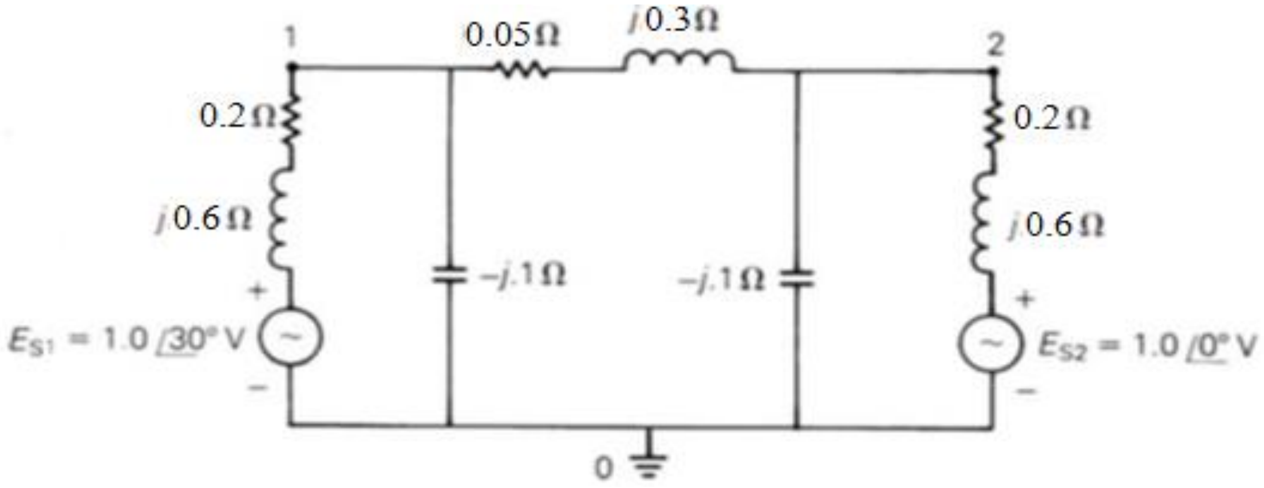
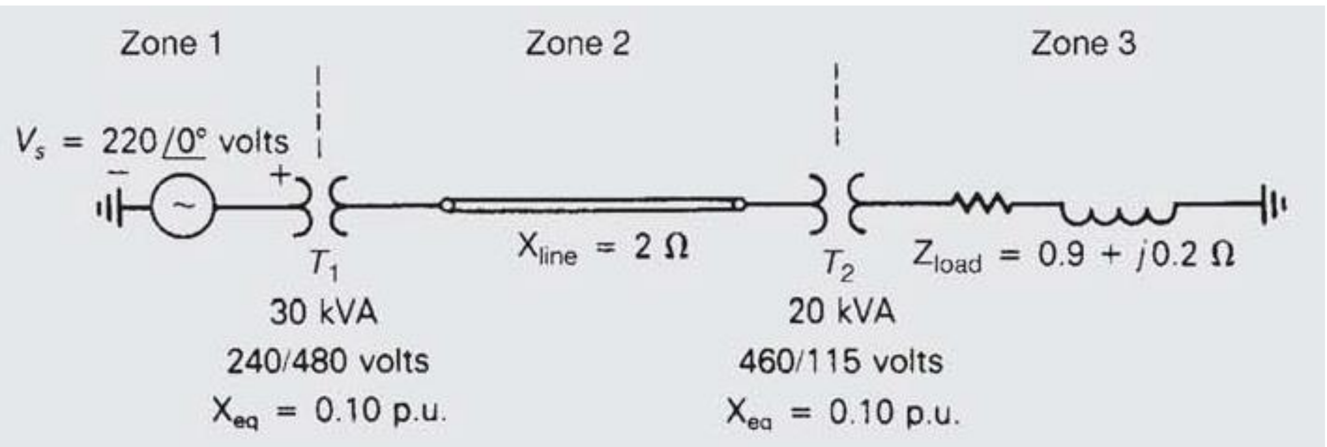
Çankaya University
Electrical & Electronics Engineering Department
EE 465 Power Systems
Midterm Exam 1 **90 mins**

