ROYAL CIVIL SERVICE COMMISSION

CIVIL SERVICE COMMON EXAMINATION (CSCE) 2009
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALIZATION PAPER for ELECTRICAL ENGG. / ELECTRICAL & ELECTRONICS ENGG. GROUP

Date	:	**08/11/2009**	**Maximum Marks**	:	**100**
Examination Time	:	**2.5 Hours**			
Reading Time	:	**15 Minutes**			

READ THE FOLOWING GUIDELINES CAREFULLY:

1. Do not write for the first **15 minutes**. This time must be spent in reading the question paper and to confirm that all questions are in order and all pages are intact and complete.
2. The time allotted for writing this paper is **2½ Hours**
3. All answers for this paper must be written in a separate **Answer Sheet** provided including all rough works.
4. Use of programmable calculators are not allowed in this exam.
5. This paper contains **TWO** Sections, **Section A** and **Section B.** Section A is further divided into **Two Parts: Part I** containing **30 Multiple Choice** questions of **One (1) Mark** each and **Part II** containing **FOUR Short Answer** type questions of **Five (5) Marks** each.
6. You must **answer ALL** the Questions in **Section A.**
7. While answering the multiple choice questions in the answer sheet provided, write only the letter of the correct answer chosen against the question number, clearly & legibly. Any over writing or double answers shall not be evaluated. (E.g.: Q1 – a); Q2 – b); Q3 – c), and so on).
8. **Section B** contains **TWO (2) Case Studies**, out of which you must **attempt only ONE (1) Case Study**. The Case Study question carries 50 marks and the marks are allocated beside the questions.
9. Marks for the Part II of Section A will be awarded based on the knowledge of the subject, clarity and preciseness of the responses, while Section B will be evaluated based on the ability to comprehend the case, apply your knowledge and present the case with solutions.
10. This paper contains **FIFTEEN (15)** printed pages in all, including this guideline page.

SECTION A

PART I – MULTIPLE CHOICE – *Answer All the Questions*

Choose the correct answer and write down the question number and the number of the correct answer chosen against it in the separate Answer Sheet provided.

1. A resistor's first three color bands are; brown, black and red. Its value is:

   a) 10 kOhms
   b) 200 Ohms
   c) 10 Ohms
   d) 1000 Ohms

2. Which one of the following equations could be used to calculate the power absorbed by a resistor?

   a) Power (p) = Voltage (v) x Current (i)
   b) Power (p) = Current squared(i^2) x Resistance(R)
   c) Power (p) = Voltage squared(v^2) / Resistance(R)
   d) All of the above

3. The method of analyzing a circuit containing multiple independent sources by activating one source at a time is called?

   a) Superposition
   b) Norton Equivalence
   c) Thevenin Equivalence
   d) Source Transformation

4. A phase sequence indicator rotates clockwise for phase sequence of RYB. If the phase sequence is changed to BRY, it will rotate?

   a) anticlockwise
   b) clockwise
   c) clockwise or anticlockwise
   d) it will not rotate

5. A 100 Watt light bulb is lighted on an average of 8 hours a day for 30 days in a month. The monthly consumption of energy will be:

   a) 240 units
   b) 800 units
   c) 3000 units
   d) 24000 units

6. The given truth table belongs to the logic gate named?

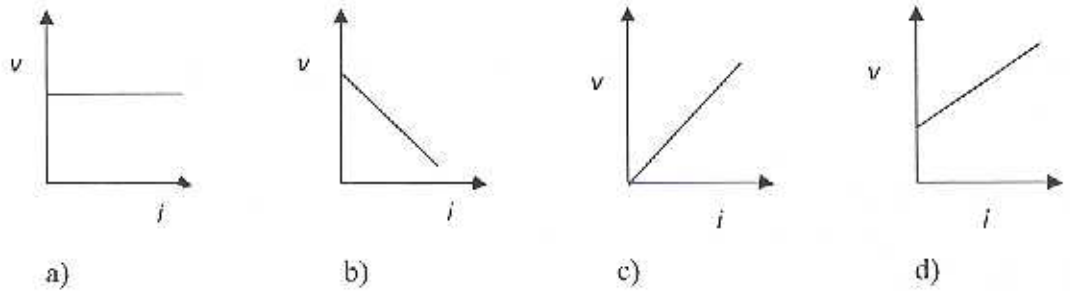
a) AND
b) OR
c) NOR
d) NAND

Input		Output
A	B	Y
1	1	0
1	0	1
0	1	1
0	0	1

7. The peak voltage of a sine wave that measures 220V AC rms is:

a) 155 V
b) 169 V
c) 311 V
d) 440 V

8. Following are the graphs between current i drawn from a cell and the terminal voltage v of the cell. The correct relationship between v and i is shown by:



a) b) c) d)

