLY A BALANCED 3φ LOAD @ 460V w/ pf = 0.8 lagging.

BY DEF, OPEN Δ CAN ONLY SUPPLY 58% OF WHAT A COMPLETE Δ-Δ CAN.

MAX SECONDARY LINE CURRENT



FOR ONE XF, $S_{rated} = 250kA$ + $V_{SEC} = 460V$.

$$\therefore \quad I_{2,max} = \frac{250k}{460} = \boxed{543.5A}$$

REAL POWER DELIVERED BY EACH XF

$P_{ab} = \underbrace{VI}_{S}\cos(30° + \phi)$ $\nearrow$ $\phi = \cos^{-1}(0.8) = +36.9°$

$P_{bc} = VI\cos(30° - \phi)$

$\rightarrow P_{ab} = (250k)\cos(30° + 36.9°) = \boxed{98.1kW = P_{ab}}$

$\rightarrow P_{bc} = (250k)\cos(30° - 36.9°) = \boxed{248.2kW = P_{bc}}$

PRIMARY LINE CURRENTS

CAN FIND I_1 USING TURNS RATIO

$$a = \frac{230}{460} = \frac{1}{2}$$

$\therefore \quad I_1 = \left(\frac{1}{a}\right) I_2 = 2(543.5)$

$\Rightarrow \boxed{I_1 = 1.09kA}$

%↑ OF REAL POWER w/ COMPLETED Δ

$S_{3\phi} = 3VI = 3S_{1\phi} = 3(250k) = 750kVA$

$P = S \cdot pf \Rightarrow P_{3\phi} = S_{3\phi}pf = (750k)(0.8) = 600kW = P_{3\phi}$

$$\Delta\% = \frac{P_{new} - P_{old}}{P_{old}} \times 100\% = \frac{600k - \overbrace{(98.1k + 248.2k)}^{\text{old total active}}}{(98.1k + 248.2k)} \times 100\% = \boxed{73.3\% \text{ increase}}$$