UNIVERSITY OF SWAZILAND

SUPPLIMENTARY EXAMINATION, SECOND SEMESTER

JULY 2018

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Switchgear and Protection

COURSE CODE: 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 ONE ***(25 marks)***

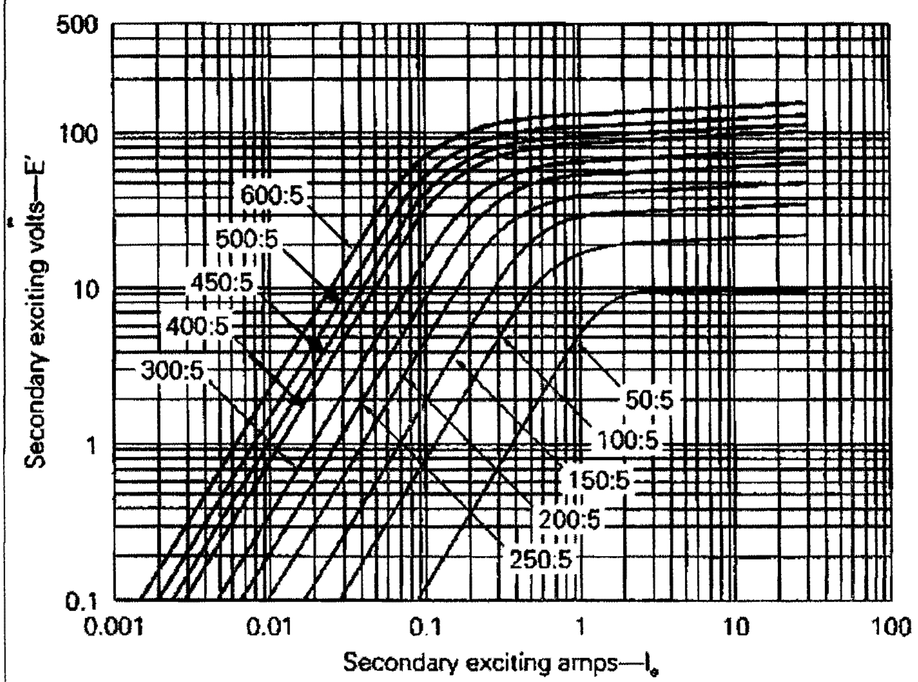
(a) What are the consequences and protection of the following generator faults

i. Prime mover failure. [5]

ii. Loss of excitation [5]

(b) Discuss the properties of a special protection scheme (SPS) [5]

(c) The Fig. Q.1 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

Fig.Q.1

(i) Evaluate the performance of the multi-ratio Current Transformer with a 450 : 5 CT ratio, for the following secondary output currents $I' = 5A$ and burden $Z_B = 0.37\ \Omega$ [10]

QUESTION TWO ***(25 marks)***

(a) With an aid of a labeled diagram show the total clearing time of a fault in a protection system? [6]

(b) Fault current ratings for cables are usually given in the manufacturers' specifications and tables, Refer to **Table 1** at the end, these ratings must be modified by taking into account the fault duration or operation time of the protective device. The cable between breaker 4 and 5 in Fig.Q.2 is a 240 mm^2 PVC/copper cable.

Find the short circuit current that the cable can withstand if the operation time of the protective devices in 4 below is 0.8 seconds. [7]

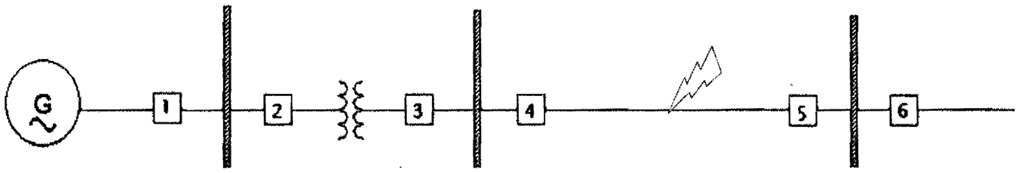


Fig. Q.2

(c) In power system, the causes of over voltage can be categorized into two main categories **Internal causes** example Resonance and External **causes**, example Lightening.

(i) With an aid of a labeled simple RLC circuit, illustrate the Effects of Resonance in Voltage levels. [8]

(ii) How can you protect the power system against resonance conditions [4]

Question Three (25 Marks)

(a) Define the following terms as used in protection relay systems

(i) Pick up value [1]

(ii) Plug setting multiplier [2]

(b) A star connected 3 phase, 15 MVA, 11 kV alternator has a phase reactance of 15%. It is protected by Merz-Price circulating current scheme which is set to operate for fault current not less than 150 A. Calculate the value of earthing resistance to be provided in order to ensure that 90% of the alternator winding is protected. [12]

(c) A three phase Delta-Wye connected 30 MVA; 66/11kv transformer is protected by a differential relay. The ratios on the primary and secondary side are 600: 5 and 5000: 5 respectively as shown in Fig. Q.3.

