08:30	01/06/2012	H29 - BAL	EXAMS OFFICE

University of the Witwatersrand, Johannesburg

Course or topic No(s)	ELEN4005
Course or topic name(s) Paper Number & Title	POWER TRANSMISSION AND PROTECTION
Examination/Test* to be held during month(s) of (*delete as applicable)	EXAMINATION JUNE 2012
Year of Study (Art & Science leave blank)	FOURTH
Degrees/Diplomas for which this course is prescribed (B.Sc.(Eng.) should indicate which branch)	B.Sc.(Eng.) ELECTRICAL
Faculty/ies presenting candidates	ENGINEERING
Internal examiner(s) and telephone extension	DR JM VAN COLLER 717 7211
External Examiner(s)	MR A BARTYLAK
Special materials required (graph/ music/ drawing paper maps, diagrams, tables, computer cards, etc.)	Single A4 handwritten formula sheet prepared by student is allowed Skin effect curves (attached)
Time allowance	Course: ELEN4005 Hours: 3
Instructions to candidates (Examiners may wish to use this space to indicate, *inter alia,* the contribution made by this examination or test towards the year mark, if appropriate)	a) ANSWER ANY 5 QUESTIONS OUT OF 7 b) ENGINEERING CALCULATORS MAY BE USED c) HANDWRITTEN FORMULA SHEET TO BE HANDED IN (INSERT INTO 1st ANSWER BOOK)

(THIS PAGE TO FOLLOW EXAMINATION COVER SHEET SUBMITTED)

Internal Examiners or Heads of Departments are requested to sign the following declaration:

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Question 1

A three-phase transmission line, operating at 50 Hz, is shown in cross-section in Figure 1.

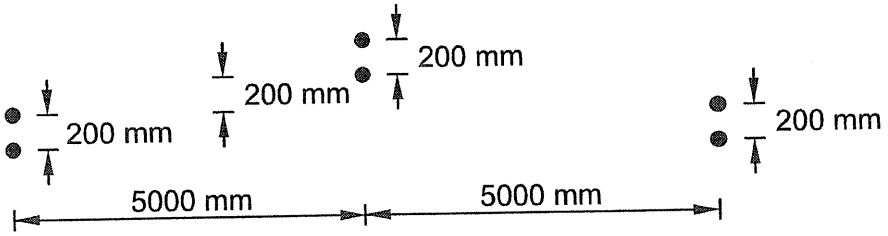


Figure 1: Conductor geometry of a three-phase transmission line

(a) Determine the inductance, capacitance and resistance per unit length per phase taking skin-effect into account. Any assumptions must be clearly stated. Assume a subconductor radius of 15 mm. (14)

Note: $\rho_{al} = 2{,}83 \times 10^{-8} \Omega m$

$\mu_0 = 4\pi \times 10^{-7} H/m$

$\varepsilon_0 = \frac{10^{-9}}{36\pi} F/m$

(b) Does the use of a two-subconductor bundle affect the line inductive reactance? Justify your answer with the relevant equation. (3)

(c) Suggest an alternative phase conductor geometry where transposition would not be required. Justify your answer. (3)

Question 2

(a) Explain why an overhead line would be expected to have a higher X/R ratio than a similarly rated cable. (6)

(b) A 100 km three-phase ac transmission line operating at 50 Hz may be represented by the single-phase equivalent circuit shown in Figure 2.

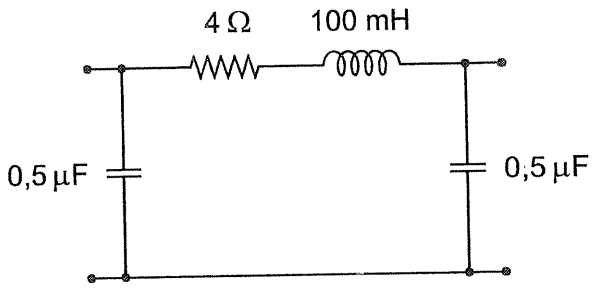


Figure 2: Equivalent circuit of a 100 km ac line

(i) The line operates at 275 kV and supplies a large industrial load of 300 MW at a power factor of 0,94 lagging. Determine the nature and magnitude of the compensation required at the load if both the sending and receiving end voltages are to be maintained at 275 kV. (8)

(ii) Define the Surge Impedance Loading (SIL) of a transmission line and explain why knowledge of its value is important when operating a transmission line. (6)

Question 3

(a) What is meant by the term 'transient stability'? For what type of network is it an issue? (2)

(b) Explain two ways in which the transient stability limit of a long transmission line can be increased. List the advantages and disadvantages of each. (6)

