ABET Outcomes Assessment: *c*

Grade: 28 /30

University of Jordan | School of Engineering | Electrical Engineering Department

EE482: Power System Analysis (2) | 2nd Exam | 2nd Semester 2017-2018 | 15/04/2018 | Time: 03:00-4:30 pm

Q # 1 (8)	Q # 2 (14)	*Q # 3 (34) *c*	Q # 4 (12)	Q # 5 (22)	GRADE
3	14	33	12	22	84 / 90

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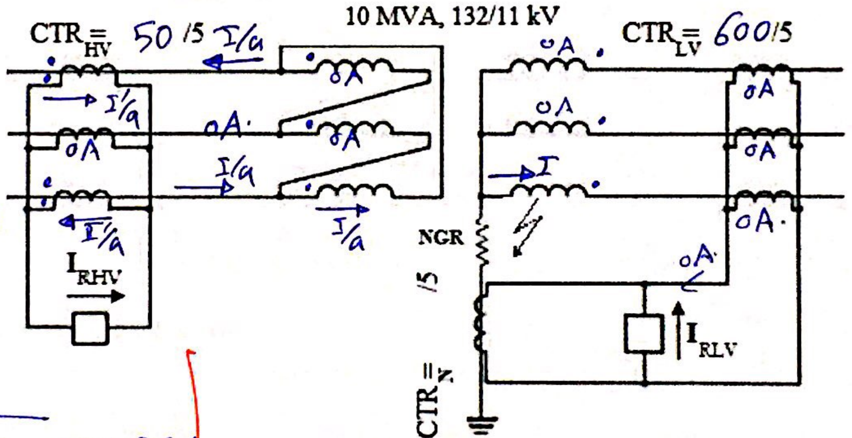
Question # 1 (8 points) **Show Your Calculations**

A 132/11 kV, 10 MVA Δ-Y 3-phase transformer is protected by restricted earth fault protection scheme at the Y-side. The percentage of LV winding protected against phase to ground fault is 85%. The relay setting is such that it trips for 20% out of balance. Calculate:

a.	the appropriate CTR_{HV}, CTR_{LV} and CTR_N.	CTR_{HV} =	50/5	
		CTR_{LV} =	600/5	
		CTR_N =	600/5	
b.	the relay pick up current I_{pickup} (primary and secondary levels).	$I_{pickup-primary}$ =	18.25	A
		$I_{pickup-secondary}$ =	446.131	A
c.	the corresponding relay currents I_{RLV} and I_{RHV}.	I_{RLV} =	3.72	A
		I_{RHV} =	1.825	A
d.	the neutral grounding resistance (NGR) to be added in the neutral to ground connection.	NGR=	12.1	Ω



$x = 0.85$

$I_{HV} = \frac{10 \times 10^6}{\sqrt{3} \times 132 \times 10^3} = 43.74A$

$I_{LV} = \frac{10 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 524.86A$

$CTR_{HV} = 50/5$

$CTR_{LV} = 600/5$

CTR_N should read for 524.86 A.

so also choose $CTR_N = 600/5$,

$I = (0.85) I_{LV}$

$= 0.85 \times 524.86$

$I = 446.131A$ } pickup on the secondary.

$I_{pickup\ primary} = \frac{I}{a}$; $a = \frac{132}{11/\sqrt{3}} = 20.78$

so $I_{pickup\ primary} = (0.85) * \frac{1}{20.78} * 446.131$

$= 18.25 A$

* for NGR:

$NGR \Rightarrow I = \frac{x V_{sec}}{NGR}$

$NGR = \frac{(0.85) \times 11000/\sqrt{3}}{446.131}$

$\Rightarrow NGR = 12.1\ \Omega$

$I_{RLV} = \frac{446.131}{600/5} \Rightarrow I_{RLV} = 3.72A$

$I_{RHV} = \frac{18.25}{50/5} \Rightarrow I_{RHV} = 1.825A$

ABET Outcomes Assessment: c

Grade: 30 /30

University of Jordan — School of Engineering — Electrical Engineering Department

EE482 Power System Analysis (2) — 2nd Exam — 2nd Semester 2017-2018 — 15/04/2018 — Time: 03:00-4:30 pm

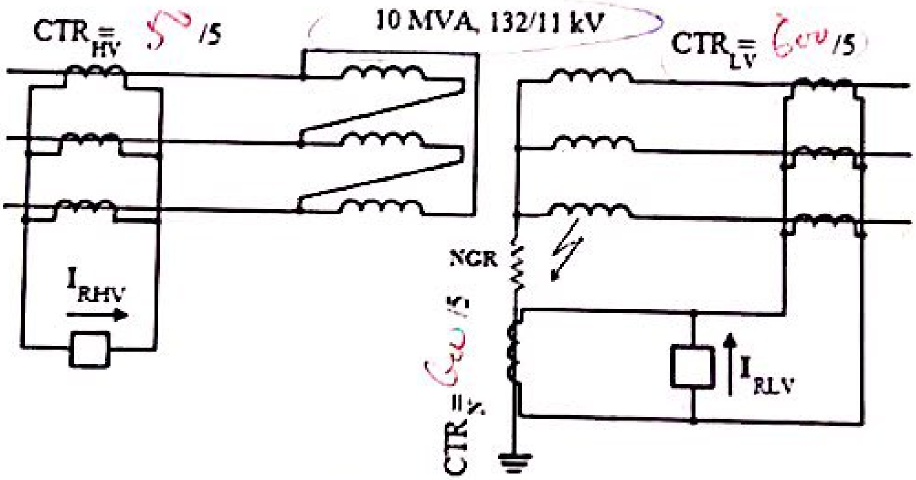
Q # 1 (8)	Q # 2 (16)	Q # 3 (34)	Q # 4 (12)	Q # 5 (20)	GRADE
					90/ 90

