ERGU Tutorial Week No: 8 – Electrical Power Systems

Q.1

With the aid of a diagram , briefly describe the components within a typical electrical power system.

Q.2

Compare and contrast the terms critical medium-voltage (MV) and low-voltage distribution.

Q.3

With the aid of a diagram , briefly sketch a typical power grid.

Q.4

Briefly sketch a typical power distribution network and its components.

Q.5

Compare and contrast the costs and drawbacks involved with overhead lines to underground cables.

Q.6

State the advantages and disadvantages of overhead lines

Q.7

State the advantages and disadvantages of underground cables.

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Q.8

An 11 kV, 50 Hz, three-phase overhead line has a cross-sectional area of 30 mm^2 and an inductance per km of 1 mH. If the line is 8 km long, calculate the voltage required at the sending end when delivering to the load 500 kW at 11 kV and 0.9 lagging power factor. If 500 kW at 11 kV and 0.9 lagging power factor were supplied at the sending end what would be the voltage, power and power factor at the receiving end?

$$p = 1.7/\mu\Omega\text{cm}$$

Q.9.

A substation is supplied by two feeders, one having an impedance of (1 + j2) Ω/ph, and the other (1.5 + jl.5) Ω/ph. The total current delivered to the substation is 700 A at 0.8 lagging p.f. Find the current and its p.f. at the receiving end in each feeder.

Q.10.

The three-phase busbars of a power station are divided into two sections A and B by a section switch. Each section is connected by a feeder to a substation C at which the voltage is 6.6 kV. Feeder AC has an impedance of (0.5 + j0.6) Ω/ph and delivers 9 MW at 1.0 p.f. to C. Feeder BC has an impedance of (0.3 + j0.4) Ω/ph and delivers 6 MW at 0.8 p.f. to C. Determine the voltage across the section switch.

Q.11.

A substation is fed at 11 kV by two parallel feeders. One feeder is 50 per cent longer than the other but has a conductor of twice the cross-sectional area. The reactance per km is the same for both and equal to 1/3 of the resistance per km of the shorter feeder. If the load on the substation is 4 MW at 0.9 p.f. lagging find the current and power in each feeder.

Q.12.

A 33 kV feeder with impedance (2 + j10) Ω/ph supplies a 33/6.6 kV substation containing two parallel connected transformers of 10 and 5 MV A each with a 0.1 pu reactance. The 6.6 kV side of the sub-station supplies a 6.6 kV feeder with an impedance of (0.05 + j0.2)Ω/ph. 9.6 MW at a p.f. of 0.8 lag is supplied to the 33 kV feeder at 33 kV. Determine the voltage at the end of the 6.6 kV feeder. Use both the ohmic value and the per-unit method.

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Q.13.

A transmission system consists of a generator, a step-up transformer, transmission line, step-down transformer and a load. The following parameters apply to each system component.

(i)	Generator	130 MV A, 11KV 0.16 pu
(ii)	Step-up transformer	135 MV A, 11/132 kV j0.15 pu
(iii)	132 kV transmission line	4 + j12 Ω
(iv)	Step-down transformer	125 MV A, 132/11 kV j0.112 pu

If we require to deliver125 MW at 1 p.f. and 11 kV at the load, what voltage and p.f. exist at the supply?

Q.14.

A factory is supplied from a substation containing two 500 kV A, 11kV/400V transformers connected in parallel, each having a reactance of 0.08 pu. A 750 kV A generator with 0.12 pu reactance also supplies the 400 V busbars which in turn supply a 400 V feeder having an impedance of (0.01 + j0.015) Ω/ph. Calculate the short-circuit current in the feeder and the voltage of the 400 V busbars when a symmetrical three-phase fault occurs at the far end of the feeder. The fault level of the 11 kV system is 100 MV A.

Q.15.

A three-phase generating station contains a 50 MV A generator of 0.1 pu reactance and a 30 MV A generator of 0.08 pu reactance feeding the same 11 kV busbars. An outgoing 33 kV feeder having an impedance of (0.6 + jl.5) Ω/ph is supplied from these busbars through an 11/33 kV, 20 MV A transformer of reactance 0.1 pu. Calculate, by (a) the ohmic value method and (b) the pu method, the short-circuit current and MV A when a symmetrical three-phase short circuit occurs (i) on the feeder side of the transformer and (ii) at the far end of the feeder. Calculate also the busbar voltage during the short circuit for each case.