9. In practice, earth is chosen as a place of zero electric potential because it:

a) is non-conducting
b) is easily available
c) has almost constant potential
d) none of the above

10. The transformer cores are laminated in order to:

a) simplify its construction
b) minimize eddy current loss
c) reduce cost
d) reduce hysteresis loss

11. The sag produced in the conductor of a transmission line depends on:

a) the weight of the conductor per unit length
b) the tension of the conductor
c) the height of the transmission tower
d) none of the above.

12. A synchronous generator has higher power handling capability when operating at:

a) a leading pf
b) a lagging pf
c) it does not depend upon the pf of the generator
d) it depends upon the load pf, as generator has no pf of its own

13. A three phase synchronous generator is feeding rated power to an infinite bus. If its excitation fails, then it will act as a:

a) synchronous motor
b) synchronous generator
c) reluctance generator
d) induction generator

14. A series *RLC* circuit above resonant frequency is called?

a) resistive
b) capacitive
c) inductive
d) impedance

15. The forward resistance of a diode is?

a) zero
b) infinity
c) small
d) large

16. In a fluorescent tube circuit, the function of the ballast choke is to?

a) prevent flicker
b) improve the *pf* of the circuit
c) suppress high current
d) provide momentary high voltage to establish the main arc

17. For providing a load power of 100MW at 0.8 pf, the ratings of alternator, its prime mover and the transformer should respectively be:

a) 100 MW, 125 MVA, 125 MVA
b) 125 MVA, 100 MW, 125 MVA
c) 125 MVA, 125 MVA, 125 MVA
d) 100 MW, 100 MW, 125 MVA

18. All other factors remaining the same, what is the effect of increasing wire gauge, for example, from SWG 22 to SWG 26?

a) Impedance will decrease.
b) Resistance will increase.
c) Inductance will decrease.
d) Capacitance will increase.

19. If *mmf* refers to 'magnetomotive force' and *emf* refers to 'electromotive force', the formula for current in an electric circuit can be written as:

$$Current = \frac{emf}{resistance}$$

Its analogy (equivalent formula) in a magnetic circuit will be:

a) $Current = \frac{mmf}{reluctance}$

b) $Current = \frac{emf}{reluctance}$

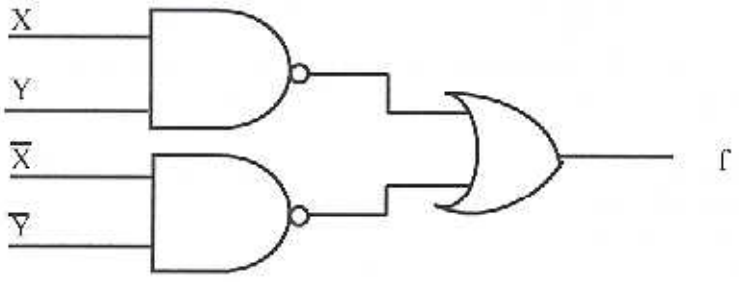
c) $Flux = \frac{mmf}{reluctance}$

d) $Flux = \frac{mmf}{resistance}$

20. Binary number for decimal number 100 is:

a) 100
b) 1100
c) 100 100
d) 1100 100

21. The output function 'f' of the figure given below is:



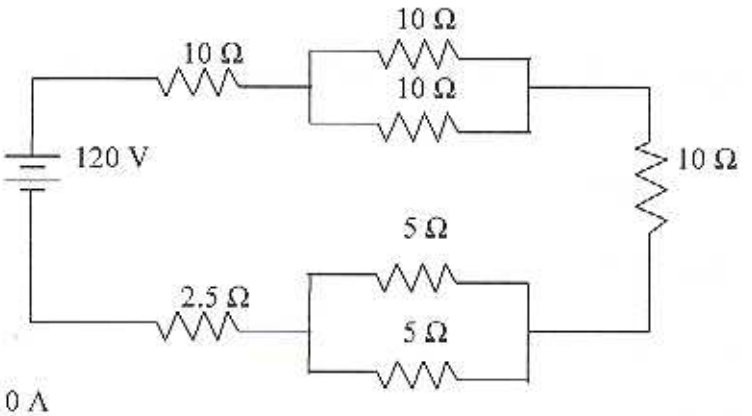
a) $\overline{XY} + XY$

b) $Y + \overline{XY}$

c) $XY + \overline{XY}$

d) $\overline{XY} + Y$

22. In the figure given below, the current flowing through 120 V battery will be:



a) 10 A
b) 8.0 A
c) 4.5 A
d) 4.8 A

23. Theoretical maximum efficiency of a full wave rectifier is:

a) 40.6%
b) 50%
c) 75%
d) 81.2%

24. The characteristic impedance 'Z' of a lossless transmission line is:

a) $Z = \sqrt{L/C}$
b) $Z = \sqrt{1/LC}$
c) $Z = \sqrt{LC}$
d) $Z = \sqrt{C/L}$

25. If the secondary of a Current Transformer (CT) is opened suddenly,

a) its primary current will become zero
b) CT will blast and will be damaged
c) magnetizing current will flow in its primary
d) measuring circuit will break

26. The power measured by a 3-voltmeter method using voltmeters V_1, V_2 and V_3 will be given by the formula:

a) $\text{Power} = \frac{(V_1^2 - V_2^2 - V_3^2)}{R}$

b) $\text{Power} = \frac{(V_1^2 - V_2^2 - V_3^2)}{2R}$

c) $\text{Power} = \frac{(V_1^2 + V_2^2 + V_3^2)}{2R}$

d) All of the above

27. For harmonic distortion D_1, D_2, ... D_n, the total harmonic distortion D will be given by:

a) $D = \frac{1}{n}(D_1 + D_2 + \cdots + D_n)$

b) $D = \frac{1}{n}\sqrt{(D_1 + D_2 + \cdots + D_n)}$

c) $D = \sqrt{(D_1^2 + D_2^2 + \cdots + D_n^2)/n}$

d) $D = \sqrt{(D_1^2 + D_2^2 + \cdots + D_n^2)}$

28. Lenz's Law states that:

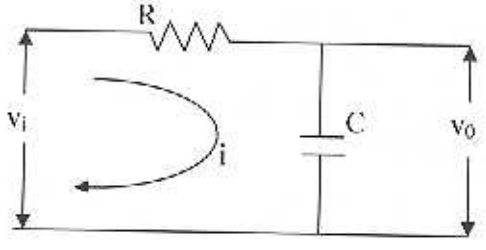
a) the direction of the generated voltage in the coil is such that it tends to produce a current flow opposing a change of flux through the coil

b) the magnitude of the generated voltage is directly proportional to the rate at which a conductor cuts magnetic lines of force

c) an electromotive force acting on any linear network produces the same effect whether it acts alone or in conjunction with other electromotive forces

d) the linear network behind a pair of terminals may be replaced by a constant-voltage generator with an e.m.f. equal to the open-circuit voltage at the terminals and an internal impedance equal to the impedance seen at the actual terminals, with all internal sources removed and replaced by their internal impedances

29. The transfer function of the circuit shown in the figure below using Laplace Transform is:



a) $\frac{R}{(1+sRC)}$

b) $\frac{1}{(1+sRC)}$

c) $\frac{C}{(1+sRC)}$

d) $\frac{RC}{(1+sRC)}$

30. The frequency of a signal is INVERSELY proportional to which of the following:

a) period
b) amplitude
c) phase
d) power

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PART II – SHORT ANSWER QUESTIONS *(Answer All the FOUR Questions)*

