Indian Institute of Technology Patna
Department of Electrical Engineering
EE3101 - Power Systems-I
Autumn - 2025
Mid Semester Exam — Solution.
September 25, 2025

Total Marks : 25 Time: 2 Hours

Section - A

Each question carries two (2) marks.

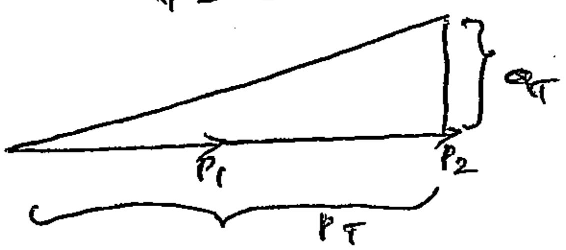
1. Two loads connected in parallel are supplied from a three phase 400 V supply. The two loads draw a total real power of 400 kW at 0.8 power factor lagging. One of the load draws 120 kW at unity power factor. Find the real power in kW and the power factor of the second load.

Load 1:

$P_1 = 120$ kW
$Q_1 = 0$
pf $= 1$

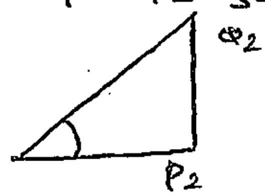
Total load:

$P_T = 400$ kW
pf $= 0.8$ lagging
$Q_T = 300$ kVAr



Load 2:

$P_2 = P_T - P_1 = 280$ kW
$Q_2 = Q_T - Q_1 = 300$ kVAr



pf $= \cos\phi_2 = 0.6823$ lagging

2. The load factor of a consumer is 40 % and the monthly consumption is 500 kWh. If the tariff of electricity is Rs 50 per kW of maximum demand plus Rs 6 per kWh. Find the monthly bill,

$$\text{Load Factor} = \frac{\text{Average load in kW}}{\text{Maximum Demand in kW}}$$

$$0.4 = \frac{\text{Average load} \times 30 \times 24}{\text{Max. Demand} \times 30 \times 24} = \frac{\text{Monthly consumption in kWhr}}{\text{Max Demand} \times 720}$$

$\therefore$ Max. Demand $= 1.74$ kW

Monthly bill $= 1.74 \times 50 + 500 \times 6$
$= \text{Rs } 3086.8$

3. A single phase load is supplied with a sinusoidal voltage $v(t) = 200\cos(377t)$ V. The resulting instantaneous power is $p(t) = 800 + 1000\cos(754t - 36.87°)$ W. What are real power (P) and reactive power (Q)?

$p(t) = 800 + 800\cos 754t + 600\sin 754t$

On comparision with the standard equation,

$P = 800$ W

$Q = 600$ VAr

4. Determine the geometric mean radius (GMR) of the following configurations for inductance in terms of the radius r of the individual strand.

$$GMR = \sqrt[16]{(0.7788r \times d \times d \times d)^2 \times (0.7788r \times d \times d \times 2\sqrt{3}d)^2}$$

$$\sqrt[16]{(0.7788r)^4 \times (2\times2\times2\sqrt{3})^2 \times (2\times2\times2)^2 \times r^{12}}$$

$$= \boxed{1.692r}$$

5. A three phase transmission line having 2 conductors per bundle is designed with equilateral spacing of D m. The spacing between the conductors of the bundle is d m. It is decided to build the line with horizontal spacing. The conductors are transposed. What should be the spacing between the adjacent conductors in order to obtain the same inductance as in the original design?

$L_1 = 2\times10^{-7} \ln\left(\frac{D}{\sqrt{r' \times d}}\right)$ For symmetrical spacing

$L_2 = 2\times10^{-7} \ln\left(\frac{GMD}{\sqrt{r' \times d}}\right)$ For horizontal spacing.

$L_1 = L_2$, $D = GMD$

$= \sqrt[3]{D_{12} \times D_{13} \times D_{23}}$

Since $D_{12} = D_{23} = 2D_{23}$

(2) ∴ The spacing between 1 and 2

$\boxed{D_{12} = 0.8D}$

Section - B

Each question carries five (5) marks.

1. A residential consumer has a connected load of 6 lamps each of 100 W and 4 fans of 60 W at his/her premises. His/her demand is as follows:

Time	Demand (W)
12 AM- 5 AM	120
5 AM - 6 PM	No Load
6 PM - 7 PM	380
7 PM - 9 PM	680
9 PM - 12 AM	420

(a) Find the energy consumption during 24 hours.

