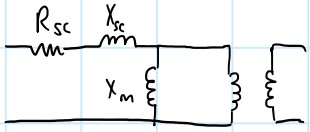
ASN8

Monday, April 8, 2024 9:04 PM

1) 210 MVA (S_{rated}) 230 kV / 115 kV (V_{HVS} / V_{LVS}) Δ-Δ



$R_{sc} = 0.05_{pu}$ $X_{sc} = 0.38_{pu}$

$R_c = 180_{pu}$ $X_m = 30_{pu}$

(a) 168 MVA (S_{supp}) supplied, pf = 0.6 lagging — V_{reg} = ?

(b) Single-phase: R_{sc}, X_{sc}, R_c, X_m = ? on LVS

(a) $I_{LVS} = \frac{S_{supp}}{V_{LVS}} = 1460.8696$ A

$I_{LVSR} = \frac{S_{rated}}{V_{LVS}} = 1826.0870$ A base (for p.u.)

$I_{LVSPU} = \frac{I_{LVS}}{I_{LVSR}} = 0.8$

$\theta = a\cos(pf) = 0.9273$

$I_{LVSPh} = \text{CONJ}(I_{LVSPU}(\cos\theta + j\sin\theta)) = 0.48 - j0.64$

$V_{ph} = 1 + I_{LVSPh}(R_{sc} + jX_{sc}) = 1.2672 + j0.1504$

$V_{reg} = |V_{ph}| - 1 = 0.2761 \rightarrow 27.6094\%$

(b) $Z_b = \frac{V_{LVS}^2}{S_{rated}} = 62.9762\ \Omega$

$R_{sc1} = 3R_{sc}Z_b = 9.4464\ \Omega$

$X_{sc1} = 3X_{sc}Z_b = 71.7929\ \Omega$

$R_C = 3R_cZ_b = 34007.1429\ \Omega$

$X_m = 3X_mZ_b = 5667.8571\ \Omega$

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2) 170 kVA 24,000/277 V LVS Δ - HVS Y

LVS OCT: $V_{LOC} = 277\sqrt{3}$ V, $I_{LOC} = 4.1$ A, $P_{3\phi OC} = 1250$ W

HVS SCT: $V_{LSC} = 1600$ V, $I_{LSC} = 2$ A, $P_{3\phi SC} = 1500$ W

HVS
SCT: $V_{LSC} = 1600\ V$, $I_{LSC} = 2A$, $P_{3\phi SC} = 1500W$

(a) p.u. equivalent circuit

pf = 0.8:

(b) $V_{reg} = ?$

(c) $\eta = ?$

(a) $I_{PHSC} = \frac{I_{LSC}}{\sqrt{3}} = 1.1547\ A$

$Z_{hvsb} = \frac{V_{HVS}^2}{S_{rated}} = 3388.2353$

$\theta_1 = \text{acos}\left(\frac{P_{3\phi sc}}{3\,V_{LSC}\,I_{PHSC}}\right) = 1.2967$

$Z_{eq} = \frac{V_{LSC}}{I_{PHSC}} = 1385.6406\ \Omega$

$R_{SC} = Z_{eq}\cos\theta_1 = 375$

$X_{SC} = Z_{eq}\sin\theta_1 = 1333.9321$

$R_{SCpu} = \frac{R_{SC}}{Z_{hvsb}} = 0.1107\ p.u.$

$X_{SCpu} = \frac{X_{SC}}{Z_{hvsb}} = 0.3937\ p.u.$

$V_{phoc} = \frac{V_{LOC}}{\sqrt{3}} = 277\ V$

$Z_{LVSb} = \frac{V_{LVS}^2}{S_{rated}} = 0.4513\ \Omega$

$\theta_2 = \text{acos}\left(\frac{P_{3\phi oc}}{3\,V_{phoc}\,I_{LOC}}\right) = 1.1951$