(c) 500 MW is transferred via a double circuit 275 kV three-phase ac transmission line having a series inductive reactance of 30 Ω per circuit. Consider the situation where the load is fed via both circuits operating in parallel and a three-phase short circuit occurs on the one circuit. The fault is cleared by isolating the faulty circuit and throwing all the load onto the other circuit. The inertias of the system are such that, under short circuit conditions, the line load angle increases at a rate of 0,5° per ms. Determine the maximum duration of the three-phase short circuit that the system can tolerate before instability occurs. (12)

Question 4

(a) Why are circuit breakers given short circuit current ratings? What will be the consequence if a circuit breaker is used that is not adequately rated? (4)

(b) Explain with the aid of the circuit diagram of a capacitor-coupled VT (CVT) why it is used to measure 50Hz voltages and not harmonic voltages. (4)

(c) Explain what is meant by a CT nameplate rating of 500/1A, 15VA-10P20. (4)

(d) Explain with the relevant waveforms why it is problematic to use iron-cored CTs in circuits with high X/R ratios. (8)

Question 5

A radial feeder is shown in Figure 3.

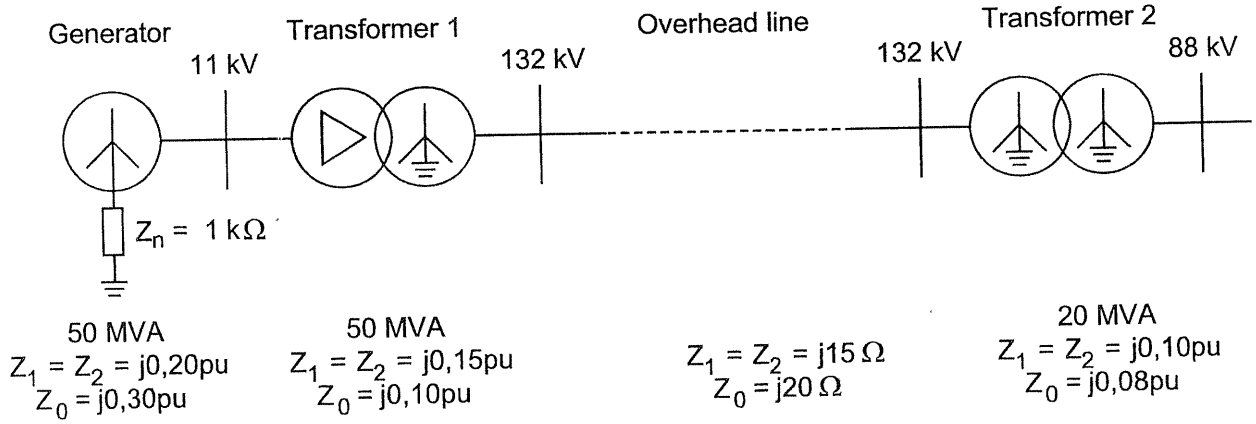


Figure 3: Radial feeder

(a) For single-phase-to-earth faults occurring on the 11 kV, 132 kV and 88 kV busbars, identify for each case the zero sequence current paths. Explain your answers. (5)

(b) Calculate the ratio of the three-phase short circuit currents and the single-phase-to-earth fault currents when the fault occurs

(i) On the secondary side of the 132/88 kV transformer. (5)

(ii) On the secondary side of the 11/132 kV transformer. (5)

(iii) At the generator terminals. (5)

Question 6

IDMT relays (standard inverse) are to be used to protect the network in Figure 4.

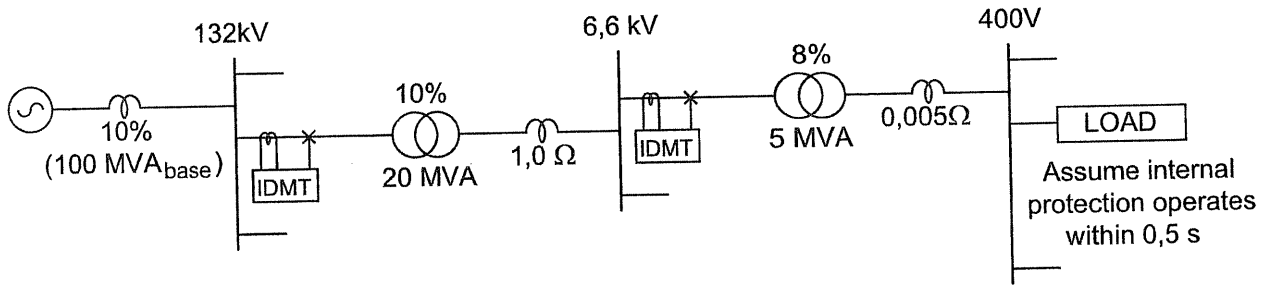


Figure 4: Radial network

(a) Choose suitable CT ratios and calculate suitable settings for the IDMT relays (14)

