UNIVERSITY OF ESWATINI

MAIN EXAMINATION, FIRST SEMESTER

DECEMBER 2019

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Switchgear and Protection

COURSE CODE : EEE551/EE551

TIME ALLOWED: Three Hours

INSTRUCTIONS:

1. **There are five questions in this paper. Answer any four questions. Each question carries 25 marks.**
2. **If you think not enough data has been given in any question you may assume any reasonable values.**

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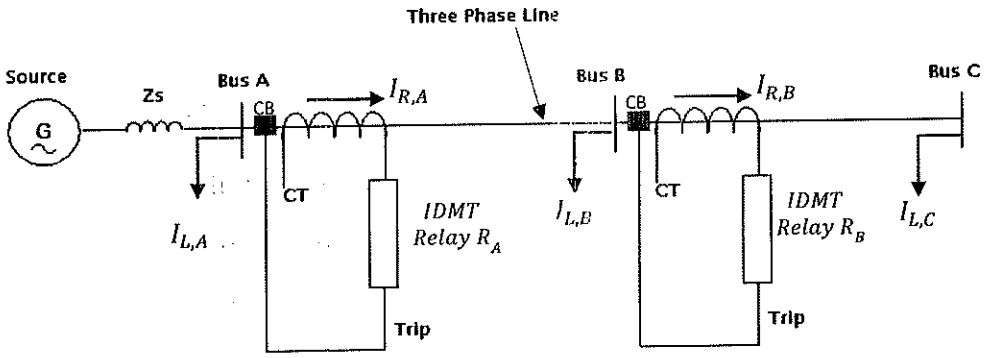
THIS PAPER CONTAINS SEVEN (7) PAGES INCLUDING THIS PAGE

Question 1 ***(25 Marks)***

(a) State any four functions of protective relaying. [4]

(b) What is the difference between a short circuit and an overload? [4]

(c) Consider a radial feeder with three buses A, B and C where very *inverse IEEE* relays are used. The load current at each bus and fault currents when having a fault at each bus are given below



Bus A	Bus B	Bus C
$I_{L,A}$ = 200 A	$I_{L,B}$ = 115 A	$I_{L,C}$ = 125 A
$I_{FA,\,max}$ = 2500 A	$I_{FB,\,max}$ = 2000 A	$I_{FC,\,max}$ = 1500 A

a) Determine the CT ratios and the plug settings for the relays at bus A and bus B. Assume 20% overload when calculating the maximum load, 5 A relay rating is used and the plug settings to be done at 130%. [4]

Note: Assume the available CT ratings are: 100 A, 200 A, 300 A, 400 A, 500 A, 600 A ..., etc.

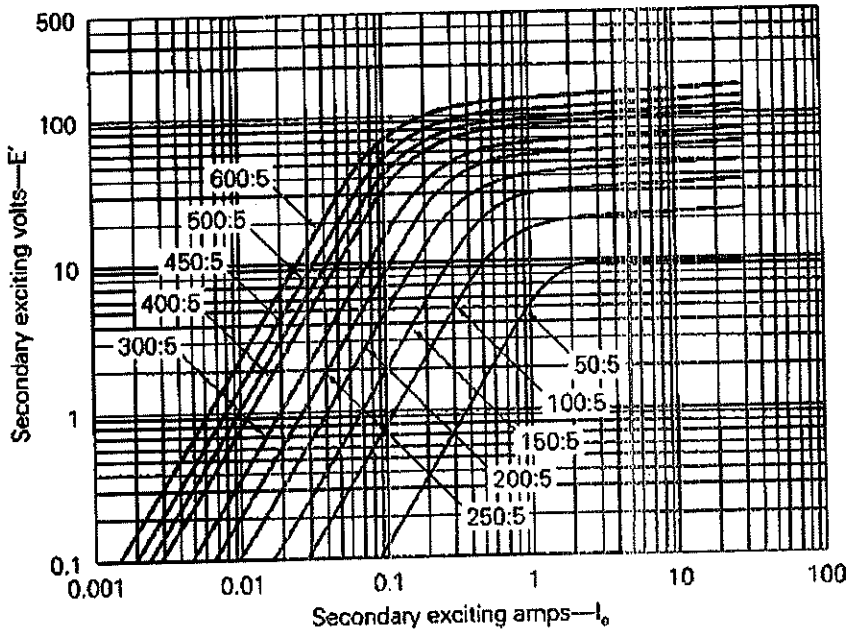
b) Determine the time dial setting for the relay at bus A. Assume the time dial setting for the relay at bus B is 0.1 sec ($T_{DS,B}$ =0.1 sec), each circuit breaker operating time is 0.3 sec (T_{CB} = 0.3 sec) and each relay overshoot time is calculated to be 15% of the summation of relay operating time and circuit breaker operating time of the previous coordinated relay $T_{OS} = 0.15(T_{CB} + T_R)$ [12]