Q1-(35) A three-phase line with an impedance of (0.2+j1) Ω/phase feeds three balanced three-phase loads connected in parallel.
Load 1: Is an inductive load with 150 kW and 120 kvar
Load 2: Delta connected capacitive load with an impedance of (150 –j48) Ω/phase,
Load 3: Is 120 kVA at 0.6 PF leading
If the line-to-neutral voltage at the load end of the line is 2000 V (rms), **determine the magnitude of the line-to-line voltage at the source end of the line.**

Q2-(30) For the circuit shown below, convert the voltage sources to equivalent current sources and write nodal equation in matrix format using bus 0 as the reference bus. Do not solve the equation.



Q3-(35) Three zones of a single-phase circuit are identified in the figure shown below. The zones are connected by transformer T_1 and T_2, whose ratings are also shown. Using base values of 30 kVA and 240 V in the zone 1, draw the per-unit circuit and determine the per-unit impedances and the per-unit source voltage. Then calculate the load current both in per-unit and in amperes. Transformer winding resistances and shunt admittance branches are neglected.



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Solution of EE 465 Midterm Exam1 **15-11-2018**

1-

On a per-phase basis $\overline{S}_1 = \frac{1}{3}(150 + j120) = (50 + j40)\,\text{kVA}$

$$\therefore \overline{I}_1 = \frac{(50 - j40)10^3}{2000} = (25 - j20)\,\text{A}$$

Note: PF Lagging

Load 2: Convert Δ into an equivalent Y

$$\overline{Z}_{2Y} = \frac{1}{3}(150 - j48) = (50 - j16)\,\Omega$$

$$\therefore \overline{I}_2 = \frac{2000\angle 0^\circ}{50 - j16} = 38.1\angle 17.74^\circ$$

$$= (36.29 + j11.61)\,\text{A}$$

Note: PF Leading

$$\overline{S}_3 \text{ per phase} = \frac{1}{3}\left[(120 \times 0.6) - j120\sin\left(\cos^{-1} 0.6\right)\right] = (24 - j32)\,\text{kVA}$$

$$\therefore \overline{I}_3 = \frac{(24 + j32)10^3}{2000} = (12 + j16)\,\text{A}$$

Note: PF Leading

Voltage at the sending end: $\overline{V}_{AN} = 2000\angle 0^\circ + (73.29 + j7.61)(0.2 + j1.0)$

$$= 2007.05 + j74.81 = 2008.44\angle 2.13^\circ\,\text{V}$$

Line-to-line voltage magnitude at the sending end $= \sqrt{3}(2008.44) = 3478.62\,\text{V}$

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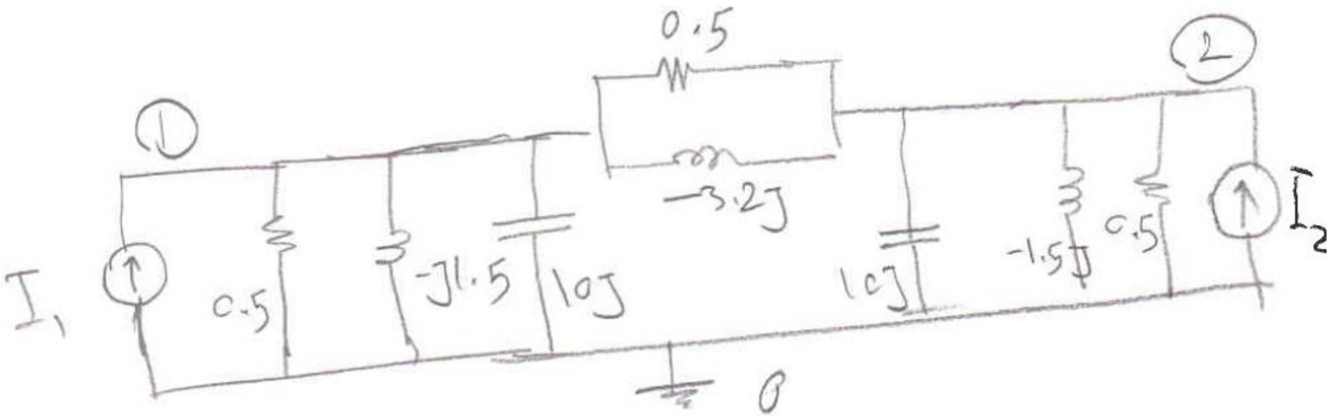
2-