Q.16

A large industrial complex has four 5 MV A generators each of reactance 0.08 pu supplying the busbars of its power station. Determine the rating of any circuit breakers connected to the busbars. Due to increased electricity demand in the factory it is proposed to make a connection to the grid through two 2MVA transformers in parallel each with a reactance of 0.1 pu. The fault level at the grid connection point is 1000 MV A. What will now be the required rating of circuit breakers connected to the busbars?

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Q.17.

A power station contains three 15 MVA generators each having a reactance of 0.1 pu and connected to a set of 33 kV busbars. The outgoing circuit breakers connected to these busbars have a breaking capacity of 750 MV A. It is proposed to make a connection to the grid through a 30 MV A transformer having a reactance of 0.06 pu and the short-circuit MV A of the grid at the point of connection is 1500 M VA. Determine the reactance of a reactor (in ohms) to be inserted between the busbars and the transformer if the existing switchgear in the power station is to be retained.

Q.18.

A 33 kV substation has three sets of busbars A, B and C. Each of the busbars A and B is connected to C by 15 MV A reactors of 0.1 pu reactance. Busbar A is supplied by a power system having a fault level of 1000 MV A and busbar B is supplied by a 50 MV A generator of 0.3 pu reactance. Busbar B supplies an 11kV transmission line of reactance 5Ω/ph via a 10 MV A 33/11 kV transformer of reactance 0.1 pu. If a symmetrical three-phase fault occurs at the far end of the transmission line determine the fault current and voltages on busbars A, B and C.

Q.19.

The busbars of an 11 kV generating station are divided into three sections A, B and C, to each of which is connected a 20 MV A generator of 0.3 pu reactance. Each of the three busbars A, B and C is connected to a common busbar D via three 15 MV A reactors of 0.1 pu reactance. Busbar A feeds a 33 kV transmission line of reactance 15 Ω/ph via an 11/33kV, 10 MV A transformer of reactance 0.1 pu. If a symmetrical three-phase fault occurs at the far end of the transmission line find the fault current and the voltage on busbar A during the fault (You could also attempt this question using the ohmic value method.)

Q.20

State several reasons why power systems analysis is required?

Q.21

State 5 fault types that can arise in a three-phase power systems?

Q.22

Briefly describe why power system engineers prefer the per-unit method of calculation?

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Q.23

A Power System is shown overleaf in **Figure Q.23.** One of the distributors has developed a three-phase short-circuit fault at point "F" on the 400V busbar. Calculate the following to a base of **20 MVA**:

(i) Calculate the per unit (p.u.) reactance of each component in the system.

(ii) Sketch and label a single-line schematic diagram showing the system components reactances with their p.u. values connected together.

(iii) Calculate the combined p.u. reactance of the system down to the fault point.

(iv) At the fault point "F" calculate the short-circuit MVA and the magnitude of short-circuit current of the system.

