ABET Outcomes Assessment: *c*

28.5/30

Grade: 28.5/30

University of Jordan | School of Engineering | Electrical Engineering Department

EE482: Power System Analysis (2) | Final Exam | 1st Semester 2017-2018 | 10/01/2018 | Time: 09:00-11:00

Q # 1 (5)	Q # 2 (3)	Q # 3 (8)	Q # 4 (3)	Q # 5 (4)	Q # 6 (5)	*Q # 7 (7) c	Q # 8 (10)	GRADE
5	3	8	3	4	5	7	7.5	42.5/45

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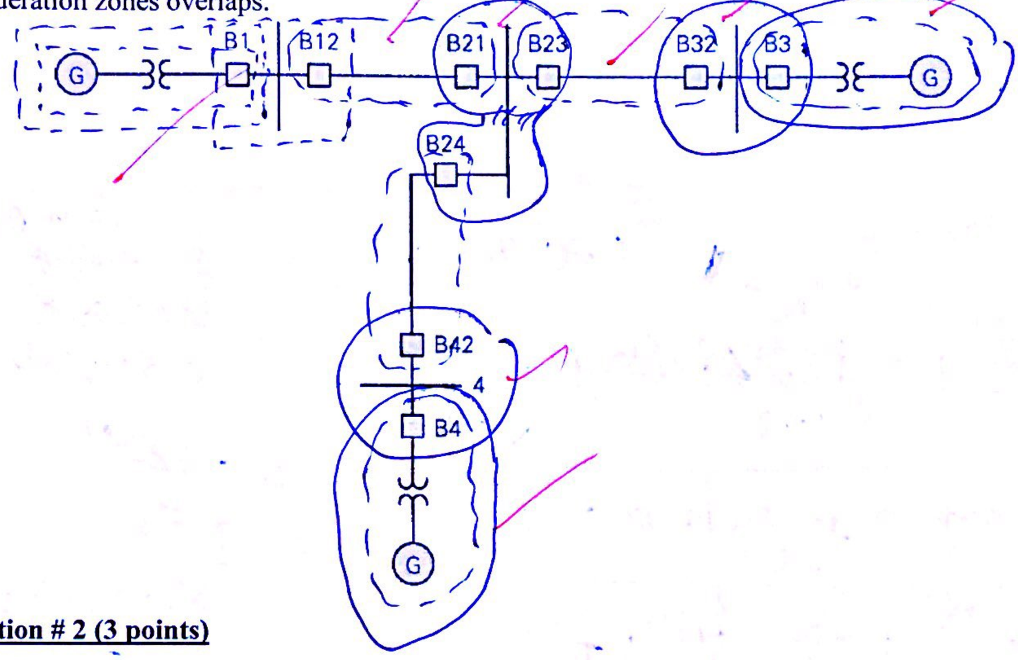
Question # 1 (5 points)

Draw the protection zones for the following power system (Gen, TX, Motor, TL, etc) taking into consideration zones overlaps.



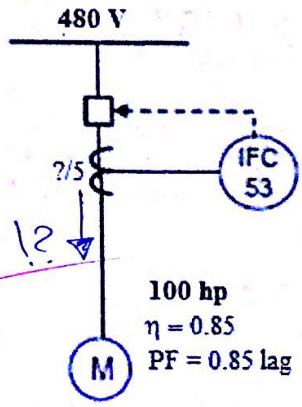
Question # 2 (3 points)

A 100 hp, 480 V, 0.85 PF, motor consumes 88 kW at full-load condition. If the motor is **not allowed** to work beyond full-load condition, select:

a.	the appropriate CT ratio with 5 A secondary	*CTR* =	150/5	A
b.	the current tap setting of the IFC53 OC relay	*CS* =	5	A

CTS

- For the IFC53, the available ampere-tap (AT) settings are 0.5, 0.6, 0.7, 0.8, 1, 1.2, 1.5, 2, 2.5, 3, 4, 5 & 6 A.
- Use CTs with Ratios: 100/5, 150/5, 200/5, 250/5, 400/5, 600/5, 800/5.



