EXAMS OFFICE

University of the Witwatersrand, Johannesburg

Course or topic No(s)	ELEN4018A
Course or topic name(s) Paper Number & Title	POWER SYSTEMS
Examination/Test* to be held during month(s) of (*delete as applicable)	EXAMINATION, JUNE 2018
Year of Study (Art & Science leave blank)	FOURTH YEAR
Degrees/Diplomas for which this course is prescribed (B.Sc.(Eng.) should indicate which branch)	BSc(Eng) ELECTRICAL
Faculty/ies presenting candidates	ENGINEERING
Internal examiner(s) and telephone extension	DR JM VAN COLLER 011 717 7211
External Examiner(s)	DR AKSAY SAHA
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: ELEN4018A; 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 THE 7 b) ENGINEERING CALCULATORS MAY BE USED c) HANDWRITTEN FORMULA SHEET TO BE HANDED IN (INSERT INTO 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.

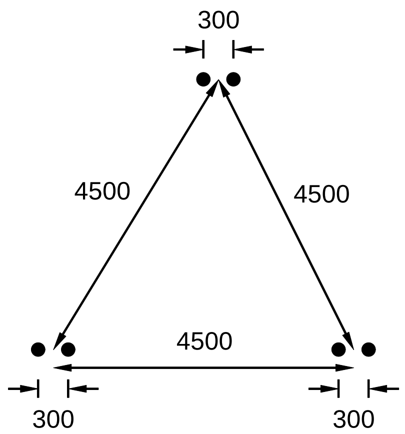


Figure 1: Conductor geometry of a three-phase transmission line. Dimensions in mm

(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. (16)

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

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

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

(b) List two major advantages of a triangular phase conductor geometry (as in Figure 1) over a horizontal phase conductor geometry. (4)

[20]

Question 2

(a) List two major disadvantages of HVDC transmission over HVAC transmission. (4)

(b) A 100 km three-phase transmission line may be represented by the (per phase) equivalent circuit shown in Figure 2.

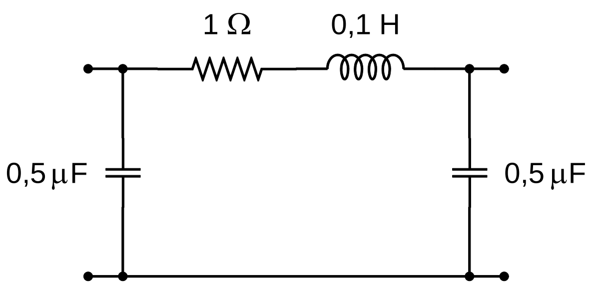


Figure 2: Equivalent circuit of a 100 km HVAC transmission line

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. (16)

[20]

Question 3

(a) Explain the application of the nodal admittance matrix in load flow studies. (10)

(b) 600 MW is transferred via a 400 kV three-phase line having a series reactance of 50 Ω (the series resistance can be ignored). Consider the situation where a three-phase short-circuit occurs on the line. The inertias of the generators are such that, under short-circuit conditions, the load angle increases at a rate of 0,5°/ms. Determine the maximum duration of the three-phase short circuit that the system can tolerate without the generators losing synchronism. What are the assumptions? (10)

[20]

Question 4

A radial feeder is shown in Figure 3.

