MID-TERM EXAM – Sample

1. QUESTION 1 (25 points)
   A single phase 600 V, 60 Hz feeder supplies 2 loads in parallel: (a) a heating load with a 10 Ω resistance; (b) a 70 kVA motor load, with a power factor of 0.70 (lagging). Compute the total current, power, reactive power and power factor. Draw the V-I vector diagram. A capacitor is connected in parallel with the loads to increase the power factor to 0.95. Compute the reactive power supplied by the capacitor and the value of the capacitor bank in μF.

QUESTION 1

$Vl := 600$

$R := 10$ $\quad Ir := \frac{600}{10}$ $\quad Pr := Vl \cdot Ir$ $\quad Ir = 60$ $\quad Pr = 3.6 \times 10^4$

$S := 70000$ $\quad pf := 0.70$ $\quad Pm := S \cdot pf$ $\quad \phi := acos(pf)$ $\quad Im := \frac{S}{Vl}$

$\phi \cdot \left(\frac{180}{\pi}\right) = 45.573$ $\quad Pm = 4.9 \times 10^4$ $\quad Im = 116.667$ $\quad Qm := S \cdot \sin(\phi)$ $\quad Qm = 4.999 \times 10^4$

$Irc := Ir$

$Imc := Im \cdot \cos(\phi) + Im \sin(\phi) \cdot i$ $\quad Imc = 81.667 + 83.317i$ $\quad a := \frac{180}{\pi}$

$Itc := Irc + Imc$ $\quad Itc = 141.667 + 83.317i$

$|Itc| = 164.351$ $\quad \left(\frac{180}{\pi}\right) \cdot arg(Itc) = 30.461$

$\cos(arg(Itc)) = 0.862$

$Pt := Pr + Pm$ $\quad Pt = 8.5 \times 10^4$

$Qt := Qm$ $\quad Qt = 4.999 \times 10^4$

$Stc := Pt + Qt \cdot i$ $\quad Stc = 8.5 \times 10^4 + 4.999i \times 10^4$ $\quad |Stc| = 9.861 \times 10^4$

$pft := \frac{Pt}{|Stc|}$ $\quad pft = 0.862$ $\quad a \cdot arg(Stc) = 30.461$

$pfc := 0.95$ $\quad a \cdot acos(pfc) = 18.195$

$Stcor := \frac{Pt}{pfc}$ $\quad Qtcor := Stcor \cdot \sin(acos(pfc))$

$Qtcor = 2.794 \times 10^4$ $\quad Qcap := Qt - Qtcor$ $\quad Qcap = 2.205 \times 10^4$

$Xc := Vl \cdot \frac{Vl}{Qcap}$ $\quad Xc = 16.325$

$Icc := \frac{Vl}{Xc \cdot i}$ $\quad Icc = -36.753i$

$Itcc := Itc + Icc$ $\quad Itcc = 141.667 + 46.564i$ $\quad a \cdot arg(Itcc) = 18.195$

$C := \frac{1}{(60 \cdot 2 \cdot \pi \cdot Xc)}$ $\quad C = 1.625 \times 10^{-4}$

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2. QUESTION 3 (25 points)

Three identical single-phase 69 kV/6.9 kV, 60 Hz, 33 MVA distribution transformers, with a leakage reactance of 0.10 on the transformer base, are fed from the 69 kV bus. They supply two three phase 12 kV loads connected in parallel: a 60 MW, 0.8 power factor (lagging) load (assume a Y connection) and a capacitor bank of three elements (-*j*15 Ω) connected in Δ (hint: convert into Y). Compute: (a) total line current; (b) the total power and total reactive power drawn from the feeder; (c) the resulting power factor. Draw the single line pu circuit, using a 100 MVA, 12 kV base.