$P = 88K = \sqrt{3} I_L V_L \cos\theta$ (PF)

$I_L = \frac{88 \times 10^3}{\sqrt{3} \times 480 \times 0.85} = 124.5A \angle -31.8°$

~~$I = \frac{124.5}{CTR}$~~ the appropriate CTR is 150/5

$CTS = I_{pickup} = \frac{124.5}{\frac{150}{5}} = 4.15 A$.

take 5A

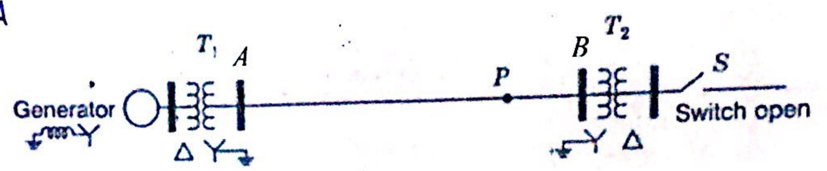
1

Question # 3 (8 points)

The single-line diagram of a small power system along with its parameters is shown below.

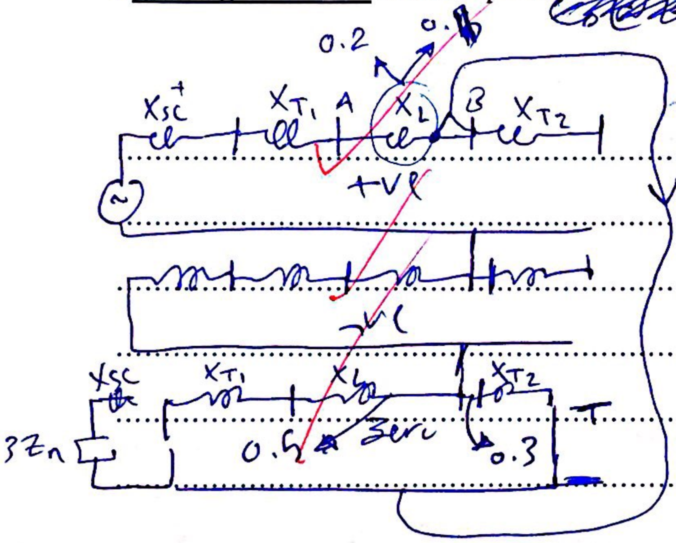
Generator: 100 MVA, 20 kV; $X^+ = X^- = 20\%$, $X^0 = 4\%$, $X_n = 5\%$
Transformer T₁: 100 MVA, 20Δ/220Y kV; $X^+ = X^- = X^0 = 10\%$
Transformer T₂: 100 MVA, 20Δ/220Y kV; $X^+ = X^- = X^0 = 10\%$
Transmission line: on base of 100 MVA, 220 kV the reactance are
From ***A*** to ***P***: $X^+ = X^- = 20\%$, $X^0 = 50\%$
From ***B*** to ***P***: $X^+ = X^- = 10\%$, $X^0 = 30\%$

$MVA_b = 100\,MVA$



If the pre-fault voltage at point ***P*** is 220 kV, determine the fault current in per unit and in amperes if a **line-to-ground fault** occurs at point ***P***.