Question 2 (25 Marks)

a) Differentiate between a CT and VT [6]

b) Describe the knee point voltage of Current Transformer [4]

c) The figure below shows excitation curves for a multi-ratio bushing CT with a C100 ANSI accuracy classification.



CT ratio	Secondary resistance Ω
50:5	0.061
100:5	0.082
150:5	0.104
200:5	0.125
250:5	0.146
300:5	0.168
400:5	0.211
450:5	0.230
500:5	0.242
600:5	0.296

Evaluate the performance of the multi-ratio Current Transformer with a 200: 5 CT ratio, for the following secondary output currents $I' = 5$ A and burden $Z_B = 0.5\ \Omega$ [5]

d) A current transformer has turns ratio 1:188 and is rated 1000/5A. The core loss component is 2.5A and the magnetizing component is 8 A under full load conditions. Find the phase and ratio errors under full load conditions if the secondary circuit power factor is 0.75 lagging.

i. The Ratio error [6]

ii. The Phase Angle error [4]

Question 3 (25 marks)

a) Discuss the theories which explain the phenomenon of arc extinction. [4]

b) Compare the oil ,air and SF6 circuit breakers based on the following factors

(i) Safety [2]
(ii) Size [2]
(iii) Maintenance [2]
(iv) Environmental factors [2]
(v) Endurance [2]

c) Define the following terms as used in Circuit breakers

(i) Re-striking voltage [1]
(ii) Recovery voltage [1]
(iii) RRRV [1]

d) A three phase short circuit test of breaker gave the following results:

- ✓ Full line voltage 66 kV
- ✓ Power factor of the fault is 0.3
- ✓ Recovery voltage 0.92 times full line voltage
- ✓ Breaker current is symmetrical with magnitude of 5 kA.
- ✓ Re-striking transient had natural frequency 30 kHz.

(i) Calculate the rupturing capacity of this circuit breaker. [2]
(ii) Determine the average RRRV. Assume fault is grounded [6]

Question 4 (25 marks)

(a) What is meant by the following:

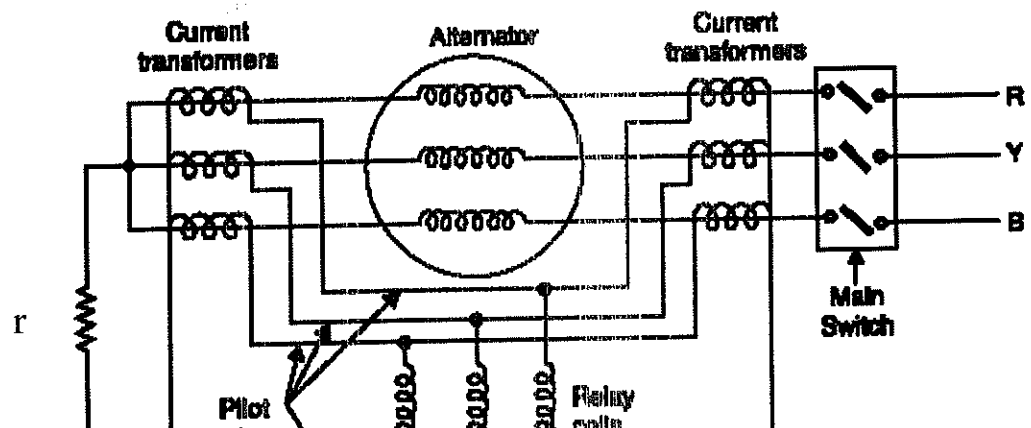
(i) differential relay [2]

