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 2017
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 011 717 7211
External Examiner(s)	MR T MODISANE
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: ELEN4018 — 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:

- As Internal Examiner/Head of Department, I certify that this question paper is in final form, as approved by the External Examiner, and is for reproduction.

  (application to formal examinations as approved by an external examiner)

- As Internal Examiner/Head of Department, I certify that this question paper is in final form and is ready for reproduction.

  (application to formal tests not requiring approval by external examiner)

(Delete whichever not applicable)

Name: ....

Signature: ....

(THIS PAGE NOT FOR REPRODUCTION)

Question 1

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

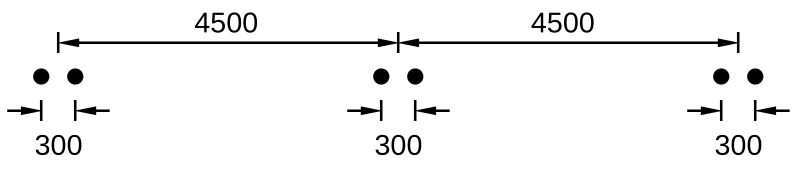


Figure 1: Conductor geometry of a three-phase transmission line. Dimensions in mm

(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 12 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) What are the advantages and disadvantages of a triangular phase conductor geometry compared with a horizontal geometry? (4)

[20]

Question 2

(a) Briefly explain the advantages and disadvantages of HVDC over HVAC for transmission lines. (6)

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

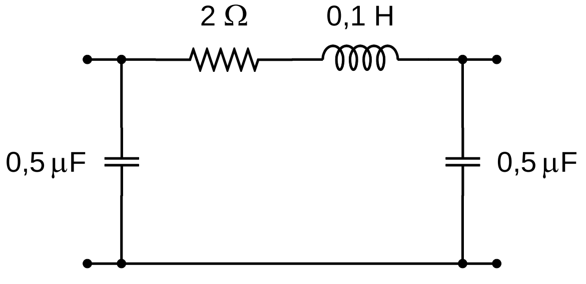


Figure 2: Equivalent circuit of a 100 km HVAC transmission line

The line operates at 400 kV and supplies a large industrial load of 600 MW at a power factor of 0,98 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 400 kV. (14)

[20]

Question 3

(a) What are the three factors that limit the amount of real power that can be transferred along an HVAC line? (6)

(b) 500 MW is transferred via a 400 kV three-phase line having a series reactance of 100 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° per 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)

(c) Does it matter where along the line the short circuit occurs? (4)

[20]

Question 4

(a) Draw the circuit diagram of a capacitor-coupled VT (CVT) connected to a substation busbar and derive the equivalent circuit for 50 Hz operation. What are its advantages and disadvantages over a conventional VT? (6)

(b) Explain what is meant by a CT nameplate rating of 1000/1A, 15VA-10P20. (6)

(c) Show how three CTs can be interconnected to measure the zero sequence current. What is the disadvantage of this connection compared to a single core-balance CT, also used to measure the zero sequence current component. (4)

(d) Why should a current transformer never be open circuited and a voltage transformer should never be short circuited? (4)

[20]

Question 5

A radial feeder is shown in Figure 3.

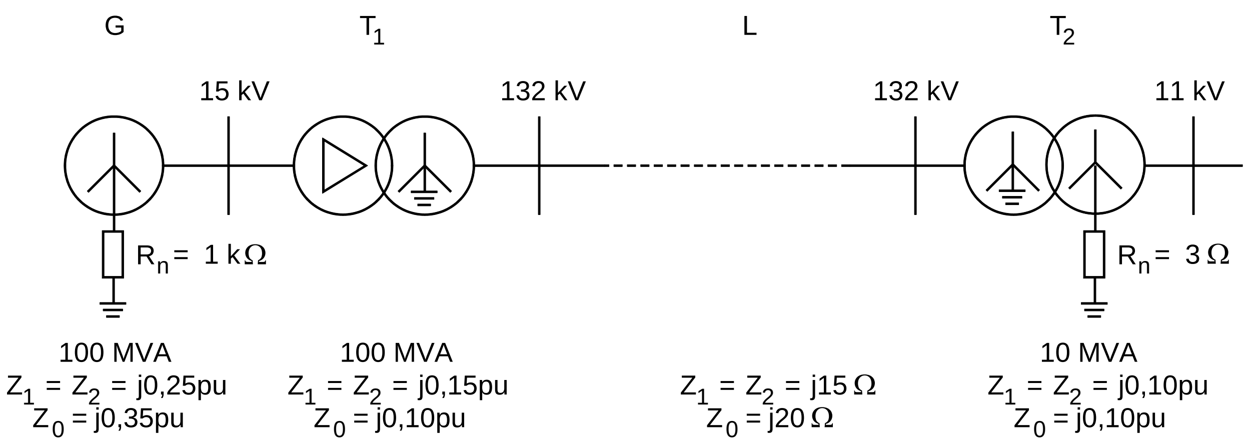


Figure 3: Radial feeder.