I_f =	~~2.6786~~ 2.4194 pu	pu
I_f =	~~702.95~~ 634.85	A



$I_{LG} = 3I^{(0)}$

$= \frac{3E_a}{X_0 + X_1 + X_2}$

$X_1 = X_2 = 0.5 = 0.2 + 0.1 + 0.2$

~~$X_0 = 0.1 // 0.6$~~

~~$X_0 = (0.1+0.1) // (0.1+0.3)$~~
~~$= 0.12$~~

$X_0 = (0.1+0.3) // (0.5+0.1)$

$= 0.24$

So $I_{LG} = \frac{3}{0.24 + 2\times0.5}$

$= 2.4194\,pu$ ~~2.6786 pu~~

$I_b = \frac{100\times10^6}{\sqrt{3}\times220\times10^3} = 262.4\,A$

So I_{LG} = ~~702.95 A~~

634.85 A

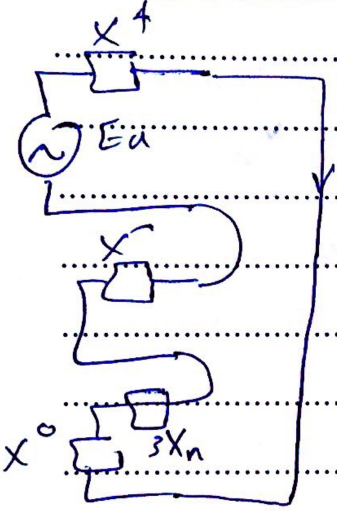
Question # 4 (3 points)

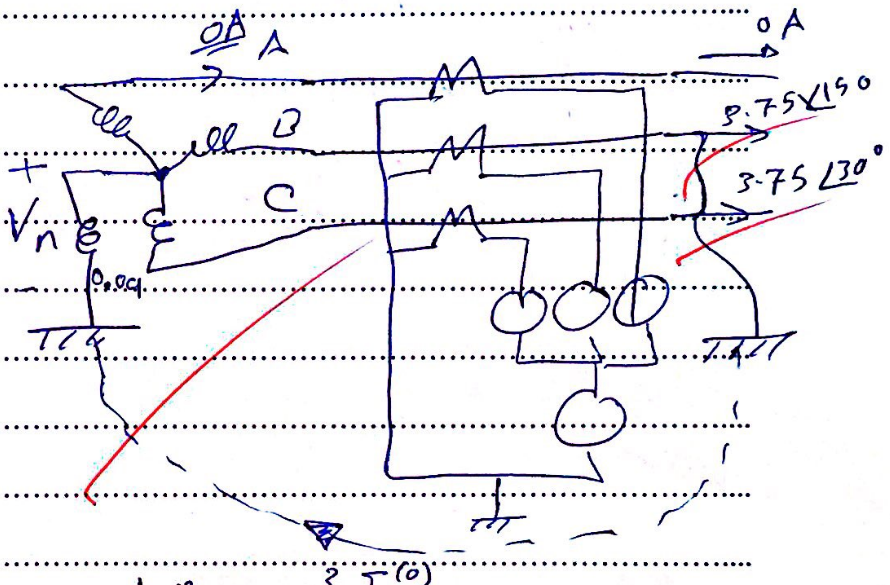
A Y-connected synchronous generator has sequence reactances $X^0 = 0.09$, $X^+ = 0.22$ and $X^- = 0.36$ all in p.u. The neutral point of the generator is grounded through a reactance of 0.09 p.u. The generator is running on no-load with rated terminal voltage when it suffers unsymmetrical fault. The fault currents out of the generator are

$$I_a = 0.0 p.u \quad I_b = 3.75\angle 150^0 \; p.u \quad I_c = 3.75\angle 30^0 \; p.u$$

Determine:

a.	the type of the fault.	LG	LL	LLG	LLL	LLLG
b.	The voltage of the neutral point of the generator with respect to the ground.	$\lvert V_n \rvert =$	0.3375			V





$$I^{(0)} = \frac{E_a}{X^+ + X^- + X^0 + 3X_n} = \frac{1.0}{0.09 + 0.22 + 0.36 + 3 \times 0.09}$$

$$I^{(0)} = 1.0638 \Rightarrow I_{LLG}$$

$$I_{residual} = I_B' + I_C'$$

$$I_{earth} = I_b + I_c = 3.75\angle 90^0$$

so $|V_n| = |I_n| \times |0.09| = 0.3375$ volt

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Question # 5 (4 points)

i. The circuit shown below has a line-to-line fault of 10 kA going out of line B and back on line C. Choose the current through line B to be as the reference line and show the directions of current flow through the CTs and relays, then calculate:

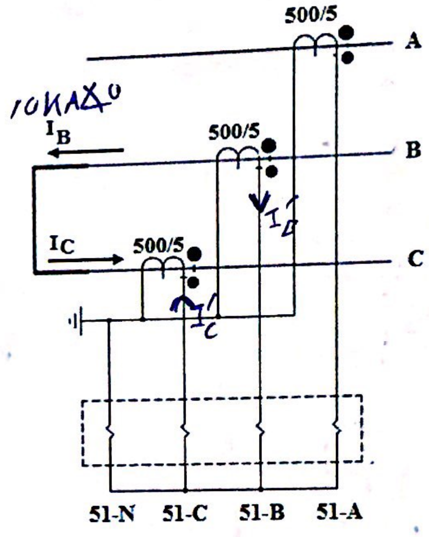
a.	the currents through the OC phase relays	$I'_A =$	0	A
		$I'_B =$	100 ∠0	A
		$I'_C =$	100 ∠180°	A
b.	the current through the EF relay, I_r	$I_r =$	0	A

$I_A' = 0$

$I_B' = \frac{10K}{500/5} = 100\angle 0\ A$

$I_C' = 100\angle 180°\ A$

$I_r = I_B' + I_C' = $ zero.



ii. If a LLG fault occurred on phases *B* and *C* with $I_B = 10\angle 150°$ kA and $I_C = 10\angle 30°$ kA, show the directions of current flow through the CTs and relays, then calculate:

a.	the currents through the OC phase relays	$I'_A =$	0	A
		$I'_B =$	100 ∠150°	A
		$I'_C =$	100 ∠30°	A
b.	the current through the EF relay, I_r	$I_r =$	100 ∠90°	A

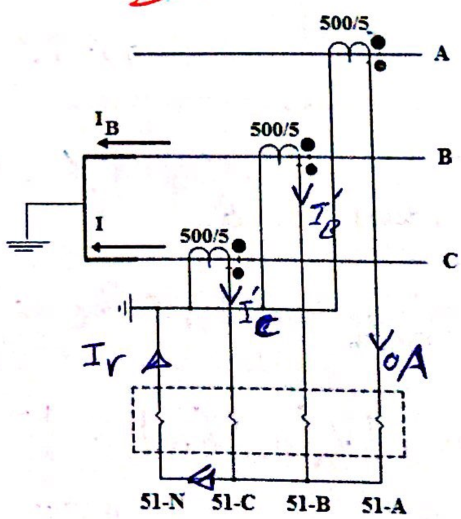
$I_A' = 0$

$I_B' = \frac{10000\angle 150}{500/5} = 100\angle 150°\ A$

$I_C' = 100\angle 30°\ A$

$I_r = I_B' + I_C'$

$= 100\angle 90°\ A.$



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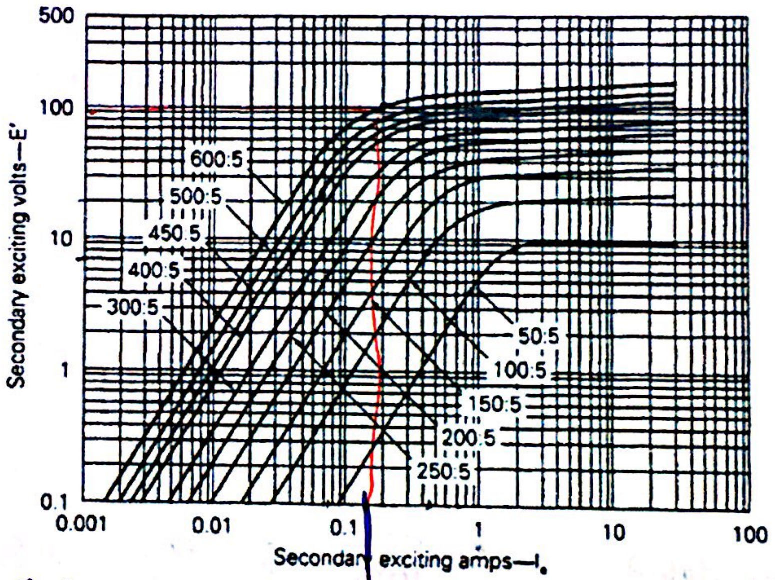
Question # 6 (5 points)