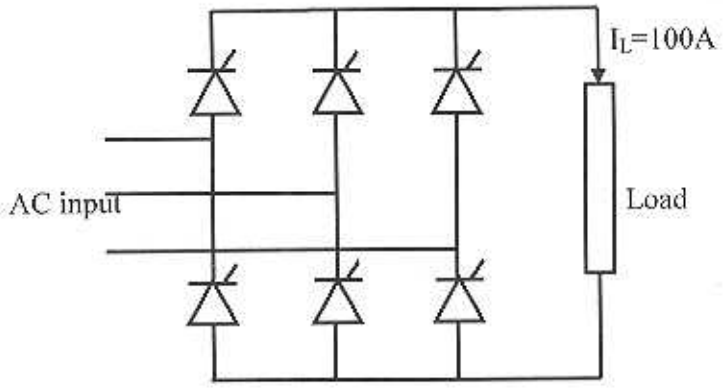
1) A 25 kVA, 2300/230 Volt single phase distribution transformer has the following resistance and leakage-reactance values: primary winding resistance, $R_p = 0.8\ \Omega$, primary winding leakage-reactance, $X_p = 3.2\ \Omega$, secondary winding resistance, $R_s = 0.009\ \Omega$ and secondary winding leakage-reactance, $X_s = 0.03\ \Omega$. (Neglect the component of no-load current that flows in the primary winding).

   i. Calculate the equivalent values of resistance, reactance, and impedance:
      a) in secondary terms
      b) in primary terms

   ii. Calculate the equivalent resistance and reactance drops for a secondary load current of 109A:
      a) in secondary terms
      b) in primary terms

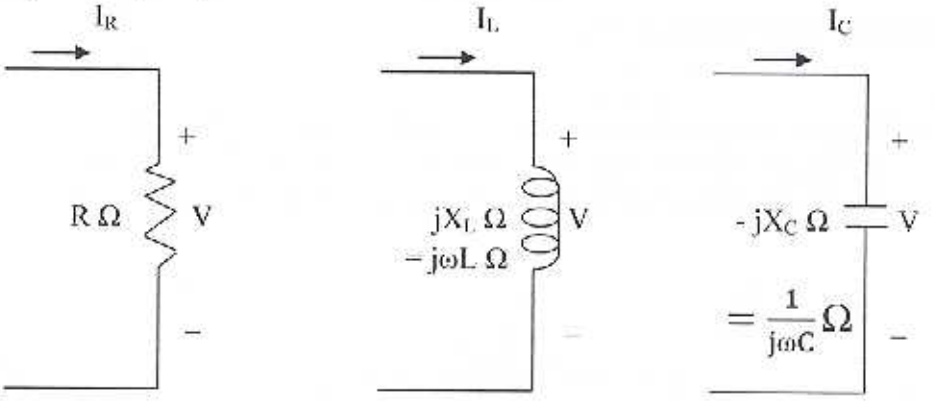
   iii. Calculate the percent regulation of the transformer:
      a) for unity power factor
      b) for a lagging power factor of 0.8
      c) for leading power factor of 0.866

2) A 3-phase fully-controlled thyristor bridge supplies a smooth direct current load, I_L of 100A as shown in the figure:



   i. Sketch the waveforms with respect to time of three-phase input voltages and the load current I_L.
   ii. Calculate the required average and root mean square (rms) current ratings of the thyristors.
   iii. Calculate the rms values of the total supply Alternating Current (AC).

3) (a) In the given figures (i), (ii) and (iii), write the formula for the current I_R, I_L and I_C. Also show the relationships between phasors: V and I_R, V and I_L, and, V and I_C with the help of phasor diagrams. (Assume that all the three circuits are excited with sinusoidal-steady-state inputs)



(i) (ii) (iii)

(b) If the instantaneous voltage applied across a load comprising of R, L and C elements is $v(t) = V_{max} \cos(\omega t+\alpha)$ volts and the instantaneous current flowing into the same load is $i(t) = I_{max} \cos(\omega t+\beta)$ amps.

Show that the instantaneous power p(t) absorbed by the load is:

$$p(t) = VI \cos(\alpha-\beta)\{1+\cos[2(\omega t+\alpha)]\} + VI \sin(\alpha-\beta) \sin[2(\omega t+\alpha)]$$

Where:

$$V = \frac{V_{max}}{\sqrt{2}}$$

and

$$I = \frac{I_{max}}{\sqrt{2}}$$

4) In the digital circuit theory, a NAND gate is also called as a universal gate. Using three NAND gates, illustrate how an OR gate can be obtained through the combination of NAND gates. Also, show the outputs of the gates at each stage by use of truth tables to confirm the final output of the combination as same to that of the OR gate output?