(b) Calculate the demand factor, average load, and load factor.

a) Energy Consumption for a day

$= 5 \times 120 + 1 \times 380 + 2 \times 680 + 3 \times 420$

$= \underline{3.6 \text{ KWhr}}$

b) Demand Factor $= \dfrac{\text{Maximum Demand}}{\text{Connected load}} = \dfrac{680}{6 \times 100 + 4 \times 60}$

$= \underline{0.81}$

Average load $= \dfrac{\text{Energy Consumption /day}}{24 \text{ hrs}} = \underline{150 \text{ W}}$

Load Factor $= \dfrac{\text{Average load}}{\text{Max demand}} = \dfrac{150}{680} = \underline{0.22}$

2. In a factory, there are following two loads :
Lighting and heating load : 100 kW
Induction motor load : 1000 HP at 0·7 lagging power factor and 85 % efficiency
The overall load power factor of the factory has to be raised to 0.95 lagging. A 3-phase synchronous motor is installed for the above purpose. The synchronous motor is rated at 300 HP with 100 % efficiency. Find the power factor of the synchronous motor. Given 1 HP (horsepower) = 746 watts.

Load 1:

$P_1 = 100$ KW

$Q_1 = 0$

Load 2:

$P_2 = P_{input}$ to the motor $= \frac{P_{o/p}}{\text{efficiency}}$

$P_2 = \frac{1000 \times 746}{0.85} = 877.65$ KW

$Q_2 = P_2 \times \tan(\cos^{-1}(0.7))$

$= 895.38$ KVAR

$P_T = 977.65$ KW

$Q_T = 895.38$ KVAR

Synchronous Motor:

$P_{motor} = 300 \times 746$

$P_{motor} = 223.8$ KW

$P_{Total} = P_{Load} + P_{motor} = 1201.5$ KW

To achive the required power factor of 0.95 lagging.

$Q_{req} = P_{Total} \times \tan(\cos^{-1}(0.95)) = 394.8975$ KVAR

$\therefore Q_{syn\ motor} = Q_{req} - Q_L$

$= -500.48$ KVAR

pf of the motor $= \cos\left(\tan^{-1}\left(\frac{Q_{motor}}{P_{motor}}\right)\right) = 0.4083$ leading

3. A 15 km long, 50 Hz, 3-phase overhead line delivers 5 MW at 11 kV at a power factor of 0.8 lagging. Line loss is 12 % of the power delivered. Line inductance is 1·1 mH per km per phase. Calculate:

   (a) Sending end voltage and voltage regulation.

   (b) Power factor of the load to make voltage regulation zero. (Hint: Use the phasor diagram with leading power factor.)

$X = 2 \times \pi \times 50 \times 1.1 \times 10^{-3} \times 15 = 5.1836\ \Omega$

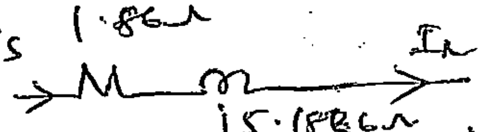
$Loss = 0.12 \times 5 = 0.6\ MW$

$3I^2R = 0.6\ MW$

$I = \frac{5 \times 10^3}{\sqrt{3} \times 11 \times 0.8} = 328.04\ A$

$\therefore R = \frac{0.6 \times 10^6}{3 \times (328.04)^2} = 1.86\ \Omega$

Short line



$\bar{V}_s \qquad V_R = \frac{11}{\sqrt{3}}\ kV$

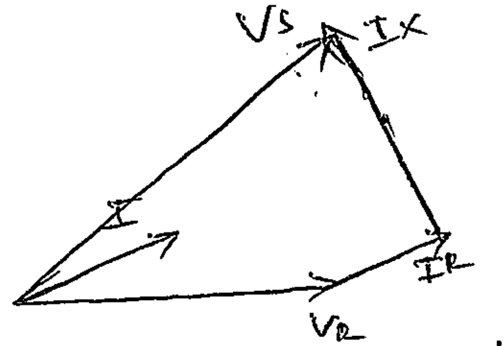
$V_{s\,phase} = \frac{11}{\sqrt{3}} \times 10^3 \angle 0^\circ + 328.04 \angle -36.87^\circ \times (1.86 + j5.1836)$

$\bar{V}_{s\,phase} = 7.5 \angle 7.2^\circ\ kV$

a) $V_{s\,L-L} = 13.7\ kV$

$\%\ regn = \frac{13.7 - 11}{11} \times 100 = 24.55\ \%$

b)



To get zero regulation,

$|V_s| = |V_R|$

$\therefore IR\cos\phi - IX\sin\phi = 0$

$\tan\phi = \frac{R}{X}$

Hence

(5)

$pf = \cos(\tan^{-1}(R/X))$

$pf = 0.9412$ leading