$$Y_1 = \frac{1}{Z_1} = \frac{1}{0.2 + J0.6} = 0.5 - J1.5$$

$$Y_2 = \frac{1}{Z_2} = \frac{1}{0.05 + 0.3} = 0.5 - 3.2J$$

$$I_1 = \frac{1.0\angle 30}{0.2 + 0.6J} = 1.58\angle -41.56$$

$$I_2 = \frac{1.0\angle 0}{0.2 + 0.6J} = 1.58\angle -71.56$$

$$Y = \begin{vmatrix} 1.04 + J\,5.26 & -0.54 + J3.24 \\ -0.54 + J3.24 & 1.04 + J\,5.26 \end{vmatrix}$$

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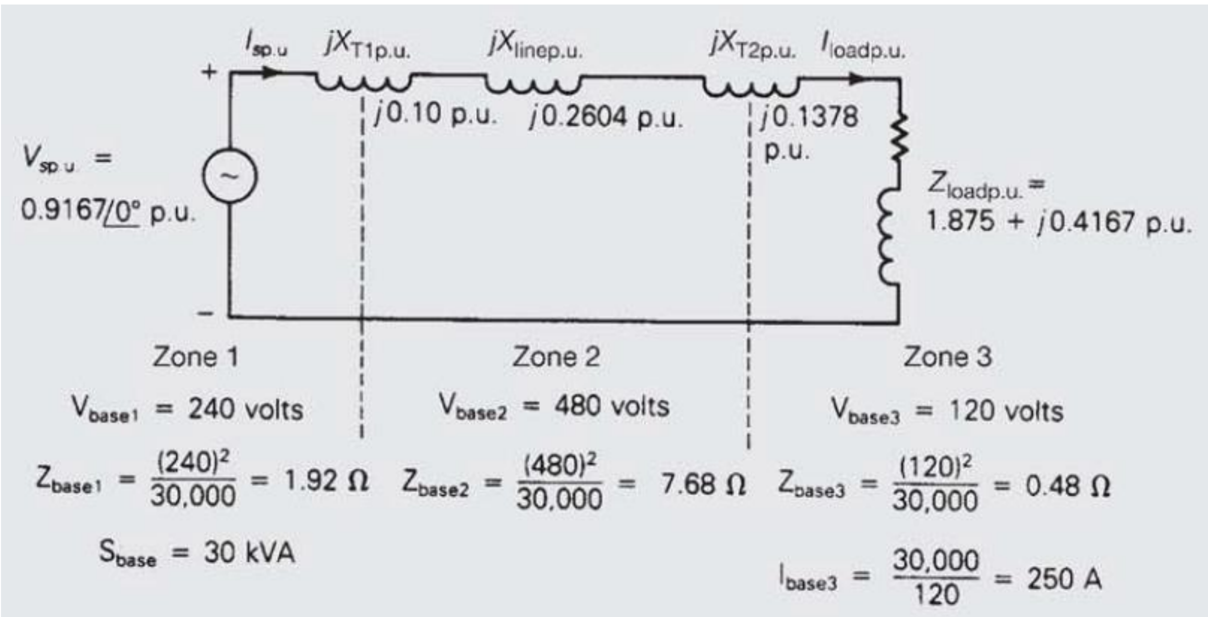
$$\begin{vmatrix} 1.04+J\,5.26 & -0.54+J3.24 \\ -0.54+J3.24 & 1.04+J\,5.26 \end{vmatrix} \begin{vmatrix} V_1 \\ V_2 \end{vmatrix} = \begin{vmatrix} 1.58\angle -41.56 \\ 1.58\angle -71.56 \end{vmatrix}$$