Assume that a CT has rated current ratio of 600/5A. The impedance of the secondary winding $Z_s = 0.1 + j0.5\ \Omega$ and the burden impedance $Z_b = 6.8 + j1.5\ \Omega$. The lead impedance is negligible. The core X-section area $A = 2.8\times10^{-3}\ m^2$. The CT must operate at maximum primary current of 1500 A. The core is built from silicon steel with a 60 Hz frequency magnetization characteristics as shown below. If the lower limit of saturation occurs at $B_m = 1.2$ T, calculate:

a.	the secondary current, I_s	$I_s =$	12.5	A
b.	the voltage induced on the secondary coil, V_s	$V_s =$	89.8 ∠16.2°	V
c.	determine whether or not the CT will saturate		Yes	(No)
d.	the secondary exciting current, I_e	$I_e =$	0.15	A
e.	the CT percentage error, ε.	$\varepsilon =$	1.2	%

$Z_s = 0.1 + j0.5$
$Z_b = 6.8 + j1.5$
$A = 2.8\times10^{-3}\ m^2$
$I_{prim} = 1500$ A
$f = 60$ HZ.
$B = 1.2$



0.15

$I_s = \frac{1500}{600/5} = 12.5$ A

$V_s = I_s \times R_{Total} = 12.5 \times (Z_s + Z_b)$

$= 12.5\,(6.9 + j2) = 89.8 \angle 16.2°$

$V_K = 4.44\ BAfN = 107.4$ volt. volt.

so it won't saturate.

from the curve $I_e \simeq 0.15$ A

$\varepsilon = \frac{I_e}{I_{prim.}} = \frac{0.15}{12.5} \times 100\%$

$= 1.2\%$

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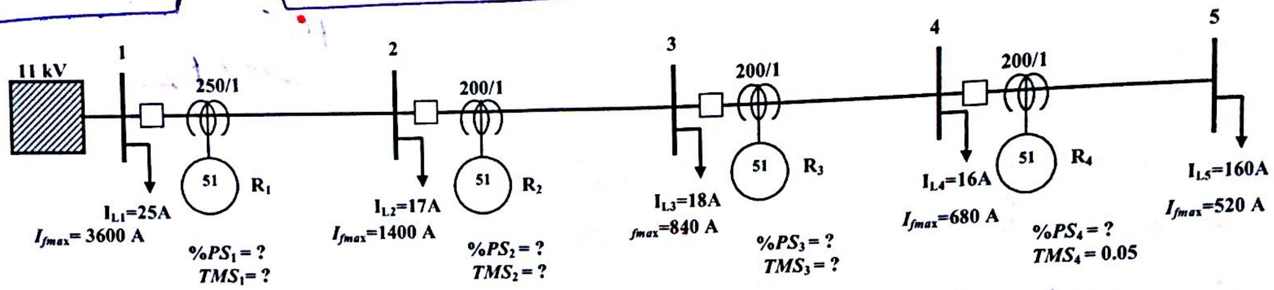
Question # 7 (7 points) **ABET outcome *c* Assessment**

A simple 11 kV radial system, with a single infeed at bus **1** and five loads at busbars (**1 - 5**). The sysem is protected with **numerical O/C** relays **R1 – R4** with standard inverse (***SI***) characteristics

$$t_p = \left(\frac{0.14}{I_r^{0.02} - 1} \right) \times TMS$$

Based on the maximum load current in the feeder, the CT ratios have been selected for CTs **1 - 4**, as shown below. The maximum fault current (I_{fmax}) at the buses **1 – 5** are shown below. If the TMS of **R4 is set at 0.05** and the **grading time ΔT is 0.3 sec**, find



a.	the %*PS* settings for relays **R4**, **R3**, **R2**, and **R1**	%*PS*4=	80%
		%*PS*3=	88%
		%*PS*2=	97%
		%*PS*1=	84.4%
b.	the **TMS** settings for relays **R3**, **R2**, and **R1**	*TMS*4=	**0.05**
		*TMS*3=	0.105
		*TMS*2=	0.162
		*TMS*1=	0.238