$I_{phoc} = I_{LOC}(\cos\theta_2 + j\sin\theta_2) = 1.5042 + j3.8141\ A$

$R_C = \frac{V_{phoc}}{RE(I_{phoc})} = 184.1496\ \Omega$

$X_m = \frac{V_{phoc}}{Im(I_{phoc})} = 72.6253\ \Omega$

$R_{Cpu} = \frac{R_C}{Z_{LVSb}} = 408\ p.u.$

$X_{mpu} = \frac{X_m}{Z_{LVSb}} = 160.908\ p.u.$

(b) $\theta_3 = \text{acos}(pf) = 0.6435$

$I_{Lpu} = \text{CONJ}(\cos\theta_3 + j\sin\theta_3) = 0.8 - j0.6$

$V_{phpu} = 1 + I_{Lpu}(R_{SCpu} + jX_{SCpu}) = 1.3248 + j0.2485$

$$V_{phpu} = 1 + I_{Lpu}(R_{scpu} + jX_{scpu}) = 1.3248 + j0.2485$$

$$V_{reg} = |V_{phpu}| - 1 = 0.3479 \rightarrow \underline{34.7874\%}$$

(c) $P_{outpu} = \overset{(1)}{V_s}\,\overset{(1)}{I_s}\; pf = 0.8$ p.u.

$P_{cupu} = \overset{(1)}{I_s^2} R_{scpu} = 0.1107$ p.u.

$P_{corepu} = \dfrac{\overset{(1)}{V_p^2}}{R_{cpu}} = 2.4510E\text{-}3$ p.u.

$P_{inpu} = P_{outpu} + P_{cupu} + P_{corepu} = 0.9131$ p.u.

$eff = \dfrac{P_{outpu}}{P_{inpu}} = 0.8761 \rightarrow \underline{87.6109\%}$

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3) $\overset{V_L}{9.2\text{kV}} \rightarrow \overset{V_H}{10.7\text{ kV}}$, $\overset{S_{min}}{1.4\text{MVA}}$

a) $N_{common} : N_{series} = ?$

b) Apparent power

c) Auto transformer → transformer, $V_{H2}, V_{L2} = ?$

a) $\dfrac{N_{common}}{N_{series}} = \dfrac{V_L}{V_H - V_L} = \underline{6.13}$ = ratio

b) $P_{winding} = \dfrac{S_{min}}{3(1+\text{ratio})} = 65420.5607$ VA

$= \underline{65.42\text{ kVA}}$

c) $P_{1\phi\,transformer} = P_{winding} = \underline{65.42\text{ kVA}}$

$V_{Hr} = \dfrac{V_L}{\sqrt{3}} = 5311.6225\text{ V} = \underline{5.31\text{ kV}}$

$V_{Lr} = \dfrac{V_H}{\sqrt{3}} - V_{Hr} = 866.0254\text{V} = \underline{0.87\text{ kV}}$

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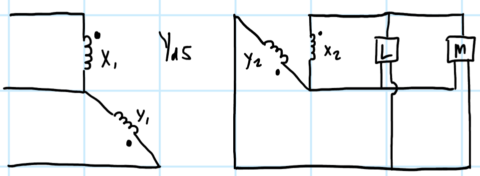
4)



V_n 10kV distribution line

V_f 305V feeder supplies 130kW @ 0.75 lagging (P_1, $pf1$)

150kW @ 0.9 lagging (P_2, $pf2$)

$$V_{x1} = \frac{V_n}{\sqrt{3}} = 5773.5027\,V = 5.7735\,kV$$

$$V_{y1} = V_{x1} = 5773.5027\,V = 5.7735\,kV$$

$$V_{x2} = V_f = 305V$$

$$V_{y2} = V_{x2} = 305V$$

$$S_1 = \frac{P_1}{pf1} = 173333.3333$$

$$S_2 = \frac{P_2}{pf2} = 166666.6667$$

$$\theta_1 = \text{acos}(pf1) = 0.7227$$

$$\theta_2 = \text{acos}(pf2) = 0.4510$$

$$Q_1 = S_1 \sin\theta_1 = 114649.2235$$

$$Q_2 = S_2 \sin\theta_2 = 72648.3157$$

$$P_{TOT} = P_1 + P_2 = 280000$$

$$\theta_3 = \text{atan}\left(\frac{Q_1 + Q_2}{P_{TOT}}\right) = 0.5896$$

$$pf_{total} = \cos\theta_3 = 0.8312$$

$$I_{x1} = \frac{P_{TOT}}{\sqrt{3}\,V_{x1}\,pf_{total}} = 33.6868\,A$$

$$I_{x2} = \frac{P_{TOT}}{\sqrt{3}\,V_{x2}\,pf_{tot}} = 637.6757A$$

$$I_{y1} = I_{x1} = 33.6868A$$

$$I_{y2} = I_{x2} = 637.6757A$$

$$P_x = I_{x2} V_f \cos\left(\tfrac{30\pi}{180} + \theta_3\right) = 85931.8577\,W \rightarrow 85.9319\,kw$$