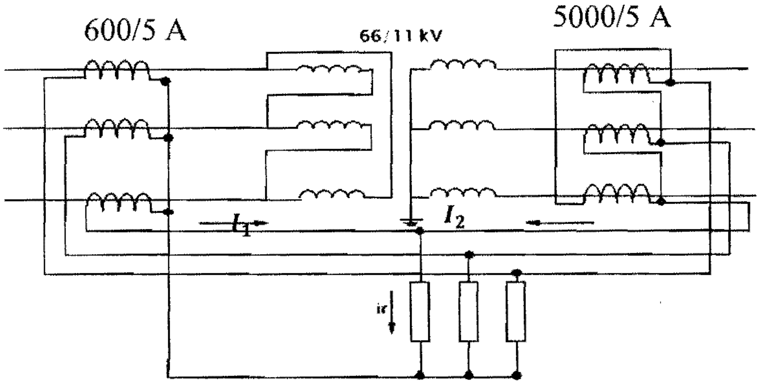


Fig. Q.3

Compute the relay current setting for faults drawing up to 200 % of rated transformer current. [10]

QUESTION FOUR *(25 marks)*

(a) 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. If there is a fault in the middle of the line CD, which relays are going to energize and what will be their operating time acceding to your coordination? [9]

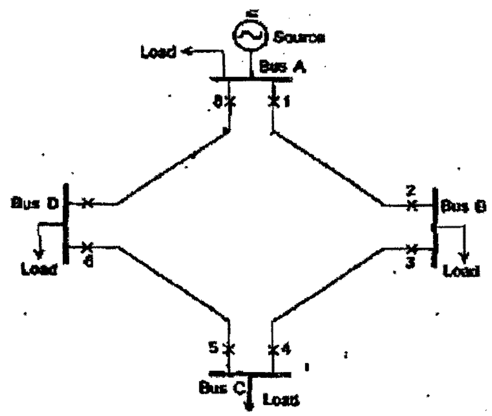


Fig. Q.4 (a)

(b) Draw

(i) The time characteristic of high speed distance relays [4]

(ii) Relay Time Characteristics of the two zone Mho relay shown in Fig. Q.4(b) [4]

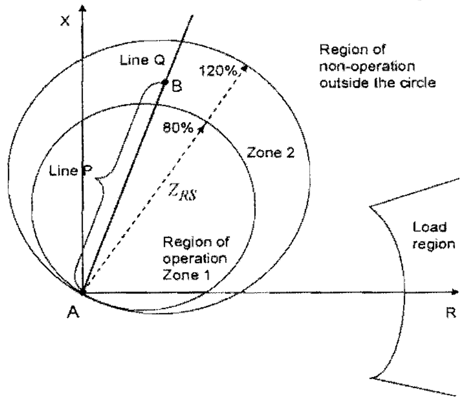


Fig. Q.4 (b)

(c) Find the value of Z_n for a Mho relay with a torque angle of 48° which has to give 100% protection to a 200 km long 132 kV transmission line with 0.78 Ω/ km and angle of 76°, given that the CT ratio is 200:5 and VT ratio is 1000:5 [8]

QUESTION FIVE *(25 marks)*

(a) What are the problems arising in differential protection in power transformer and how are they overcome? [8]

(b) Discuss the phenomena of arcing ground as observed in power systems. [8]

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

- Power factor of the fault is 0.5
- Recovery voltage 0.97 times full line voltage\
- Breaker current is symmetrical with magnitude of 4.154 kA.
- Re-striking transient had natural frequency 20 kHz.

Determine the average RRRV. Assume fault is grounded [9]

Some Useful Information

Table 1

Electrical Properties						
	Current Ratings					
Cable Size (mm^2)	Ground (A)	Ducts (A)	Air (A)	Impedance (Ω /km)	Volt Drop (mV/A/m)	1 s Short-Circuit Rating (kA)
1.5	23	18	18	14.48	25.080	0.17
2.5	30	24	24	8.87	15.363	0.28
4.0	38	31	32	5.52	9.561	0.46
6.0	48	39	40	3.69	6.391	0.69
10.0	64	52	54	2.19	3.793	1.15
16.0	82	67	72	1.38	2.390	1.84
25.0	126	101	113	0.8749	1.515	2.87
35.0	147	120	136	0.6335	1.097	4.02
50.0	176	144	167	0.4718	0.817	5.75
70.0	215	175	207	0.3325	0.576	8.05
95.0	257	210	253	0.2460	0.427	10.92
120.0	292	239	293	0.2012	0.348	13.80
150.0	328	269	336	0.1698	0.294	17.25
185.0	369	303	384	0.1445	0.250	21.27
240.0	422	348	447	0.1220	0.211	27.60
300.0	472	397	509	0.1090	0.189	34.50

$K = 115$ for PVC/copper cables of 1000 V rating
$K = 143$ for XLPE/copper cables of 1000 V rating
$K = 76$ for PVC/aluminum (solid or stranded) cables of 1000 V rating
$K = 92$ for XLPE/aluminum (solid or stranded) cables of 1000 V rating.