QUESTION 3 - Three-phase circuits

$Vline := 12000$

$Plphase := 60\cdot\frac{10^6}{3}$ $\quad pf := 0.8$ $\quad Vlphase := \frac{Vline}{\sqrt{3}}$ $\quad Vlphase = 6.928\times10^3$

$\phi := -acos(pf)$ $\quad a\cdot\phi = -36.87$ $\quad Slphase := \frac{Plphase}{pf}$ $\quad Slphase = 2.5\times10^7$

$Illine := \left(\frac{Slphase}{Vlphase}\right)\cdot(\cos(\phi) + i\cdot\sin(\phi))$ $\quad Illine = 2.887\times10^3 - 2.165i\times10^3$

$|Illine| = 3.608\times10^3$

$Icphase := \frac{Vlphase}{\left(-i\cdot\frac{15}{3}\right)}$ $\quad Icphase = 1.386i\times10^3$

$Icline := Icphase$

$Iline := Illine + Icline$ $\quad Iline = 2.887\times10^3 - 779.423i$

$|Iline| = 2.99\times10^3$ $\quad a\cdot arg(Iline) = -15.11$

$\cos(arg(Iline)) = 0.965$

$Pt := 3\cdot Slphase\cdot\cos(\phi)$ $\quad Pt = 6\times10^7$

$Qt := 3\cdot Slphase\cdot\sin(-\phi) - 3\cdot|Icline|\cdot Vlphase$ $\quad Qt = 1.62\times10^7$ $\quad a\cdot atan\left(\frac{Qt}{Pt}\right) = 15.11$

$Sbase := 100\cdot\frac{10^6}{3}$ $\quad Vbase := \frac{12000}{\sqrt{3}}$ $\quad Ibase := \frac{Sbase}{Vbase}$ $\quad Zbase := \frac{Vbase}{Ibase}$

$Zbase = 1.44$

Load $\quad p := 20\cdot\frac{10^6}{Sbase}$ $\quad p = 0.6$ $\quad pf = 0.8$

Capacitor $\quad xc := \frac{15}{3\cdot Zbase}$ $\quad xc = 3.472$

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3- **A 300 MVA, 20 kV three-phase generator has a subtransient reactance of 20%. The generator supplies a number of synchronous motors over 64-km transmission line having transformers at both ends, as shown in Fig. 1.11. The motors, all rated 13.2 kV, are represented by just two equivalent motors. Rated inputs to the motors are 200 MVA and 100 MVA for M1 and M2, respectively. For both motors X" = 20%. The three phase transformer T1 is rated 350 MVA, 230/20 kV with leakage reactance of 10%. Transformer T2 is composed of three single-phase transformers each rated 127/13.2 kV, 100 MVA with leakage reactance of 10%. Series reactance of the transmission line is 0.5 Ω/km. Draw the impedance diagram, with all impedances marked in per-unit. Select the generator rating as base in the generator circuit.**

Solution

Base MVA = 300

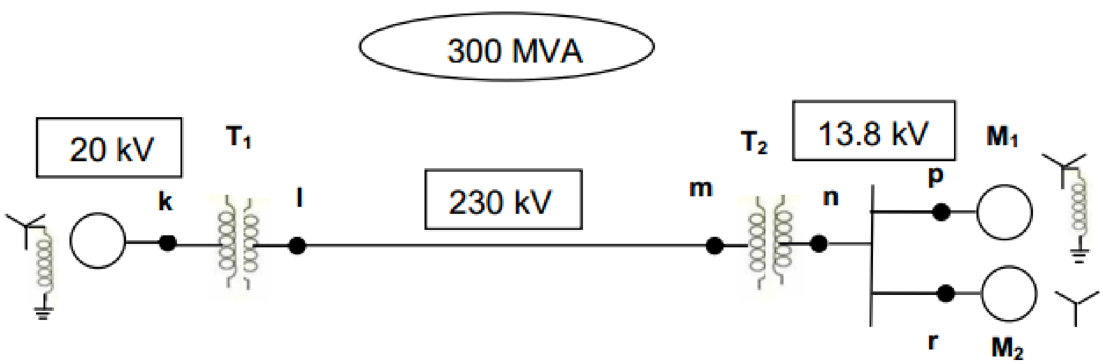
Base voltage at generator side = 20 kV

Base voltage in transmission line = 230 kV

Line to line voltages of transformer T_2 : $\sqrt{3}$ x 127 / 13.2 = 220 / 13.2 kV

Base voltage at motor side = 230 x $\frac{13.2}{220}$ = 13.8kV

Base MVA and base voltages at different sections are marked.