Student Name: Key **Student ID #:** **Serial #:**

Question # 1 (8 points) **Show Your Calculations**

A 132/11 kV, 10 MVA Δ-Y 3-phase transformer is protected by restricted earth fault protection scheme at the Y-side. The percentage of LV winding protected against phase to ground fault is 85%. The relay setting is such that it trips for 20% out of balance. Calculate:

a.	the appropriate CTR_{HV}, CTR_{LV} and CTR_N.	CTR_{HV} =	50/5
		CTR_{LV} =	600/5
		CTR_N =	600/5
b.	the relay pick up current I_{pickup} (primary and secondary levels).	$I_{pickup\text{-}primary}$ =	104.9 A
		$I_{pickup\text{-}secondary}$ =	0.874 A
c.	the corresponding relay currents I_{RLV} and I_{RHV}.	I_{RLV} =	0.874 A
		I_{RHV} =	0.0 A
d.	the neutral grounding resistance (NGR) to be added in the neutral to ground connection.	NGR=	9.08 Ω



Solution:

$$I_{HV} = \frac{10\times10^6}{\sqrt{3}\times132\times10^3} = 43.7\ A, \quad I_{LV} = \frac{10\times10^6}{\sqrt{3}\times11\times10^3} = 524.4\ A$$

CTR_{HV} = 50/5 $\quad$ CTR_{LV} = 600/5 $\quad$ CTR_N = 600/5

$$I_{pickup-Primary} = 0.2\times524.4 \Rightarrow I_{pickup} = 104.9\ A \qquad I_{pickup-Secondary} = \frac{104.9}{600/5} = 0.874\ A$$

$$I_{RLV} = \frac{104.9}{600/5} = 0.874\ A \qquad I_{RHV} = 0.0\ A$$

$$x = \frac{R\times I_p}{V_{ph}} \Rightarrow 1-0.85 = \frac{R\times104.9}{11000/\sqrt{3}} \Rightarrow R = \frac{0.15\times6350.9}{104.9} \Rightarrow \underline{R = 9.08\ \Omega}$$

Question # 2 (14 points) **Show Your Calculations**

An 11kV/415V, 1MVA 3-phase transformer is protected by a restricted earth fault (REF) relay which is connected as shown in the diagram below. Assume that the CT resistances R_{CT} and the connecting lead resistances, R_L, can be neglected. Answer the following parts to this question:

a.	i. For a LG fault from terminal A to earth of 2000 A fault current, find the CTs secondary **phasor currents,** residual current, neutral current, and the resultant current in the REF relay I_{REF}.	I'_A =	6.667	A
		I'_B =	0	A
		I'_C =	0	A
		I_r =	6.667	A
		I'_n =	6.667	A
		I_{REF} =	0	A
	ii. State if the relay should operate or not.	Yes	(No)	

