ISTANBUL AYDIN UNIVERSITY
FACULTY OF ENGINEERING

EEE442-ENERGY TRANSMISSION SYSTEMS

2024-2025
SPRING
__/07/2025

Time Duration:
70 Minutes

Solution Manual

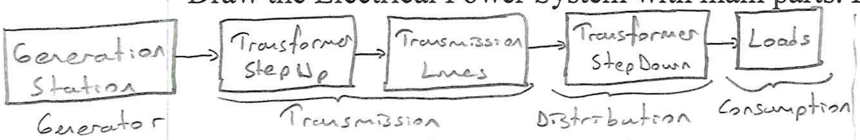
Student's Name :
Student's Number :
Student's Signature :

| *Questions* | *1* | *2* | *3* | *4* | *5* | TOTAL |
|---|---|---|---|---|---|---|
| Course Learning Outcomes | | | | | | |
| Maximum Score of the Question | 20 | 20 | 20 | 20 | 20 | 100 |
| The Score the Student Received | | | | | | |

# QUESTIONS

**Question 1:**

Draw the Electrical Power System with main parts. Explain for each part.




eneration ⇒ Generating the electrical energy from such imary energy sources.

ransmission ⇒ The system carries the high voltage electricity over long distances. High voltage is used to reduce the current which in turn reduces the resistive losses over long distances.

Distribution ⇒ In the system, high voltage is reduced or stepped down, to safer and more controllable level for end users using transformer. This is so important because high voltage is too dangerous and impractical for direct use in end user.

Consumption ⇒ After the voltage is reduced, the electricity goes through a network of lower voltage lines to deliver this power directly to end users or loads such as homes, business and industrial facilities.

**Question 2:**

**a)** Explain the purpose of capacitors, reactors and static VAR compensators used in electrical power systems.

lectrical power system can meet power unstable condition. To avoid this undesired condition, ome equipment and components are used. Capacitors support voltage stabilization by balancing luctuations and distortion on voltage waveform. It is used to balance inductive loads such as otors. Reactors are a coil with high ohmic resistance. Purpose of reactor is to limit current short ircuit. They are added as a series. The purpose of static VAR compensator is to regulate oltage by controlling reactive power with absorbing or injecting in to the power system.

**b)** Explain power factor. What is the leading and lagging power factor?

ower factor is ratio of active power which is used or consumed by load to apparent ower which demands from power supplier. Power factor is a measure of how effectively ncoming power is used in the electrical system.

-eading power means that current leads to voltage. Capacitive loads like capacitor banks ave leading power factor.

-agging power means that current lags behind voltage. Inductive loads like motors, transformer have lagging power factor.

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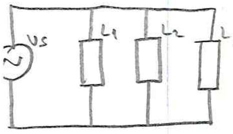
**Question 3:**

Three loads are connected in parallel across a 2200V RMS, 50 Hz single phase power supply. These loads are; **Load_1** is inductive load with 87 kVA at 0.43 power factor, **Load_2** is capacitive load with 32 kW and 64 kVAR, **Load_3** is resistive load with 24 kW.

**a)** Draw the electrical power system and find the total kW, kVAR and KVA and supplied power factor with its type. drawn current from power supplier




For load 1 = $\theta = \cos^{-1}(pf) \Rightarrow \theta = \cos^{-1}(0{,}43) = 64.53°$ (Lagging)

$S_1 = 87\angle 64.53°$ kVA $= 87k\cos(64{,}53°) + j87k\sin(64{,}53°) = 37.41kW + j.78.54kVar.$

$S_2 = 32kW + j.64kVar$

$S_3 = 24kW$

The total apparent power is $\Rightarrow S_{Tot} = S_1 + S_2 + S_3 = 37{,}4kW + 32kW + 24kW + j(78{,}54kVar + 64kVar)$

$S_{Tot} = 93{,}4kW + j.142{,}54kVar \quad |S_{Tot}| = \sqrt{93{,}4k^2 + 142{,}54k^2} = 170{,}41k \quad \theta = 56{,}76° \quad S = 170{,}41\angle 56{,}76°$ kVA

$I = \frac{S^*}{V^*} = \frac{170{,}41\angle -56{,}76° \text{ kVA}}{2200\angle 0° \text{ V}} = 77.45\angle -56{,}76$ A $\quad pf = \cos(-56{,}76°) = 0{,}55$. Lagging

**b)** It needs to correct the power factor to 0.9. Please determine what load should add. Calculate just its reactive power and reactance of the load (Suppose that it has 0 resistance).