(ii) Biased differential bus zone reduction [2]

(b) What are the limitations of Merz Price protection? [4]

(c) Give two advantages of a Peterson coil, and Calculate the inductance and kVA rating of the Peterson coil used for earthing the above system a 66 kV, 3-phase, 50 Hz, 500 km transmission line with a capacitance to earth of 0.27 μF/km per phase.. [7]

(d) A 100 MVA, 132 kV, 3-phase star connected alternator is protected by Merz-Price circulating current system. If the ratio of the current transformer is 200/5, the minimum operating current for the relay is 1 A.



Calculate the minimum resistance to provide protection for 90% of the rotor winding. [10]

Question 5 (25 Marks)

(a) Give the types of transformer faults that can be detected using a Buchholz relay [5]

(b) In ANSI/IEEE (IEEE Standard C37.2-2008) protective relays are generally referred to by standard device numbers. Letters are sometimes added to specify the application. Describe the devices denoted by the following device numbers. [5]

(i) 21
(ii) 27
(iii) 51
(iv) 67
(v) 87

(c) Coordinate the direction of supervision and the time delay between the directional OC relays in the following ring network so that a fault in any section causes only the CBs associated with that section to trip. [6]

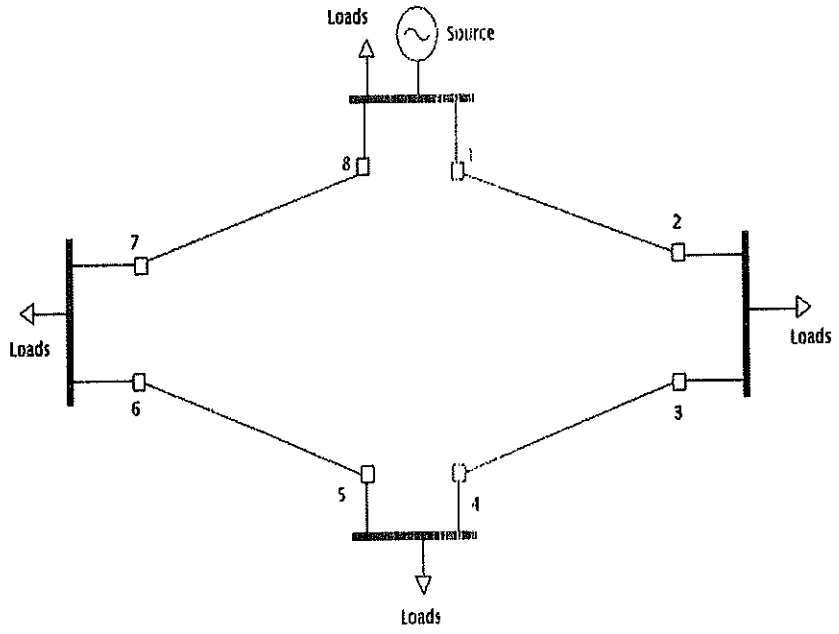


Figure Q5 (c)

(d) If there is a fault in the middle of the line 5-6, which relays are going to energize and what will be their operating time acceding to your coordination? [2]

(e) In the strict sense of protective relaying, we do not consider any control schemes to be an Special Protection System (SPS), but only those protective relaying systems that possess certain properties, discuss the properties of a Special Protection System (SPS) [7]

END OF EXAMINATION

Useful Information

Curve Description	*Standard*	α	β	L
Moderately Inverse	*IEEE*	*0.02*	*0.0515*	*0.114*
Very Inverse	*IEEE*	*2.0*	*19.61*	*0.491*
Extremely Inverse	*IEEE*	*2.0*	*28.2*	*0.1217*
Inverse	*CO8*	*2.0*	*5.95*	*0.18*
Short Time Inverse	*CO2*	*0.02*	*0.0239*	*0.0169*
Standard Inverse	*IEC*	*0.02*	*0.14*	*0*
Very Inverse	*IEC*	*1.0*	*13.5*	*0*
Extremely Inverse	*IEC*	*2.0*	*80.0*	*0*
Long Time Inverse	*UK*	*1.0*	*120*	*0*