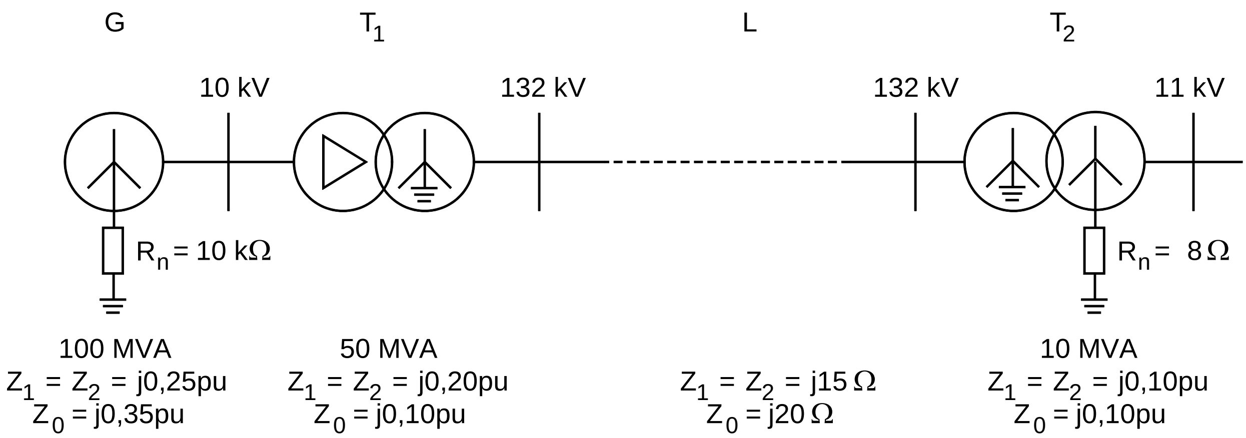


Figure 3: Radial feeder.

(a) For single-phase-to-earth faults occurring on the 10 kV, 132 kV and 11 kV busbars, identify for each case the zero sequence (only) current paths. (3)

(b) Would earth fault protection on the 10 kV side of the 10/132 kV transformer see an earth fault on the 132 kV side? Explain. (4)

(c) Explain the purpose of the delta winding of the 10/132 kV transformer and the very large resistor value at the neutral point of the generator. (4)

(d) For a single-phase-to-earth fault on the 11 kV busbar, calculate the earth fault current. (9)

[20]

Question 5

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

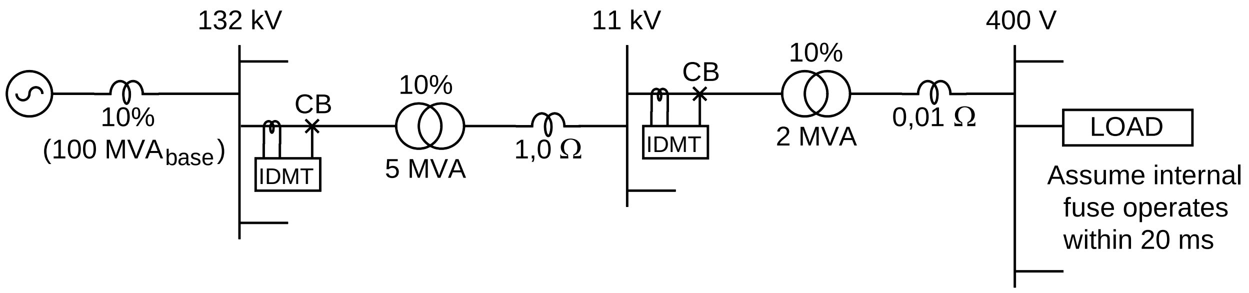


Figure 4: Radial network

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

(b) For your settings in (a), how quickly would a balanced three-phase fault on the 11 kV terminals of the 11 kV/ 400 V transformer be cleared? (6)

[20]

Question 6

(a) Why is simple IDMT-type protection often used for both large and small transformers?(4)

(b) How must the CTs be configured with a star-connected winding with earthed neutral such that an earth fault does not cause differential protection to operate? Explain your reasoning. (4)

(c) What other way could (b) be achieved (assume modern protection relays)? (4)

(d) Explain the concept of zoning when applied to distance protection relays. Assume there are distance protection relays at both ends of the transmission line. Explain how the zones are selected. Also consider the situation where the transmission line interconnects systems containing generation. (8)

[20]