(a) For single-phase-to-earth faults occurring on the 15 kV, 132 kV and 11 kV busbars, identify for each case the zero sequence (only) current paths. (4)

(b) Would earth fault protection on the primary side of the 132/11 kV transformer see an earth fault on the secondary side? Explain. (4)

(c) For a balanced three-phase fault on the 11 kV busbar calculate the short circuit current on the 132 kV line. (6)

(d) For a single-phase-to-earth fault on the 11 kV busbar, calculate the current through the 11 kV neutral earthing resistor. (6)

[20]

Question 6

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

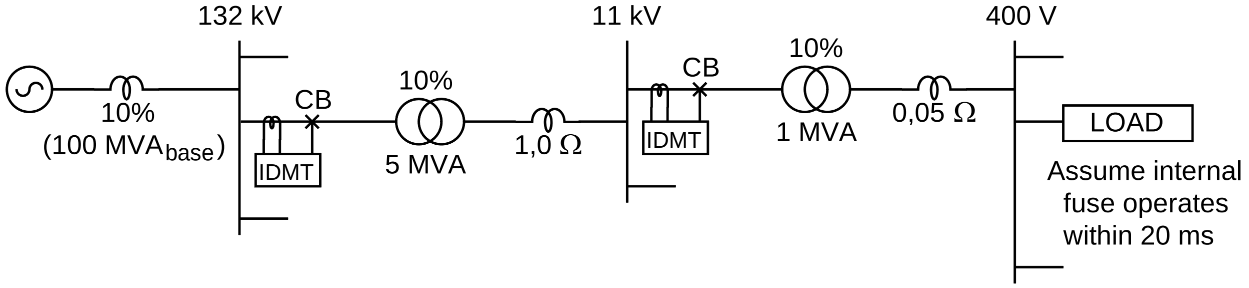


Figure 4: Radial network

(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 7

(a) Why would differential protection be preferred over IDMT protection for a large transformer? (4)

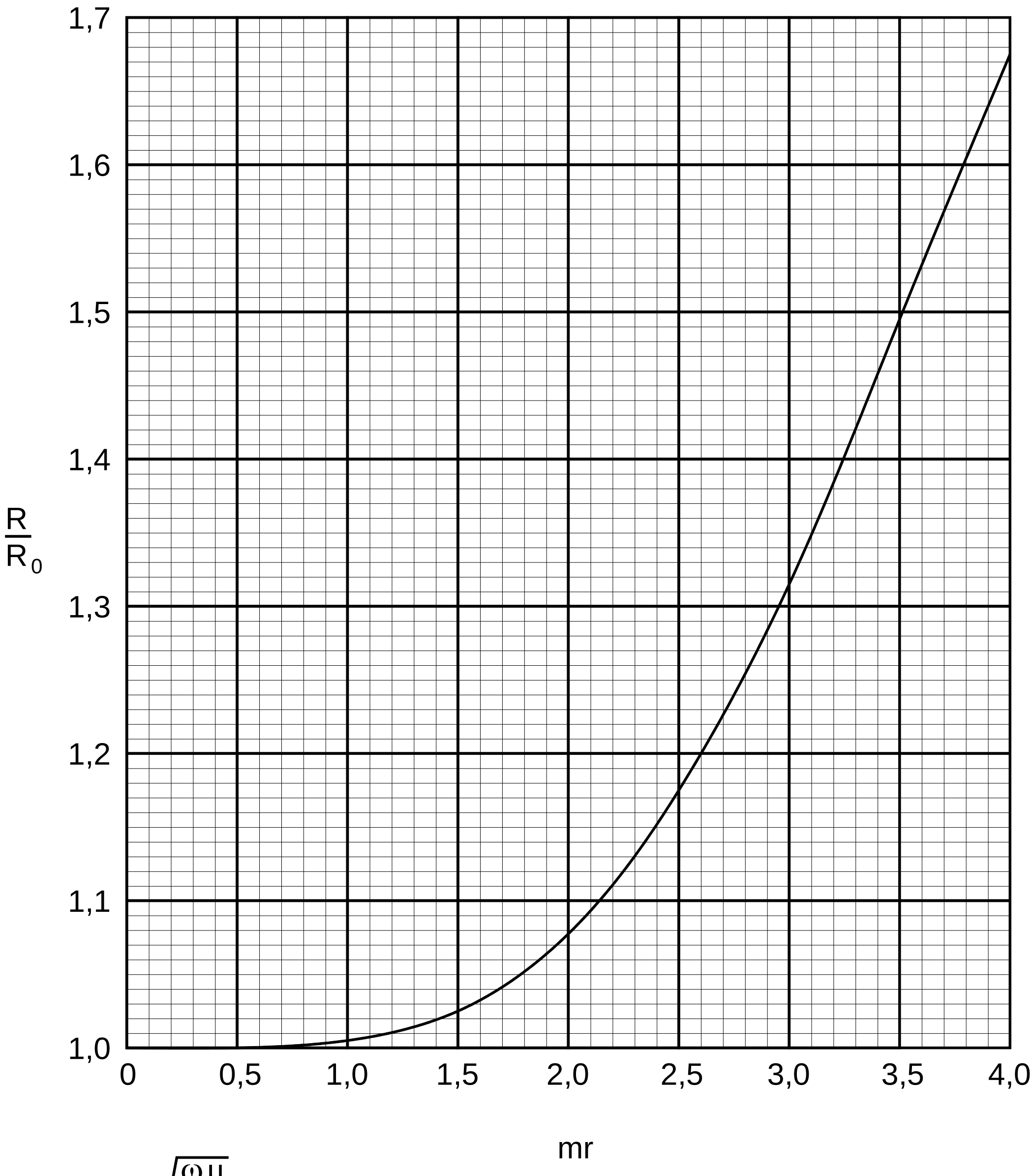
(b) How must the CTs be configured with a star-connected winding with earthed neutral such that a neutral current does not cause the differential protection to operate? Explain your reasoning. (4)