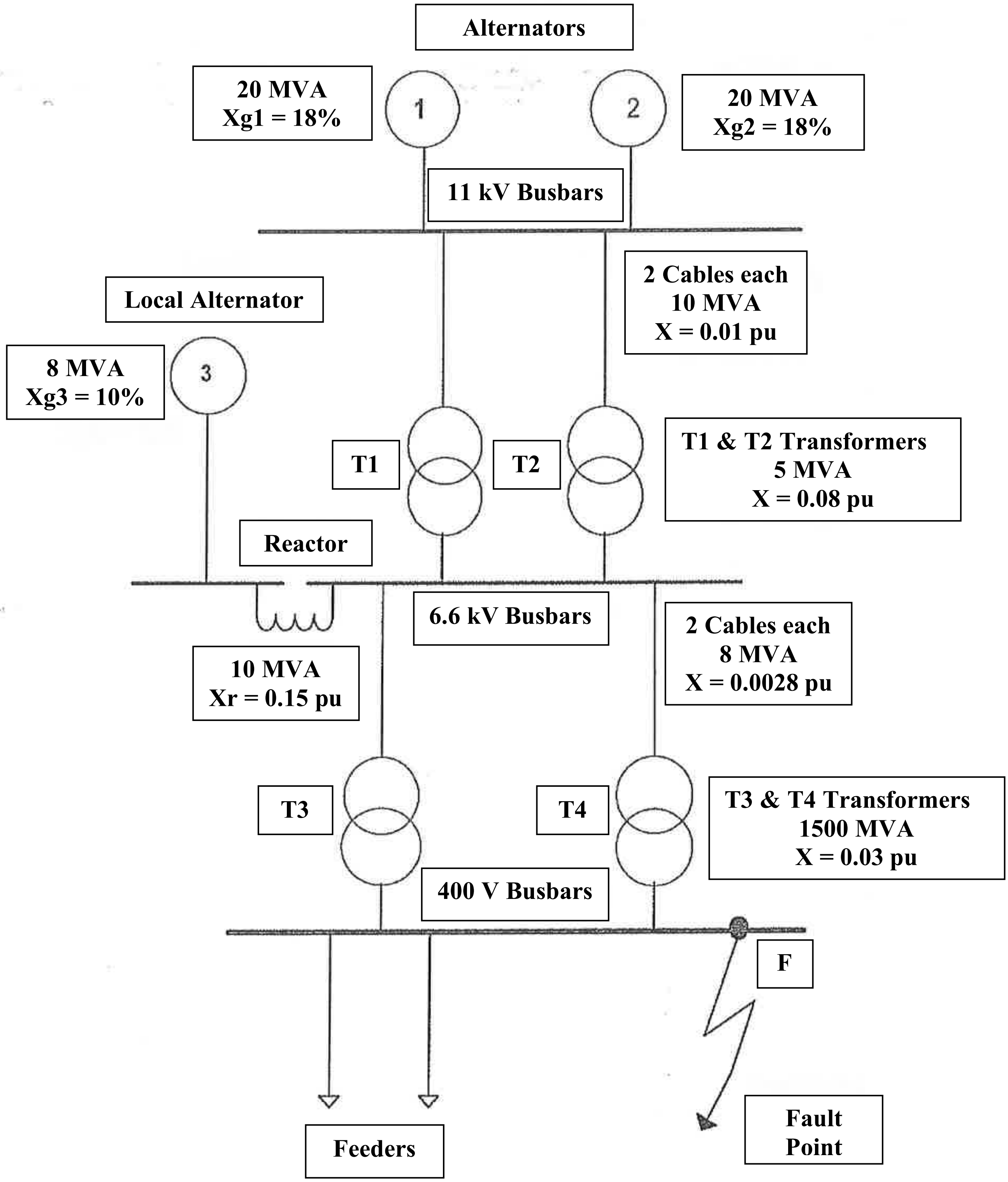
Alternators
20 MVA
Xg1 = 18%
1
2
20 MVA
Xg2 = 18%
11 kV Busbars
2 Cables each
10 MVA
X = 0.01 pu
Local Alternator
8 MVA
Xg3 = 10%
3
T1
T2
T1 & T2 Transformers
5 MVA
X = 0.08 pu
Reactor
6.6 kV Busbars
2 Cables each
8 MVA
X = 0.0028 pu
10 MVA
Xr = 0.15 pu
T3
T4
T3 & T4 Transformers
1500 MVA
X = 0.03 pu
400 V Busbars
F
Feeders
Fault
Point

Figure Q.23

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Q.24

A 240V/120V single phase transformer rated 5 kVA has a high-voltage winding impedance of 0.3603 Ω. Use 240 V and 5 kVA as the base quantities and determine the following:

- **(i)** The high-voltage side base current
- **(ii)** The high-voltage side base impedance
- **(iii)** The transformer impedance referred to the high-voltage side in per unit
- **(iv)** The transformer impedance referred to the high-voltage side in percent
- **(v)** The turns ratio of the transformer windings
- **(vi)** The low-voltage side base current
- **(vii)** The low-voltage side base impedance
- **(viii)** The transformer impedance referred to the low-voltage side in per unit
- **(ix)** What can you deduce from your calculations

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Q.25

A Power System is shown overleaf in **Figure Q.25,** comprising two three-phase alternators supplying 11kV busbars. There is two parallel interconnector lines fed from the 11kV busbars to step-down transformers, which supply a number of distributors to the load points at 400V.

One of the distributors has developed a three-phase short-circuit fault at point "F" on the 400V busbar. Calculate the following to a base of 20 MVA:

(a) With reference to the base 20 MVA, calculate the per unit (p.u.) reactance of each component in the system.