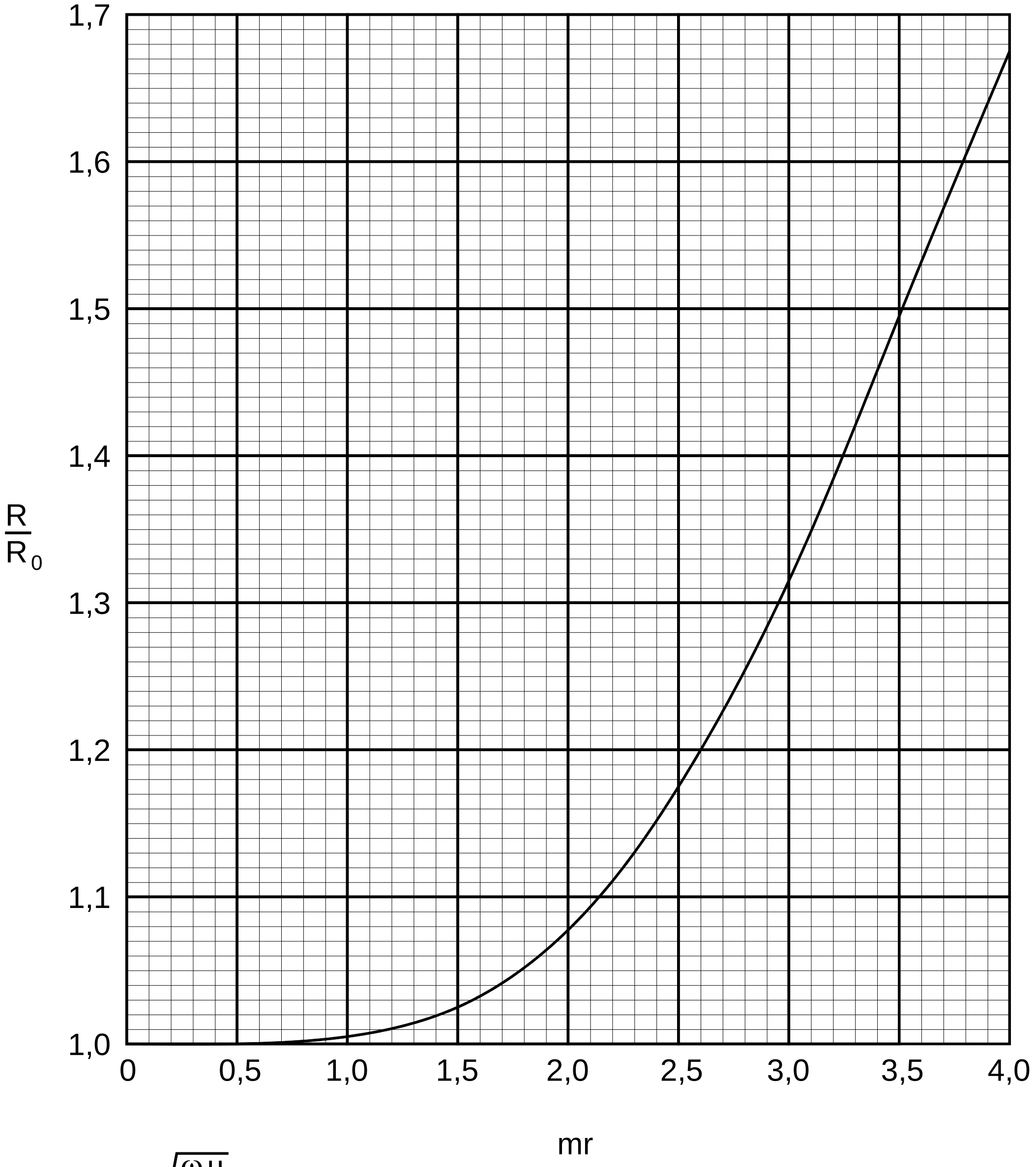
Question 7

(a) Explain, together with its equation, the concept of the Levelized Cost of Energy (LCOE) and where it is used. (10)

(b) Define and explain two concepts in generation investment decision making. (10)

[20]