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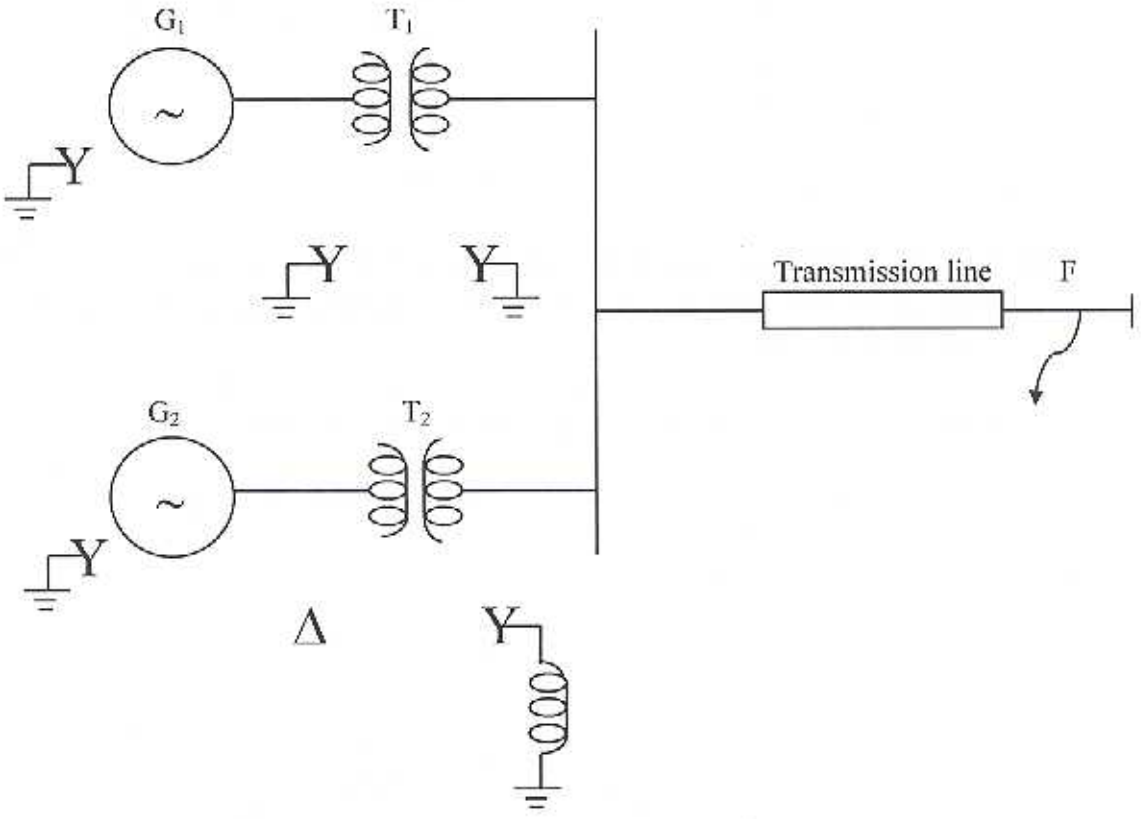
SECTION B – CASE STUDY

Answer any ONE (1) Question:

Q1. i) The figure below shows a typical three phase power system, which is initially operating at no load, meaning that, there is no current supplied by either of the generators and the end of the transmission line at point 'F' is an open circuit. The voltage at 'F' is 515 kV.



Generators G_1 and G_2 are identical and are each rated 300 MVA and 20 kV. They are both star (Y) connected with their star point solidly earthed. The machine constants are $x_d" = 30\%$, $x_2 = 40\%$ and $x_0 = 10\%$

(Note: $x_d"$ = sub-synchronous reactance, x_2 = negative sequence reactance, and, x_0 = zero-sequence reactance)

Transformer T_1 is rated at 20/500kV (that is 20kV:500kV) and 300 MVA and is star-star (Y-Y) connected with both star points solidly earthed. The positive and zero-sequence leakage reactances are both 20%.