$I_{45} = 160\,A$ | for R_4: $I_p' = \frac{160}{200} = 0.8 \Rightarrow 80\%$ $I_{P_4} = 0.8A$

$I_{34} = 176\,A$ | R_3: $I_p' = \frac{176}{200} = 0.88 \Rightarrow 88\%$ $I_{P_3} = 0.88A$

$I_{23} = 194\,A$ | R_2: $I_p = \frac{194}{200} = 0.97 \Rightarrow 97\%$ $I_{P_2} = 0.97A$

$I_{12} = 211\,A$ | R_1: $I_p = \frac{211}{250} = 0.844 \Rightarrow 84.4\%$ $I_{P_1} = 0.844A$

$I_s = 236\,A$

$TMS_4 = 0.05$

$t_{oP_4} = \frac{0.14}{\left(\frac{680/200}{0.8}\right)^{0.02} - 1} \times 0.05 = 0.238\,sec \Rightarrow t_{oP_3} = 0.3 + 0.238 = 0.538\,sec$

$0.538 = \frac{0.14}{\left(\frac{680/200}{0.88}\right)^{0.02} - 1} \times TMS_3 \Rightarrow TMS_3 = 0.105 \Rightarrow t_{oP_3} = \frac{0.14}{\left(\frac{840/200}{0.88}\right)^{0.02} - 1} \times 0.105$

$t_{oP_3} = 0.463\,sec$

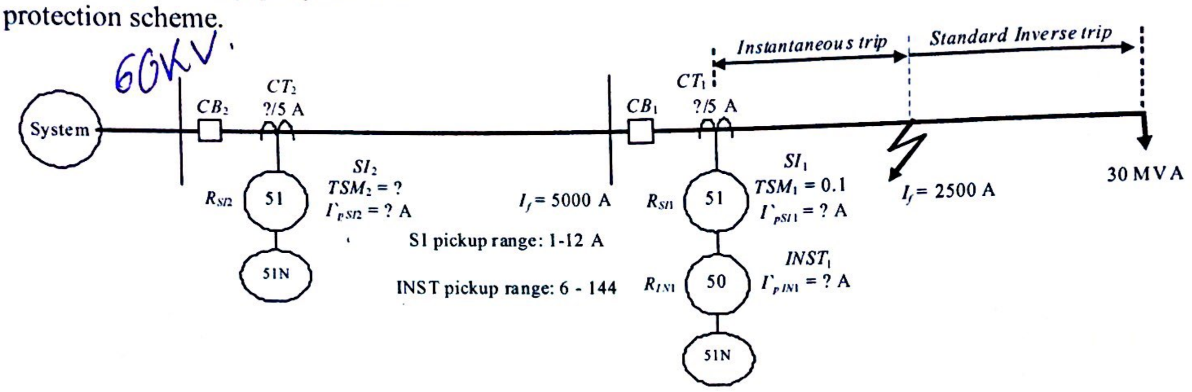
$t_{oP_2} = 0.763\,sec = \frac{0.14}{\left(\frac{840/200}{0.97}\right)^{0.02} - 1} \times TMS_2 \Rightarrow TMS_2 = 0.162$

$t_{oP_2} = \frac{0.14}{\left(\frac{1400/200}{0.97}\right)^{0.02} - 1} \times 0.162 = 0.563 \Rightarrow$ $0.863 = \frac{0.14}{\left(\frac{1400/250}{0.844}\right)^{0.02} - 1} \times TMS_1$ $\Rightarrow TMS_1 = 0.2$

$\Rightarrow t_{oP_1} = 0.863\,sec.$

Question # 8 (10 points)

For the 66 kV power system shown below, the feeder protection breaker CB_1 is operated by a modern digital relay programmed with Standard Inverse (SI), Instantaneous and E/F overcurrent protection scheme.



The fault level at the location of CB_1 is 5000A. Strong faults (above 2500A) will be cleared by the instantaneous overcurrent element of R_{IN1}. Weaker faults towards the end of the feeder (≤ 2500A) will be cleared by the *SI* element of R_{SI1}.