$$Q_x = I_{x2} V_f \sin\left(\tfrac{30\pi}{180} + \theta_3\right) = 174477.8073\,VA_r \rightarrow 174.4778\,kVA_r$$

$$P_y = I_{x2} V_f \cos\left(-\tfrac{30\pi}{180} + \theta_3\right) = 194068.1423\,W \rightarrow 194.0681\,kW$$

$$Q_y = I_{x2} V_f \sin\left(-\tfrac{30\pi}{180} + \theta_3\right) = 12819.7319\,VA_r \rightarrow 12.8197\,kVA_r$$

5. S_r = 38 kVA, V_H / V_L = 20000/320 V, D_y

OCT: $V_{Line} = 554.256\,V$, $I_L = 3.12934\,A$, $P_{3\phi} = 950\,W$

SCT: $V_{Line} = 7071.07\,V$, $I_L = 3.2909\,A$, $P_{3\phi} = 5700\,W$

a) equivalent circuit (LVS)

b) Regulation @ 0.75 lagging

c) η = ?

a) $V_{poc} = \frac{V_{Loc}}{\sqrt{3}} = 319.9999\,V$

$\theta_1 = \text{acos}\left(\frac{P_{3\phi oc}}{3 V_{poc} I_{Loc}}\right) = 1.2490$

$I_{poc} = \frac{I_{Loc}}{\cos\theta_1 + j\sin\theta_1} = 0.1896 - j\,2.9688\,A$

$R_c = \frac{V_{poc}}{RE(I_{poc})} = 323.3681\,\Omega$

$X_m = \frac{V_{poc}}{IM(I_{poc})} = -107.7893\,\Omega \rightarrow 107.7893\,\Omega$

$I_{psc} = \frac{I_{Lsc}}{\sqrt{3}} = 1.9000\,A$

$R_{scp} = \frac{\frac{P_{3\phi sc}}{3}}{I_{psc}^2} = 526.3147\,\Omega$

$R_{sc} = R_{scp}\left(\frac{V_L}{V_H}\right)^2 = 0.1347\,\Omega \rightarrow 134.7366\,m\Omega$

$Z_{eq} = \frac{V_{Lsc}}{I_{psc}} = 3721.6119\,\Omega$

$X_{scp} = \sqrt{Z_{eq}^2 - R_{scp}^2} = 3684.2079\,\Omega$

$X_{sc} = X_{scp}\left(\frac{V_L}{V_H}\right)^2 = 0.9432\,\Omega \rightarrow 943.1572\,m\Omega$

b) $\theta_3 = \text{acos}(pf) = 0.7227$

$I_{Lpu} = CONJ(\cos\theta_3 + j\sin\theta_3) = 0.75 - j\,0.6614\,A$

$Z_{h\,base} = \frac{V_H^2}{S_r} = 10526.3158\,\Omega$

$\theta_2 = \text{acos}\left(\frac{P_{3\phi sc}}{3 V_{Lsc} I_{psc}}\right) = 1.4289$

$R_{SCH} = Z_{eq} \cos\theta_2 = 526.3147\ \Omega$

$R_{scpu} = \frac{R_{SCH}}{Z_{hbase}} = 5.0000$ p.u.

$X_{SCH} = Z_{eq} \sin\theta_2 = 3684.2079\ \Omega$

$X_{scpu} = \frac{X_{SCH}}{Z_{hbase}} = 0.3500$ p.u.

$V_{ppu} = 1 + I_{1pu}(R_{scpu} + jX_{scpu}) = 1.2690 + j\,0.2294$ p.u.