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Per-unit reactance of generator = 0.2

Per-unit reactance of transformer T_1 = $0.1 \times \frac{300}{350} = 0.0857$

Per-unit reactance of transmission line = $0.5 \times 64 \times \frac{300}{230^2} = 0.1825$

Per-unit reactance of transformer T_2 = $0.1 \times (\frac{220}{230})^2 = 0.0915$

Per-unit reactance of motor M_1 = $0.2 \times \frac{300}{200} \times (\frac{13.2}{13.8})^2 = 0.2745$

Per-unit reactance of motor M_1 = $0.2 \times \frac{300}{100} \times (\frac{13.2}{13.8})^2 = 0.549$

Per-unit impedance diagram is shown in Fig. 1.12

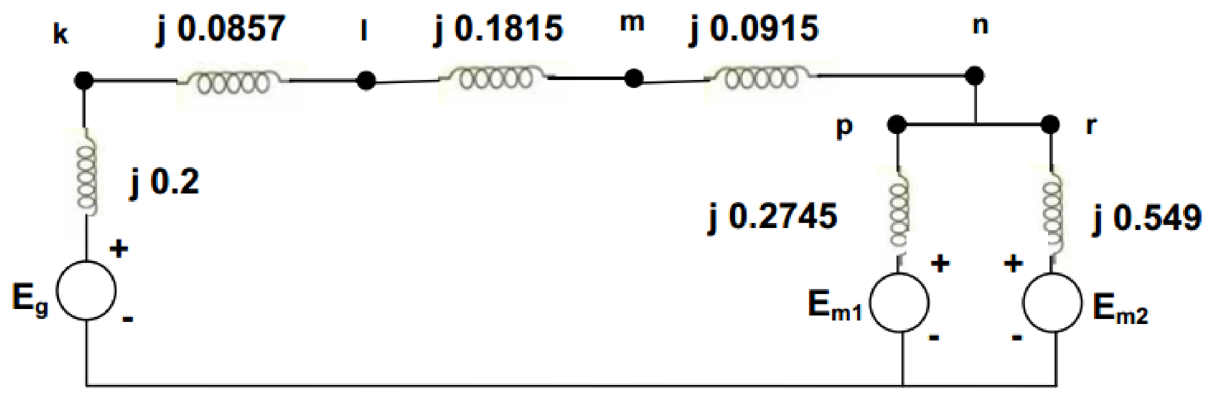
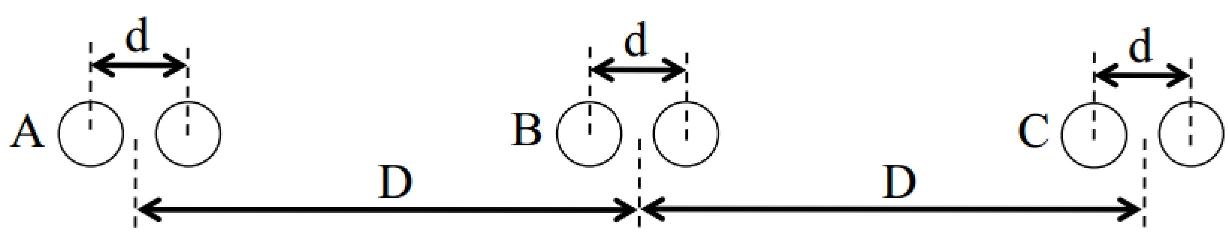


Fig. 1.12 Per-unit impedance diagram

4- A 120 MVA, 19.5 kV generator has Xs = 0.15 per unit and is connected to a transmission line by a transformer rated 150 MVA, 230 Y/18Δ kV with X = 0.1 per unit. If the base to be used in the calculation is 100 MVA, 230 kV for the transmission line, find the per unit values to be used for the transformer and the generator reactances.