$\theta_d = \cos^{-1}(0{,}9) = 25{,}84° \quad Q_d = 93{,}4k.\tan(25{,}84°) = 45{,}23kVar. \quad Q_{act} + Q_r = Q_d$

$42{,}54kVar + Q_r = 45{,}23kVar \quad Q_r = -97{,}31kVar \Rightarrow$ This load capacitive load.

$S_c = 0kW - j97{,}31kVar \rightarrow X_c = \frac{|V|^2}{S_c^*} = \frac{2200^2}{j97310} = -j49{,}7\,\Omega$

$X_c = \frac{1}{j\omega C} \Rightarrow C = \frac{1}{j\omega X_c} = \frac{1}{j.2\pi 50.(-j49{,}7)} = 64{,}04\,\mu F$

**c)** Calculate the new current drawn ~~current~~ ~~from~~ by power supplier. ~~What does adding this load affect the current drawn~~?

$S'_{Tot} = 93{,}4kW + j45{,}23kVar = 103{,}78\angle 25{,}84°$ kVA

$I' = \frac{S^*}{V^*} = \frac{103{,}78\text{kVA}\angle -25{,}84°}{2200\angle 0°} = 78{,}99\angle -25{,}84°$ A

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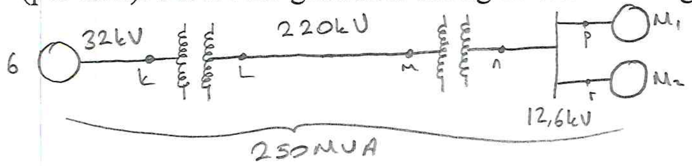
**Question 4:** A 250 MVA, 32 kV three phase generator has a reactance of 20%. The generator supplies a number of synchronous motors over 124 km transmission line having transformers at both ends. The motors all rated 12.6 kV, are represented by just two equivalent motors. Rated inputs to the motors are 180 MVA and 150 MVA for M1 and M2, respectively. For both motors have reactance of 20%. The three phase transformer T1 is rated 320 MVA, 32 kV/220 kV with leakage reactance of 10%. Transformer T2 is composed of three single phase transformers each reated 112 kV /12.6 kV, 120 MVA with leakage reactance of 10%. Series reactance of the transmission line is 0.3 ohm/km. Draw the impedance diagram, with all impedances marked pu (per unit). Select the generator rating as base in the generator circuit.




Base MVA → 250

Base Voltage at generator ⇒ 32kV

Per Unit reactance of generator ⇒ 0,2

Rated of $T_2 = \sqrt{3} \cdot 112kV/12,6kV = 193,99kV/12,6kV$

Base Voltage at Motor $\Rightarrow 220kV \, \frac{12,6kV}{220kV} = 12,6kV$

Per Unit reactance of generator is $0,2\,\Omega$

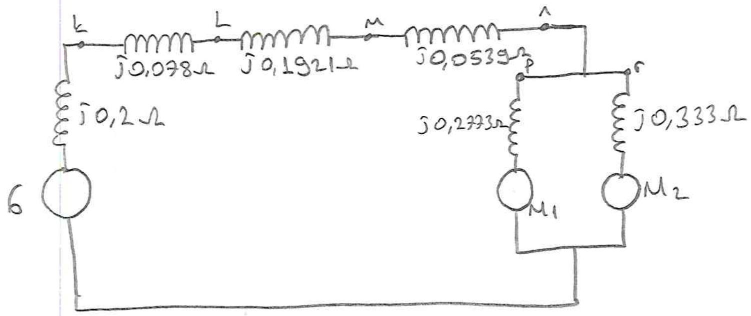
Per Unit reactance of $T_1 \Rightarrow 0,1 \cdot \frac{250MVA}{320MVA} \cdot \left(\frac{32kV}{32kV}\right)^2 = 0,078\,\Omega$