Appendix 1 Skin Effect: Resistance Ratio



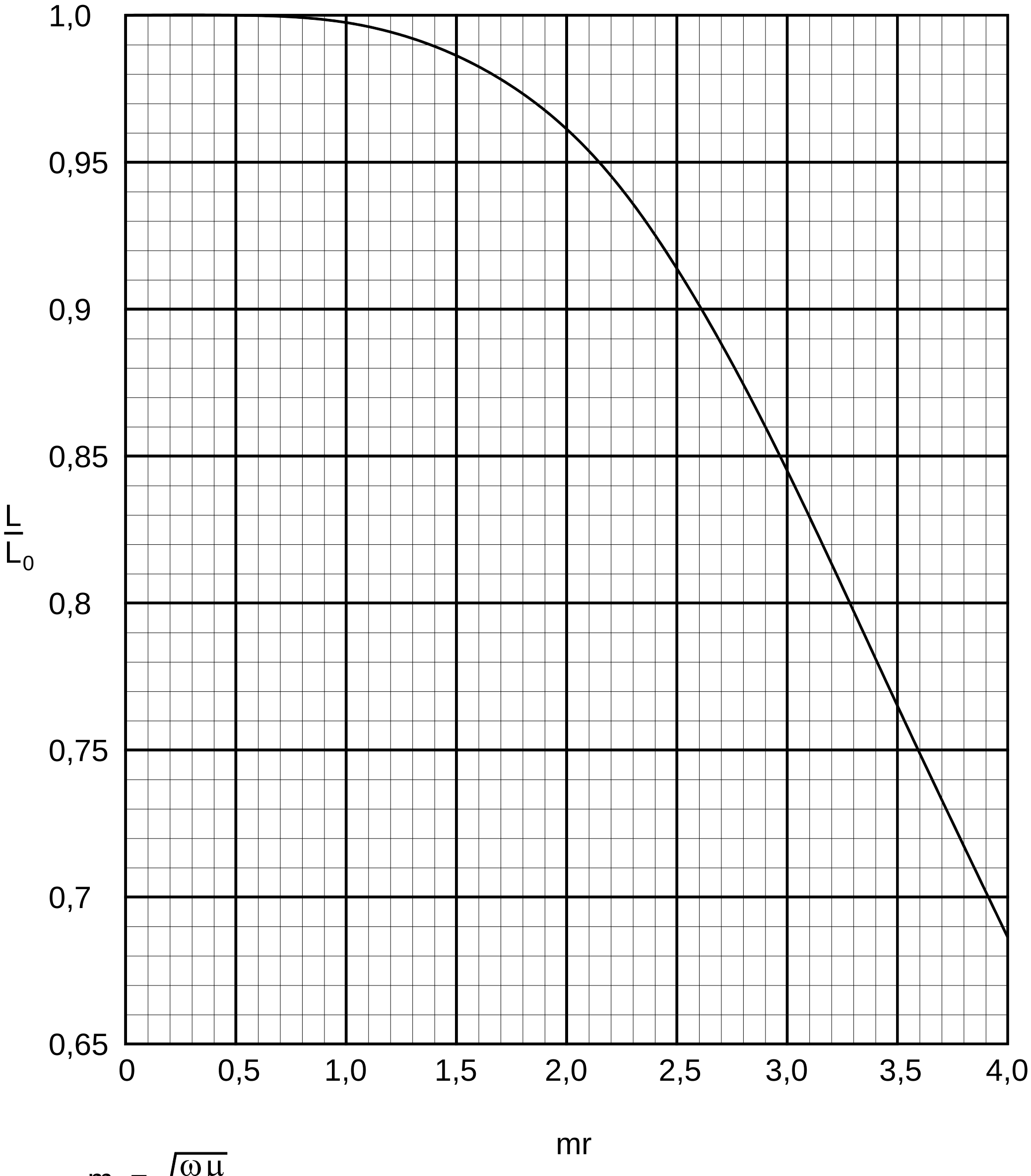
$m = \sqrt{\frac{\omega\mu}{\rho}}$

Skin Effect: Resistance Ratio

$\mu = \mu_r \mu_o$

r = radius, in m

Appendix 2: Skin effect: Internal Inductance Ratio



$$m = \sqrt{\frac{\omega\mu}{\rho}}$$

Skin Effect: Internal inductance Ratio

$$\mu = \mu_r \mu_o$$

r = radius, in m