14:00	03/06/2008	SHWWDH	**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 2008
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	PROF JP REYNDERS 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)

Question 1

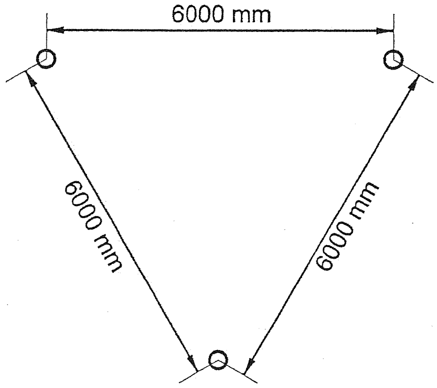


Figure 1: Conductor geometry of a 3-phase power line

(a) A compact three-phase transmission line has a delta geometry for the phase conductors with all three phases passing through a single window in the supporting towers. There is one conductor, 30mm in diameter, per phase and Figure 1 shows the phase spacings. Assuming the conductors to be smooth, solid cylinders of copper and an operating frequency of 50 Hz, determine the inductance, capacitance and resistance per phase for the line under three phase operation. Assumptions made must be justified.

(7)

Note: $r_{Cu} = 1,77 \times 10^{-8}\,\mathrm{Wm}$

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

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

(b) Briefly discuss the advantages of the delta geometry, with all the conductors all passing through the same tower window, in comparison with the more conventional geometry of all three phases in the same horizontal plane and only the centre phase passing through the tower window. Amongst others, consideration should be given to inductance, capacitance and power limit.

(6)

(c) As a short-term measure, the line is to be used for HVDC transmission. The top two conductors will comprise one pole and the lowest conductor the other pole. Determine the circuit inductance, capacitance and resistance for the dc line. All assumptions made must be stated and justified.

(5)

(d) Explain two advantages of the use of bundled conductors, instead of single conductor for each phase or a pole of a transmission line.

(2)

Question 2

Eskom are seriously considering building a power line from the Western Cape to the Inga Dam on the Congo River. This line will cover a distance of 3000km. HVAC or HVDC could be used for this line. Discuss the advantages and disadvantages of both options and briefly motivate the option you believe to be the best technical solution.

(20)

Question 3

(a) Figure 2 shows a radial system with a phase-to-phase fault, short-circuiting phases B and C at point F. Determine the magnitudes of the fault currents in each phase and neutral at the 33kV and 132kV busbars. Determine the magnitude of the phase current at F for a three-phase symmetrical fault at F and comment on the difference in the magnitudes between the two- and three-phase cases.

(15)

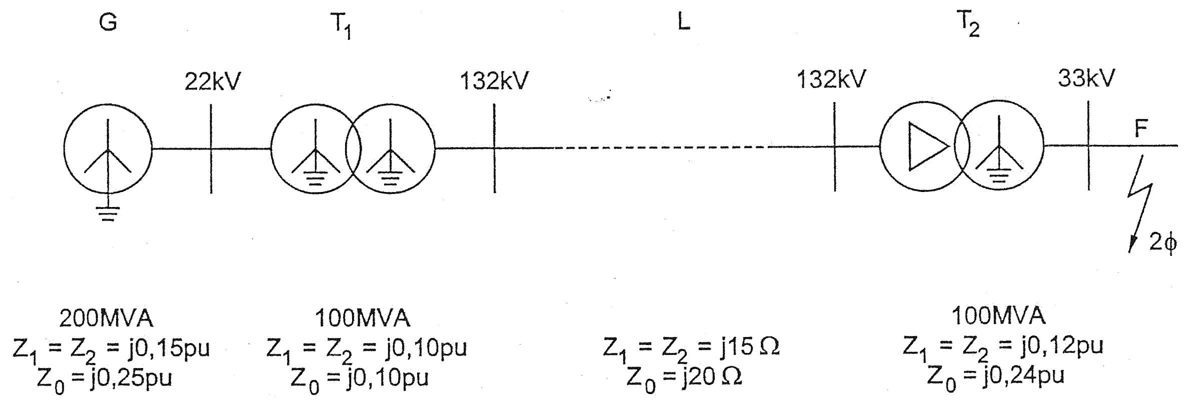


Figure 2: Radial feeder with fault.

(b) Earth faults are the most common type of fault encountered on a power line. In the radial feeder shown in Figure 2, where could impedances be placed to limit the earth fault currents at all three busbars without influencing normal three phase operation? What types of impedances would you recommend (resistance, inductance or capacitance)? Briefly explain your answer.

(5)

Question 4

(a) What is the "Power Limit" of a transmission line and what happens when it is exceeded?

(3)

(b) In a fixed frequency ac system mention two ways in which the power limit of a power line can be increased. Other than cost, are there any possible problems with either method you propose?

(4)

(c) Why is it possible for a line to loose synchronism as a result of a switching operation even if the total load is less than the power limit of the line during and after the switching operation? Only one situation is needed to support your argument.