- Relay R_{SI2} is the backup to R_{SI1} and has *SI* element only.
- The pickup current for R_{SI1} element must be set for 45MVA or 50% above the maximum load current.
- The pickup current of R_{SI2} is equivalent to 60MVA.
- The TSM_1 of R_{SI1} is set to 0.1 s.
- CT_1 and CT_2 are rated at 45MVA and 60MVA, respectively.
- CTI = 0.3 s.

> 2500 → R_{IN}
< 2500 → I_{SI}

Relays:

- Standard Inverse (SI) ⇒ $t = \dfrac{0.14}{I^{0.02} - 1} \times TSM$
- SI pickup range: 1 - 12 A, Step = 0.5 A
- TMS range: 0.1 - 1 , Step = 0.05
- Instantaneous pickup range: 6 - 144 A , Step = 1 A

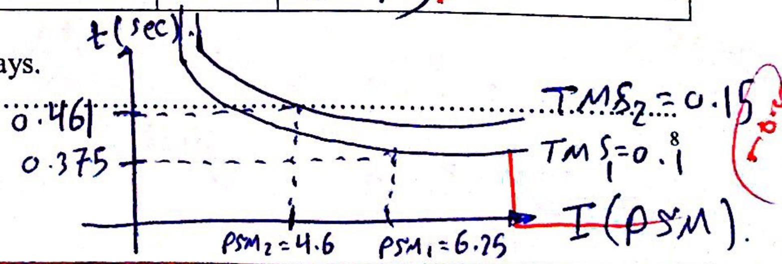
CT's:

a. Secondary: 5A
b. CTRs to select: 100/5, 250/5, 400/5, 600/5, 800/5

i. Calculate:

a.	the CT ratios for CT_1 and CT_2.	CTR_1 =	400/5	A
		CTR_2 =	600/5	A
b.	the pickup currents for the instantaneous OC element of $R_{IN/1}$ and the *SI* element of R_{SI1}	I'_{pIN1} =	6 (secondary)	A
			400 (primary)	A
		I'_{pSI1} =	5 (secondary)	A
			400 (primary)	A
c.	the pickup current for the *SI* element of R_{SI2}.	I'_{pSI2} =	4.5 (secondary)	A
			540 (primary)	A
d.	the TSM_2 for R_{SI2} to have a discrimination time of 0.3s for a fault of 2500 A.	TSM_2 =	0.15	s

ii. Draw the *t-I* characteristics for both relays.



CT₁ : MVA = 45 MVA = $\sqrt{3}\, I_L\, 66 \times 10^3$

$\Rightarrow I_{L_1} = 393.65\,A$

Take : CTR = 400/5

CT₂ : MVA = $60 \times 10^6 = \sqrt{3}\, I_L\, 66 \times 10^3$

$\Rightarrow I_{L_2} = 524.86\,A$

Take CTR = 600/5

pick-up for SS2 :

$I_p' = \frac{524.86}{600/5} = 4.37 \Rightarrow I_{p_{SS_2}}' = 4.5\,A$

$I_{pSS_2} = 540\,A$

pick-up for SS₁ :

$I_p' = \frac{393.65}{400/5} = 4.92 \Rightarrow I_{p_{SS_1}}' = 5\,A$

$\therefore I_{p_{SS_1}} = 400\,A$

TSM₂ = ?!

$t_{op_1} = \frac{0.14}{\left(\frac{2500/400/5}{5}\right)^{0.02} - 1} \times 0.1$

$= 0.375\,sec$

$t_{op_2} = 0.375 + 0.3$

$= 0.675\,sec$

$0.675 = \frac{0.14}{\left(\frac{2500/600/5}{4.5}\right)^{0.02} - 1} \times TMS_2$

$\Rightarrow TMS_2 = 0.15$

$t_{op_2} = \frac{0.14}{\left(\frac{5000/600/5}{4.5}\right)^{0.02} - 1} \times 0.15$

$= 0.461\,sec$

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