Transformer T2 is also rated at 20/500kV and 300 MVA but it is delta-star (Δ-Y) connected with the secondary star point connected to the ground through a pure reactance of 5%. The positive and zero-sequence leakage reactances are both 20%.

The positive and zero-sequence impedances of the transmission line are both j166.67 Ω per phase.

A single line to ground fault occurs at point 'F':

a) Construct the positive, negative and zero-sequence equivalent circuits for the above power system. Draw and calculate their Thevenin equivalents, looking from the point 'F'. (15 marks)

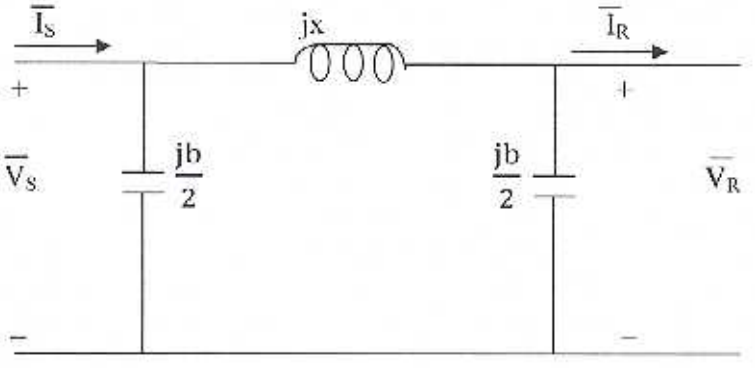
b) Derive the appropriate connection of Thevenin equivalents using the positive, negative and zero sequence Thevenin equivalents obtained in part (a) above, with a view to find the fault currents when a single phase to ground fault occurs at 'F'. (5 marks)

c) Calculate the symmetrical components of the fault current (answers either in per unit systems or actual values will be accepted). (5 marks)

d) Calculate the phase values of the fault currents in Amperes. (5 marks)

(**Hint:** Use per unit (pu) system to simplify the calculations. Assume that the fault occurs on phase 'a')

ii) A 300 km, 500 kV, 1000 MVA transmission line has the following equivalent π-circuit. (20 marks)



Where,

$x = 198.3\ \Omega$ /phase

$b = 2.802 \times 10^{-3}$ S/phase

With characteristic impedance $Z_c = 286.68\ \Omega$

The sending end voltage is held at 1.0 per unit. The transmission line can be assumed to be a lossless line.

i) Find the transmission parameters "T" of the transmission line. (3 marks)
ii) Find the receiving end voltage for each of the following loads, connected at the receiving end:
a) Open circuit. (2 marks)

b) Surge impedance loading. (2 marks)

c) An impedance load of 1.0 per unit, unity power factor. (3 marks)

d) An impedance load of 1.0 per unit, zero power factor, lagging. (3 marks)

e) An impedance load of 1.0 per unit, zero power factor, leading. (3 marks)

f) Short circuit. (2 marks)

iii) Suppose the sending end voltage is 510 kV and receiving end voltage is 500 kV, find the maximum possible real power transfer. (2 marks)