Per Unit reactance of $T_2 \Rightarrow 0,1 \cdot \frac{250MVA}{120MVA} \cdot \left(\frac{112kV}{220kV}\right)^2 = 0,0539\,\Omega$

Per Unit reactance of transmission line $\Rightarrow 0,3\,ohm/km \cdot 124km \cdot \frac{250MVA}{(220kV)^2} = 0,1921\,\Omega$

Per Unit reactance of Motor $M_1 \Rightarrow 0,2 \cdot \frac{250MVA}{180MVA} \left(\frac{13,2kV}{13,2kV}\right)^2 = 0,2778\,\Omega$

Per Unit reactance of Motor $M_2 \Rightarrow 0,2 \cdot \frac{250MVA}{150MVA} \left(\frac{13,2kV}{13,2kV}\right)^2 = 0,333\,\Omega$

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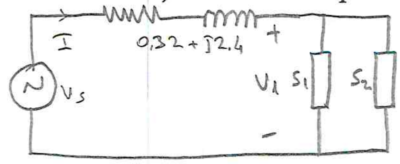
**Question ~~4~~ 5:** A three-phase line has an impedance of (0.32 + j2.4) per phase. The line feeds two balanced three phase loads are connected in parallel. One of the load is absorbing 480 kVA at 0.6 power factor lagging. The other is absorbs 124 kW at unity power factor. The line is energized at the sending end from 50-Hz, three-phase, balanced 2200 V (line-to-line).

**a)** What is the power supplier voltage?




$\theta_1 = \cos^{-1}(0,6) = 53,13^\circ \quad \theta_2 = 0^\circ$

$S_1 = 484\angle 53.13^\circ \text{ kVA} \qquad S_2 = 124\angle 0^\circ \text{ kVA}$

$V_1 = \frac{2200\text{ V}}{\sqrt{3}} = 1270,17\text{ V} = 1270,17\angle 0^\circ \text{ V}$

$S_{Tot} = S_1 + S_2 = 484k\cos(53,13) + j484k\sin(53,13^\circ) + 132k\cos(0^\circ) + j132k.\sin(0^\circ)$

$S_{Tot} = 422,4\text{kW} + j387,2\text{kVar.} \Rightarrow S_{Tot} = 573\angle 42,5^\circ \text{ kVA}$

$I = \frac{S_{Tot}^*}{3V_1^*} = \frac{573k\angle -42,5^\circ}{3.1270,17\angle 0^\circ} = 150.37\angle -42,5^\circ$

$V_S = 1270,17\angle 0^\circ + (0,32+j2,4).I = 1270,17 + (0,32+j2,4)(100.\cos(-42,5) + j100\sin(-42,5))$

$V_S = 1464.16\angle 16,09^\circ$

**b)** What is the ~~total~~ real and reactive power ~~of the line~~? used in the line?

Real power $\Rightarrow 3.R.|I|^2 = 3.(0,32).(150,37)^2 = 21,7\text{kW}.$

Reactive power $\Rightarrow 3.X.|I|^2 = 3.(2,4).(150,37)^2 = 16,28\text{kVar}.$

**c)** What are the real power and reactive power supplied by the power supplier?

$S_S = 3.V_S.I^* = 3.1464.16\angle 6,09^\circ \text{V}.150.37\angle 42.5^\circ = 660,49\angle 48,59^\circ \text{ kVA} = 436,88\text{kW} + j495,36\text{kVar}.$

Real power = 436,88kW

Reactive power = 495,36kVar.

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