(c) Why is the transformer inrush current such a problem with transformer differential protection? (4)

(d) Explain the concept of zoning when applied to distance relays. Explain how the zones are selected (also consider the situation where the transmission line interconnects systems containing generation). (8)

[20]

Appendix 1 Skin Effect: Resistance Ratio



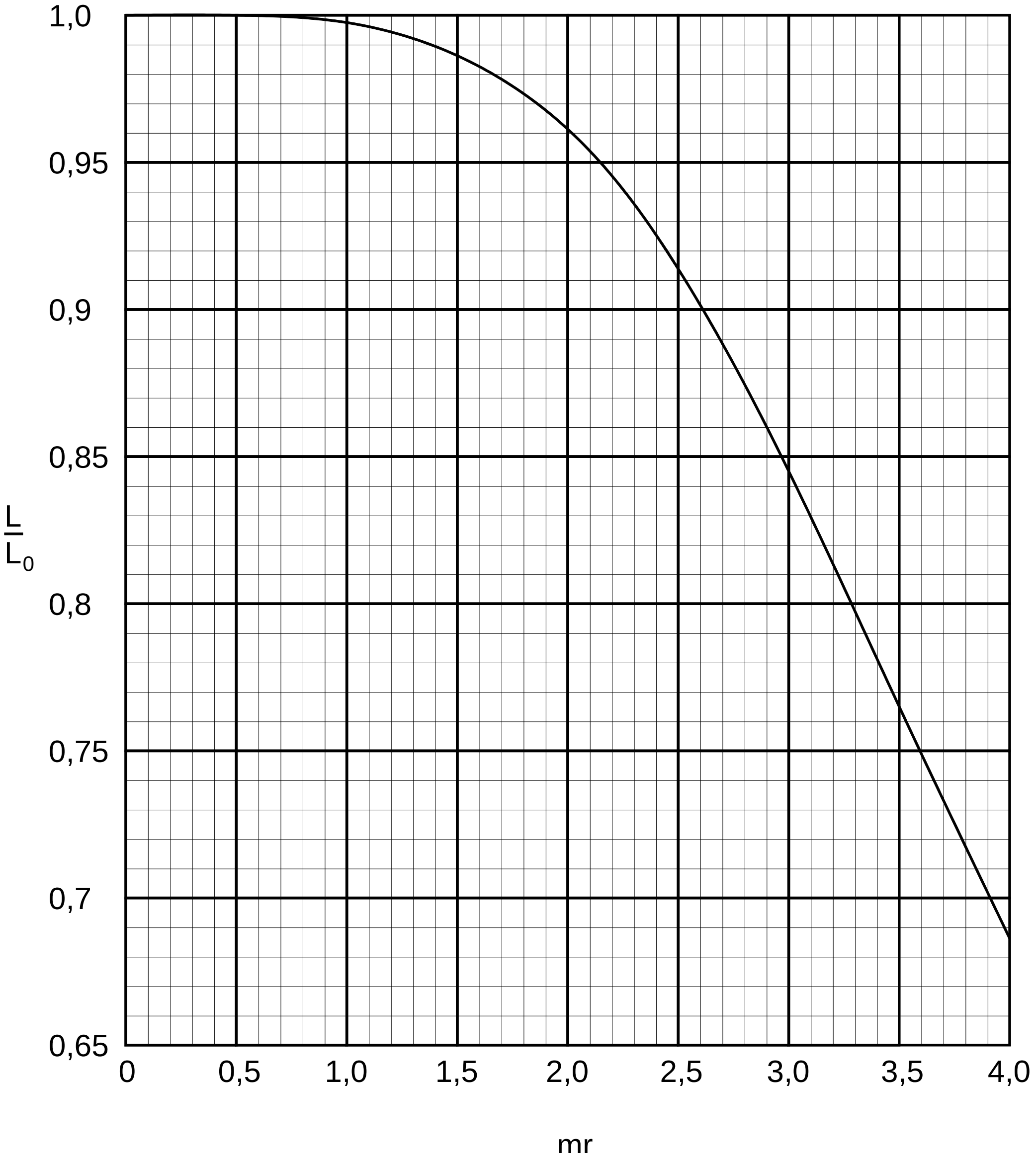
$m = \sqrt{\frac{\omega\mu}{\rho}}$

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