(b) Why is protection that has an inverse I-t characteristic so widely used? (6)

Question 7

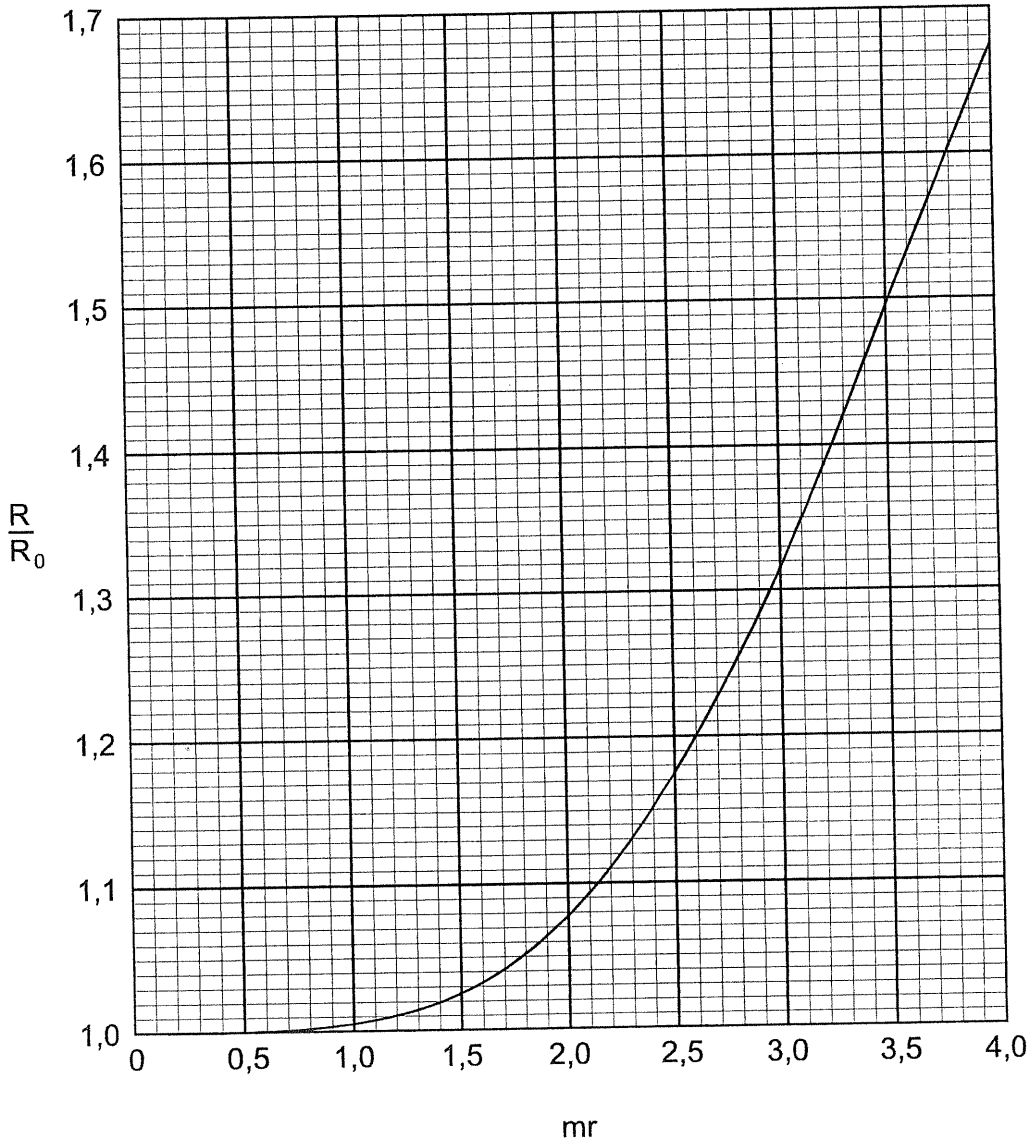
(a) Explain why it is important when using differential protection to protect transformers to know the transformer details (turns ratio, star-delta connection, etc). (6)

(b) Explain why restricted earth fault (REF) protection is widely used for transformer protection. What problems can arise when there is a lot of capacitance within the zone?(6)

(c) Explain what impedances must be known when setting distance protection for overhead transmission lines and why. What problems can be encountered when determining these? (8)

Appendix 1 Skin Effect: Resistance Ratio:

$$m = \sqrt{\frac{\omega\mu}{\rho}}$$ and r is the radius in meters



Appendix 2: Skin effect: Internal Inductance Ratio

$$m = \sqrt{\frac{\omega\mu}{\rho}}$$ and r is the radius in meters