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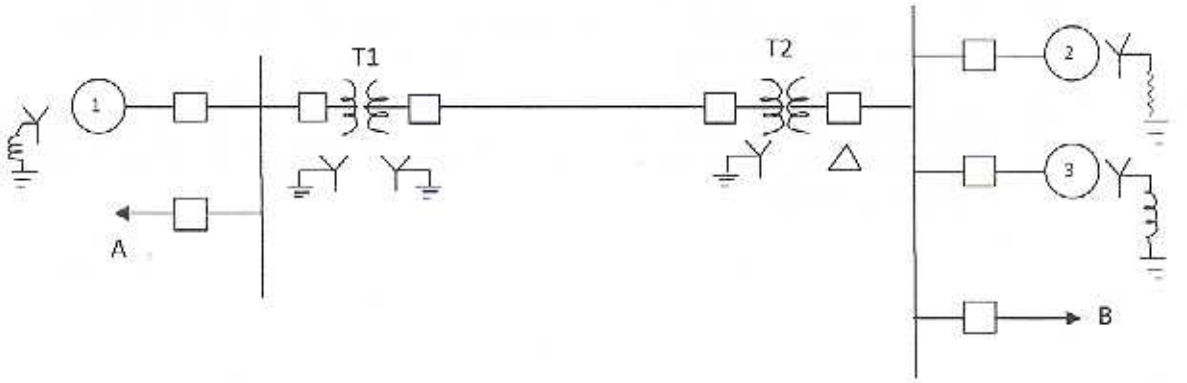
Q2. A rural electrification project involves construction of numerous transmission lines and substations of various lengths and capacities in the project's bid to achieve Electricity for all by a certain target Year. Since the majority of the rural households are located in far away and rugged places, the project has identified construction of several 66/11kV sub-stations across the project sites. The power from 66kV is distributed after stepping down to 11kV voltage levels. While the detailed design and engineering component of the project works were awarded to a consultancy firm, the several project engineers were hired to oversee the construction of the project activities who has adequate knowledge on transmission line and substation construction works. They were gathered to brainstorm on the substation layout and design by the project management with an aim to test their basic skills and were asked to construct a key diagram (Single line) of a typical 66/11kV substation taking the following into consideration:

- The substation has two 66kV incoming lines marked as "Incomer 1" and "Incomer 2" with each incoming line capable of supplying the rated substation load or both lines can be loaded to simultaneously share the substation load.
- The substation involves duplicate bus-bars connected through a "bus coupler".
- The substation has two outgoing 66kV lines which can also acts as incoming lines. Both the incoming and outgoing lines are connected through circuit breakers and isolators.
- There is an arrangement to step down the incoming supply to 11kV by two units of 3-phase transformers each supplying to a separate bus-bar. Either one transformer can supply the entire load or both the transformers can be called upon to share the load.
- There are three outgoing feeders from each bus-bar to supply power to the rural consumers
- The lightning arrestors are connected to the transformers to protect them from lightning.

i) Considering you as one of the project engineers, draw a substation single line diagram with the above given information by representing the components with appropriate circuit symbols wherever necessary and appropriate. (25 Marks)

ii) The project is said to supply power to some localities from the power system whose single-line diagram is given below along with the details of its components. Draw the impedance diagram of the power system so represented. (10 Marks)



Generator No. 1	30MVA, 10.5kV,	X" = 1.6 ohms
Generator No. 2	15MVA, 6.6kV,	X" = 1.2 ohms
Generator No. 3	25MVA, 6.6kV,	X" = 0.56 ohms
Transformer T1 (3 phase)	15MVA, 33/11kV,	X = 15.2 ohms/phase on HT side
Transformer T2 (3 phase)	15MVA, 33/6.2kV,	X = 16 ohms/phase on HT side
Transmission Line	20.5 ohms/phase	
Load A	40MW, 11kV	0.9 lagging power factor
Load B	40MW, 6.6kV,	0.85 lagging power factor

iii) The rural electrification project management has planned to distribute the power using radial distribution system to keep their supply costs to minimum and to expedite the electrification process. However, the consultants to the project has recommended for the interconnected distribution system to increase the service reliability. The interconnected system proposal involves at least two 33/11kV substations feeding a closed feeder ring and supplying power through distribution transformers at 415V (220V) to the rural consumers.

Draw a single line diagram of the proposed interconnected system where power supplies are tapped from the four different locations of the feeder ring?

In your opinion, what would be the two main disadvantages of a radial system of distribution? (10 Marks)

iv) The power to the distribution company who supplies electricity to the rural consumers is supplied by a generation company having an installed capacity of 1,480MW. The annual generation of this company is 6,960 GWh and the company is to provide 15% of this generation as royalty energy to the distribution company at the rate of Nu. 0.30 per unit, while the power drawn beyond this limit is charged at Nu. 1.20 per unit. If the distribution company draws 1500 GWh of electricity in a certain year, calculate: (5 Marks)

a) The Royalty energy eligible to draw in a year in terms of kWh and the corresponding revenue collection, given that 2.5% of the energy is lost as transmission loss?

b) The revenue generated by the generating company by selling power to the distribution company?

c) Assuming that the generating company was allowed to export all the power generated at the export price of Nu. 1.78 per unit, calculate the additional revenue earned as a result?

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