UNIVERSITY OF KWAZULU-NATAL
HOWARD COLLEGE CAMPUS
SCHOOL OF ENGINEERING

POWER SYSTEMS 2 (ENEL 4WA H1)

MAIN EXAMINATION

DATE: 28 MAY 2016 **TIME: 2 HOURS** **FULL MARKS: 80**

EXAMINERS: DR. AK SAHA (INTERNAL)
MRS. K AWODELE (EXTERNAL)

STUDENTS ARE ADVISED TO FOLLOW THE INSTRUCTIONS BELOW:

- **USE BLACK BALL PEN ONLY**
- ***ANSWER ALL THE QUESTIONS***
- **ALLOCATED MARKS ARE INDICATED IN 'SQUARE BRACKETS' NEXT TO EACH QUESTION**
- **STUDENTS CAN USE SCIENTIFIC CALCULATOR WITH A CLEARED MEMORY**
- ***STUDENTS MUST INDICATE THE QUESTIONS ANSWERED ON THE ANSWER-BOOK FRONT COVER PAGE***

QUESTION 1

(a) Briefly explain steady-state stability limit. **[2]**

(b) A generator is connected to an infinite busbar as shown in Fig. 1 to deliver electrical power. Determine the maximum powers that can be transferred in cases there is (i) no fault in the system and (ii) a three-phase short-circuit fault at 1/4th length of the line 2 from Bus1. **[13]**

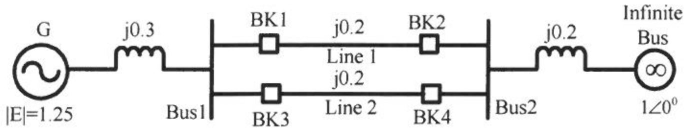

Fig. 1: Generator connected to grid

QUESTION 2

(a) Briefly explain two most important reasons of earthing in electrical power systems. **[2]**

(b) The plan view of an overhead line is shown in Fig. 2 where the legs of each tower form hollow squares of 5 m on a side. An underground copper conductor of negligible resistance internally connects the two sets of towers legs together. Find the total resistance of this earthing system assuming the following:

Depth of tower legs = 4 m Legs = 200 mm × 200 mm of galvanized iron angle
Interconnecting buried earth wire is of 19 strands of 2.8 mm diameter copper wire at a depth of 2.5 m.
Soil resistivity = 75 ohm-m, K for the equilateral arrangement = 4.258 **[16]**

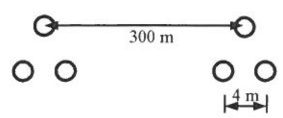

Fig. 2: Transmission tower earthing

QUESTION 3

(a) Mention two most important features of admittance matrix of buses of a power system. **[2]**

(b) Fig. 3 shows a power system having a generator that is connected to a slack bus. For the system: (i) form the admittance matrix for the buses (ii) perform two iterations of Gauss-Siedel method for the voltage at bus 2 (iii) calculate the generated power at swing bus using updated voltages (iv) determine the power factor at which the generator is operating. **[13]**

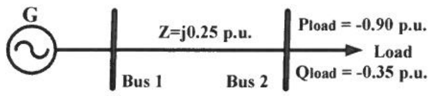

Figure 3: Two-bus system

QUESTION 4

(a) Determine the neutral current and zero sequence currents for a star-connected winding system with neutral isolated from ground. **[3]**

(b) For the single-line diagram of a power system shown in Fig. 4 and for a single-line to ground fault at point F, determine the fault current in phase-A in p.u. Show all the sequence networks with reduced impedances and interconnected sequence networks. **[13]**

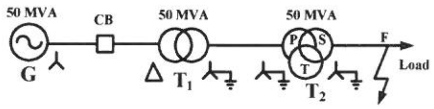

Fig. 4: Power system

TABLE 1: EQUIPMENT REACTANCES FOR FIG. 4

Equipment		X_1	X_2	X_0
Generator G		0.20 p.u.	0.15 p.u.	0.05 p.u.
Transformer T_1		0.15 p.u.	0.15 p.u.	0.15 p.u.
Transformer T_2	Primary	0.10 p.u.	0.10 p.u.	0.10 p.u.
	Secondary	0.08 p.u.	0.08 p.u.	0.08 p.u.
	Tertiary	0.05 p.u.	0.05 p.u.	0.05 p.u.

QUESTION 5

(a) Mention the desirable characteristics of a fuse element. **[3]**

(b) The locations A, B and C are protected as shown in Fig. 5 with overcurrent relays of standard IDMT characteristics and available pickup settings of 50% to 200% in step of 25% of relay current of 1 A. Find the suitable CT ratios at B and C. Hence, find the suitable relay settings at C for a 3-ph fault at 6.6 kV load-side. The protection on the outgoing 6.6 kV feeder is very fast, such that the minimum time settings can be used at C. Operating time for IDMT relay is given by $t_{op} = \frac{0.14}{M^{0.02}-1} \times TM$ where M is the multiple of pickup current setting and TM is the time multiplier with a minimum setting of 0.1. Also, determine operating time of the relay at C for the fault considered. **[13]**

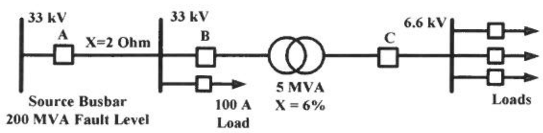

Fig. 5: Protection scheme for power system

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Formula Sheet

Current at bus i, $I_i = \sum_{k=1}^{n} Y_{ik} V_k$

Voltage at bus i, $V_i^{(x)} = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{V_i^{(x-1)*}} - \left(\sum_{\substack{k=1 \\ k \neq i}}^{n} Y_{ik} V_k \right) \right]$

Resistivity from Wenner method: $\rho = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2+4b^2}} - \frac{2a}{\sqrt{4a^2+4b^2}}}$

IEC standard inverse characteristic: $t_{op} = \frac{0.14}{M^{0.02} - 1} TMS$

IEC very inverse characteristic: $t_{op} = \frac{13.5}{M-1} TMS$

Critical clearing angle: $\delta_{cr} = cos^{-1} \left(\frac{P_{\max\_fault} \times cos\delta_0 - P_{\max\_postfault} \times cos\delta_{max} - P_{mech}(\delta_{max} - \delta_0)}{P_{\max\_fault} - P_{\max\_postfault}} \right)$