Answer: **0.06667 p.u.; 0.1467 p.u.**

5- A three-phase transmission line is mounted on the tower as shown below. The radius of each conductor is r meters. Assume that d is much smaller than D. The three line currents are defined as positive into the paper and they sum to zero.



(a) Find the distributed flux (per meter) linking conductor A in terms of I_A, I_C, d, D, and r.
(b) Find the distributed flux (per meter) linking conductor B in terms of I_B, d, D, and r.

(c) Find the distributed flux (per meter) linking conductor C in terms of I_A, I_C, d, D, and r.

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2.11 In Fig. P-2.11 which depicts two three-phase circuits on a steel tower there is symmetry about both the horizontal and vertical centre lines. Let each three-phase circuit be transposed by replacing a by b and then by c, so that the reactances of the three-phases are equal and the GMD method of reactance calculations can be used. Each circuit remains on its own side of the tower. Let the self GMD of a single conductor be 1 cm. Conductors a and a' and other corresponding phase conductors are connected in parallel. Find the reactance per phase of the system.

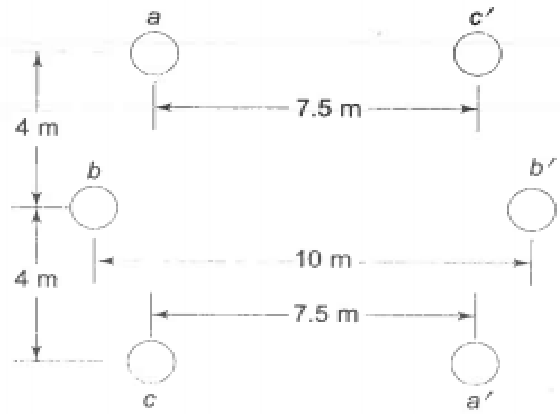

Fig. P-2.11

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2.11

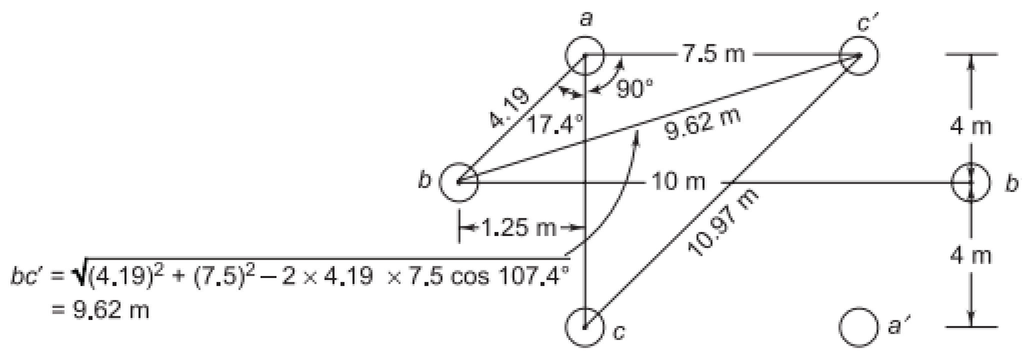

Fig. S-2.11

In section 1 of transposition cycle

$$D_{ab} = \sqrt{1.19\times 9.62} = 6.35;\ D_{bc} = \sqrt{4.19\times 9.62} = 6.35$$

$$D_{ca} = \sqrt{7.5\times 8} = 7.746$$

$$D_{eq} = \sqrt[3]{6.35\times 6.35\times 7.746} = 6.78$$

$$D_{sa} = \sqrt{0.01\times 10.97} = 0.3312 = D_{sc}$$

$$D_{sb} = \sqrt{0.01\times 10} = 0.3162$$

$$D_s = \sqrt[3]{0.3312\times 0.3312\times 0.3162} = 0.326 \text{ m}$$

$$X = 0.314 \times 0.461 \log \frac{6.78}{0.326} = \mathbf{0.191}\ \Omega\text{/km/phase}$$

2.12 $r' = 0.7788 \times 1.5 \times 10^{-2} = 0.0117$ m