(4)

(d) A 2 000 MW load is fed via two 400 kV three-phase lines having series impedances of 30 Ω and 40 Ω respectively. Consider the situation where the load is fed from both lines, operating in parallel, and a three-phase short circuit occurs on the 30 Ω line. The fault is cleared by isolating the 30 Ω line and throwing all the load on to the 40 Ω line. The dynamics of the system are such that, under short circuit conditions, the torque angle increases at a rate of 0,3° per ms. Determine the maximum duration of short circuit that the system can tolerate before instability occurs.

(9)

Question 5

(a) Explain why it is voltage rather than current that saturates a transformer. How does this affect the application of CTs?

(8)

(b) Explain what is meant by the X/R ratio of a power system. Why is knowledge of the X/R ratio important when determining the behaviour of CTs during faults?

(4)

(c) Why is CT saturation not an instantaneous effect? How can this knowledge be used in protection relay design?

(4)

(d) Why is it necessary for VTs to be designed with low flux density values during normal network operation.

(4)

Question 6

IDMT relays (standard inverse) are to be used to protect the radial network in Figure 3

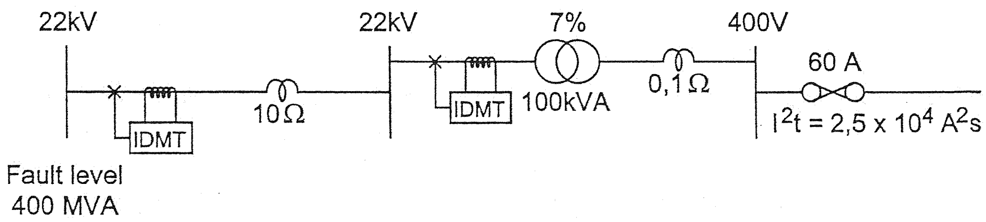


Figure 3: Radial network (22 kV line feeds 100 kVA transformer only)

(a) Choose suitable CT ratings and calculate suitable settings for the IDMT relays. (16)

(a) Explain how the time multipler and the current multiplier for an IDMT relay are determined when protecting a squirrel cage induction motor. (4)

Question 7

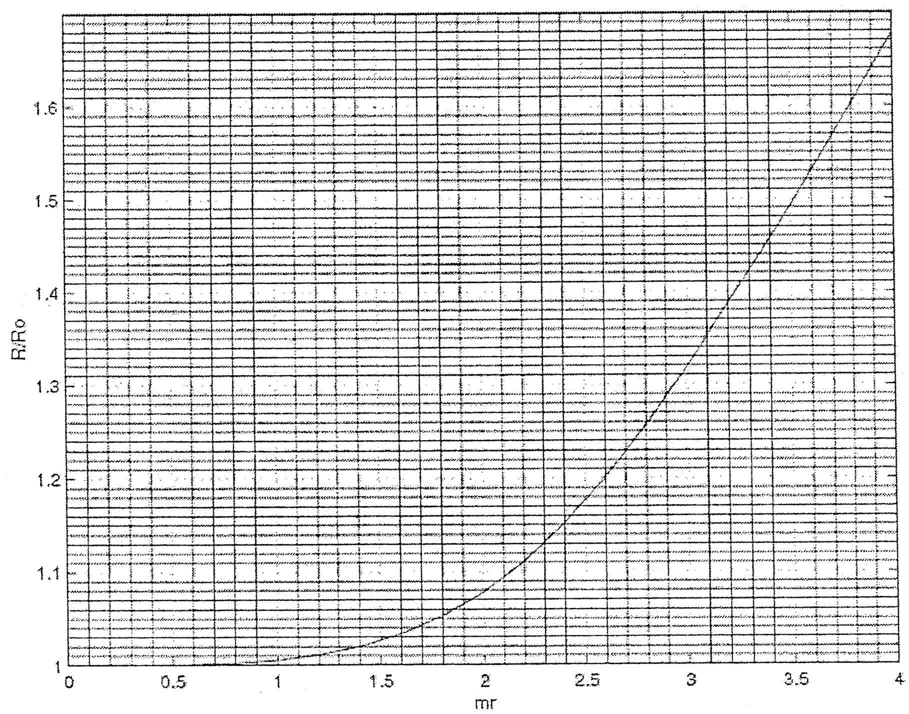
(a) List the various types of protection used with large transformers together with a short explanation of their use. (10)

(b) Explain what is meant by the term "offset Mho" when applied to distance protection. Why is its characteristic popular? (4)

(c) Explain why even though distance protection bases its decisions on the positive sequence impedance value, it is still necessary to know the zero sequence impedance. How could it be measured? (6)

Appendix 1: Skin Effect: Resistance Ratio

$$m = \sqrt{\frac{\varpi\mu}{\rho}} \quad \text{where r is the radius in meters}$$



Appendix 2: Skin effect: Internal Inductance Ratio

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