(b) Sketch and label a single-line schematic diagram showing the system components reactances with their p.u. values connected together.

(c) Calculate the combined p.u. reactance of the system down to the fault point.

(d) At the fault point "F" calculate the short-circuit MVA of the system.

(e) At the fault-point calculate the magnitude of short-circuit current of the system.

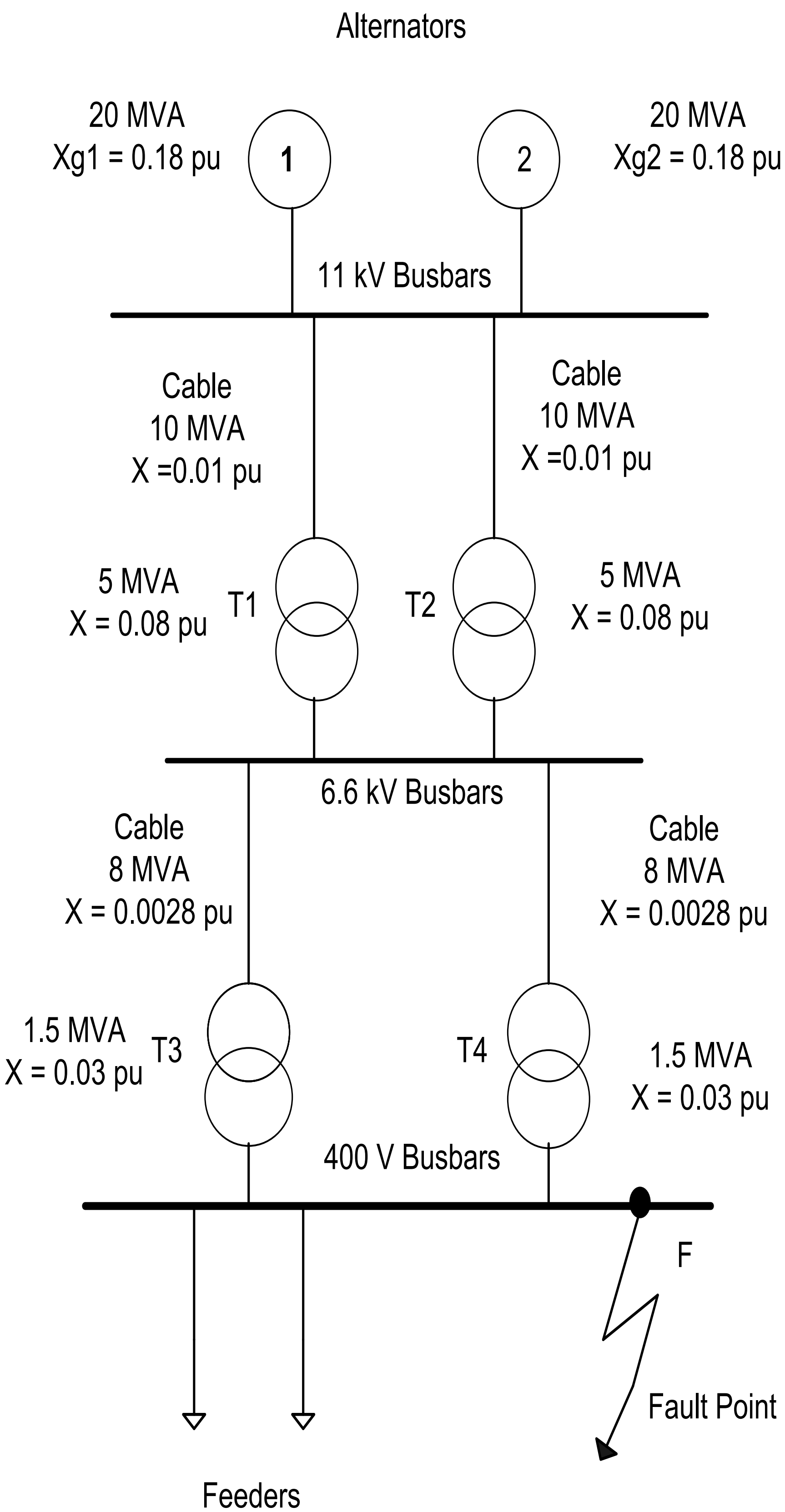

Figure Q.25

End of Tutorial – Week No: 8