3-



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First the base values in each zone are determined. $S_{base} = 30$ kVA is the same for the entire network. Also, $V_{base1} = 240$ volts, as specified for zone 1. When moving across a transformer, the voltage base is changed in proportion to the transformer voltage ratings. Thus,

$$V_{base2} = \left(\frac{480}{240}\right)(240) = 480 \quad \text{volts}$$

and

$$V_{base3} = \left(\frac{115}{460}\right)(480) = 120 \quad \text{volts}$$

The base impedances in zones 2 and 3 are

$$Z_{base2} = \frac{V_{base2}^2}{S_{base}} = \frac{480^2}{30{,}000} = 7.86 \quad \Omega$$

and

$$Z_{base3} = \frac{V_{base3}^2}{S_{base}} = \frac{120^2}{30{,}000} = 0.48 \quad \Omega$$

and the base current in zone 3 is

$$I_{base3} = \frac{S_{base}}{V_{base3}} = \frac{30{,}000}{120} = 250 \quad \text{A}$$

Next, the per-unit circuit impedances are calculated using the system base values. Since $S_{base} = 30$ kVA is the same as the kVA rating of transformer T_1, and $V_{base1} =$ 240 volts is the same as the voltage rating of the zone 1 side of transformer T_1, the per-unit leakage reactance of T_1 is the same as its nameplate value, $X_{T1p.u.} = 0.1$ per unit. However, the per-unit leakage reactance of transformer T_2 must be converted from its nameplate rating to the system base. Using (3.3.11) and $V_{base2} = 480$ volts,

$$X_{T2p.u.} = (0.10)\left(\frac{460}{480}\right)^2\left(\frac{30{,}000}{20{,}000}\right) = 0.1378 \text{ per unit}$$

Alternatively, using $V_{base3} = 120$ volts,

$$X_{T2p.u.} = (0.10)\left(\frac{115}{120}\right)^2\left(\frac{30{,}000}{20{,}000}\right) = 0.1378 \text{ per unit}$$

which gives the same result. The line, which is located in zone 2, has a per-unit reactance

$$X_{line p.u.} = \frac{X_{line}}{Z_{base2}} = \frac{2}{7.68} = 0.2604 \quad \text{per unit}$$

and the load, which is located in zone 3, has a per-unit impedance

$$Z_{load p.u.} = \frac{Z_{load}}{Z_{base3}} = \frac{0.9 + j0.2}{0.48} = 1.875 + j0.4167 \quad \text{per unit}$$

The per-unit circuit is shown in Figure 3.10(b), where the base values for each zone, per-unit impedances, and the per-unit source voltage are shown. The per-unit load current is then easily calculated from Figure 3.10(b) as follows:

$$I_{load p.u.} = I_{s p.u.} = \frac{V_{s p.u.}}{j(X_{T1 p.u.} + X_{line p.u.} + X_{T2 p.u.}) + Z_{load p.u.}}$$

$$= \frac{0.9167\angle 0^\circ}{j(0.10 + 0.2604 + 0.1378) + (1.875 + j0.4167)}$$

$$= \frac{0.9167\angle 0^\circ}{1.875 + j0.9149} = \frac{0.9167\angle 0^\circ}{2.086\angle 26.01^\circ}$$

$$= 0.4395\angle -26.01^\circ \quad \text{per unit}$$

The actual load current is

The actual load current is

$$I_{load} = (I_{load p.u.}) I_{base3} = (0.4395\angle -26.01^\circ)(250) = 109.9\angle -26.01^\circ \quad \text{A}$$

Note that the per-unit equivalent circuit of Figure 3.10(b) is relatively easy to analyze, since ideal transformer windings have been eliminated by proper selection of base values.

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