$V_{reg} = |V_{ppu}| - 1 = 0.2896 \rightarrow 28.9576\%$

c) V_s I_s

$P_{opu} = 1 \times 1 \times pf = 0.75$

I_s^2

$P_{cupu} = 1^2 \times R_{scpu} = 5.0000\ E{-}2$

$Z_{lbase} = \frac{V_L^2}{S_r} = 2.6947$

$R_{cpu} = \frac{R_c}{Z_{lbase}} = 119.9999$

V_p^2

$P_{corepu} = \frac{1^2}{R_{cpu}} = 8.3333\ E{-}3$

$P_{ipu} = P_{opu} + P_{cupu} + P_{corepu} = 0.8083$

$\eta = \frac{P_{opu}}{P_{ipu}} = 0.9278 \rightarrow 92.78\%$

V_{3L} S_{3L} PF (AF)

6) 230V, 32kVA, 0.9 lagging Load

S_F V_{FH} V_{FL} f

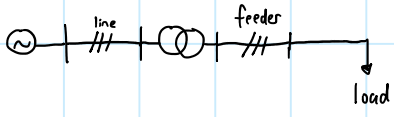
3x 16kVA, 1330/230V, 60 Hz transformer, Yd5

$Z_f = 0.003 + j\,0.015\ \Omega/\text{phase}$

$Z_{LINE} = 1.1 + j\,4.6\ \Omega/\text{phase}$

$R_{SC} = 0.1$

$X_{SC} = 0.28$



a) $V_{LOAD} = 230V \rightarrow V_{supply} = ?$

b) $V_{reg} = ?$

a) $S_{BF} = 3S_{LF} = 48000$

$Z_{BF} = \frac{V_{FL}^2}{S_{BF}} = 1.1021$

$Z_f =$

$$Z_{BF} = \frac{V_{FL}}{S_{BF}} = 1.1021$$

$$Z_{FPU} = \frac{Z_f}{Z_{BF}} = 2.7221E-3 + j\,1.3611E-2$$

$$Z_{BT} = \frac{V_{FL}^2}{S_F} = 3.3025$$

$$Z_{TPU} = \frac{Z_{SC}}{Z_{BT}} = 3.0246E-2 + j\,8.4688E-2$$

$$S_{BL} = 3S_F = 48000$$

$$V_{BL} = V_{FH}\sqrt{3} = 2303.6276$$

$$Z_{BL} = \frac{V_{BL}^2}{S_{BL}} = 110.5563$$

$$Z_{LPU} = \frac{Z_L}{Z_{BL}} = 9.9497E-3 + j\,4.1608$$

$$\theta = \text{acos}(pf) = 0.4510$$

$$S_{LPU} = \frac{S_{3L}}{3S_F}(\cos\theta + j\sin\theta) = 0.6 + j\,0.2906$$

$$I_{LPU} = \text{conj}(S_{LPU}) = 0.6 - j\,0.2906$$

$$V_{SPU} = 1 + I_{LPU}(Z_{FPU} + Z_{TPU} + Z_{LPU}) = 1.0664 + j\,7.1472$$

$$V_{SS} = |V_{SPU}|\,V_{BL} = 2462.1144\ V$$

$$V_{REG} = \frac{|V_{SS}|}{V_{BL}} - 1 = 6.8799E-2 \rightarrow 6.8799\%$$

V_{1H} V_{1L}

7) 55 kVA, 2300/230 V, 60 Hz

V_{2H} V_{2L}

4000/230 V

$Z_{eq} = 0.04 + j\,0.08$

S_{3F} V_S pf

145 kVA, 230 V, 0.79 lagging

b) $I_{LS} = \frac{S_{3F}}{3V_S} = 210.1449$ A

$a = \frac{V_{1H}}{V_{1L}} = 10$

a) $I_{LT} = \frac{I_{LS}}{a} = 21.0145$ A

c) $\theta = a\cos(pf) = 0.6600$

$Z_H = Z_{eq}\, a^2 = 4 + j8$

$V = V_{1H} + I_{LT}\, \text{conj}(\cos\theta + j\sin\theta)\, Z_H = 2469.4784 + j\,81.2751$

$V_{line} = \sqrt{3}|V| = 4279.5787$ V

d) $V_{reg} = \frac{|V| - V_{1H}}{V_{1H}} = 0.07417 \rightarrow 7.4268\,\%$