$I_A = 2000A \Rightarrow I'_A = \frac{2000}{\frac{1500}{5}} = 6.667A$

$I_B = 0 \Rightarrow I'_B = 0$

$I_C = 0 \Rightarrow I'_C = 0$

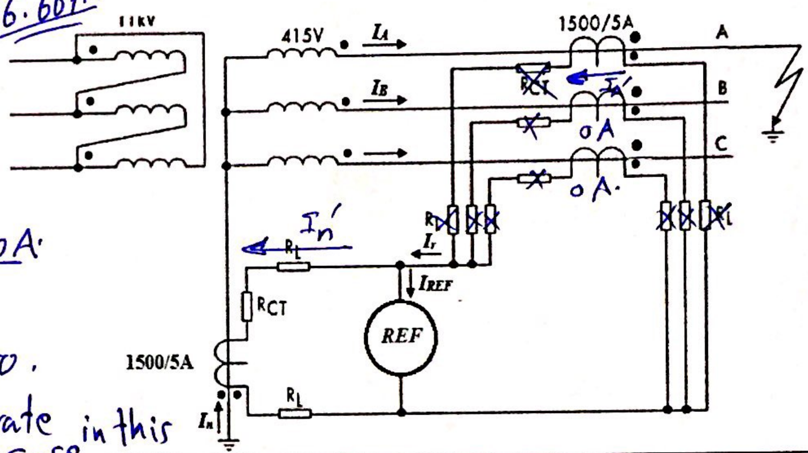
$I_r = I'_A = 6.667A$

$I_n = 6.667 \times \frac{1500}{5} = 2000A$

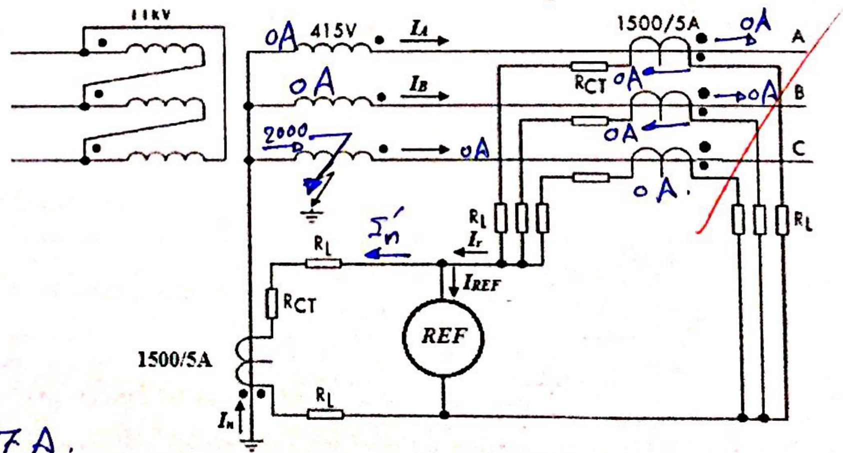
$I'_n = 6.667A$

$I_{Ref} = I_r - I'_n =$ Zero.

it won't operate in this case.



b.	i. Assume a fault of 2000 A fault current develops from the middle parts of the phase winding C of the transformer to the transformer core which is connected to earth, find the CTs secondary **phasor currents,** residual current, neutral current, and the resultant current in the REF relay I_{REF}.	I'_A =	0	A
		I'_B =	0	A
		I'_C =	0	A
		I_r =	0	A
		I'_n =	6.667	A
		I_{REF} =	−6.667.	A
	ii. State if the relay should operate or not.	(Yes)	No	



$I'_A = I'_B = I'_C = 0$

$I_r = I'_A + I'_B + I'_C = 0$

$I'_n = -I_{REF}$

$I_n = 2000A$.

so $I'_n = \frac{2000}{\frac{1500}{5}} = 6.667A$.

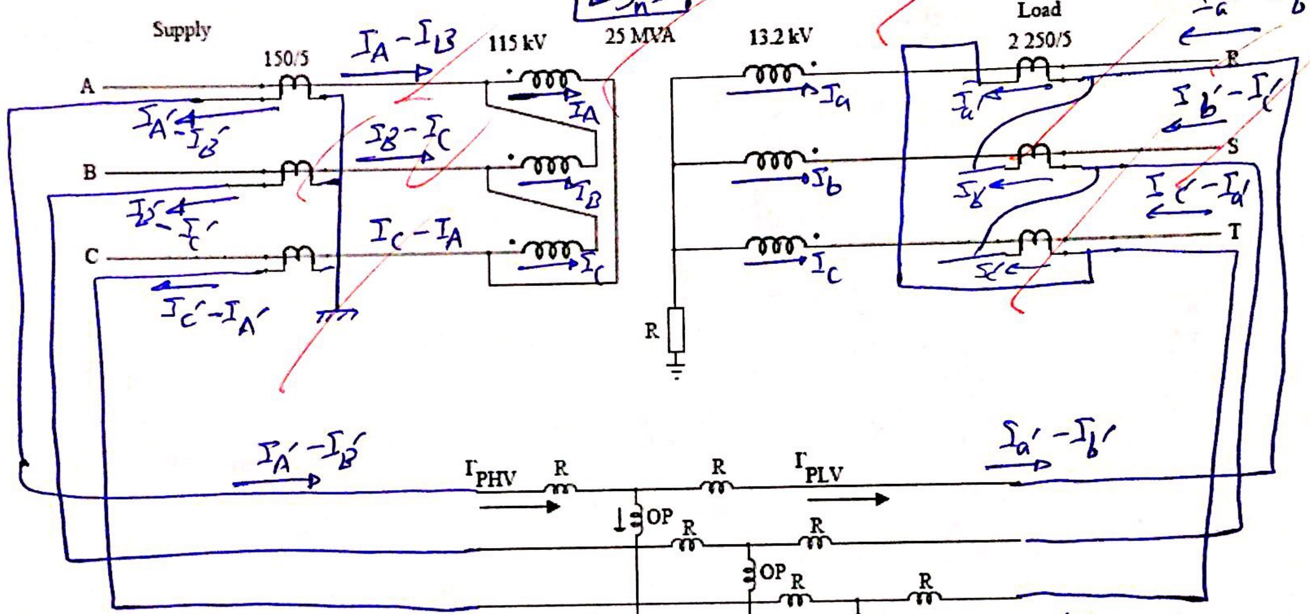
$I_{REF} = -6.667A$.

Question # 3 (34 points) **ABET outcome "c" Assessment** **Show Your Calculations**

In the figure below, an incomplete schematic diagram of a protection arrangement for a 25 MVA, 115/13.2 kV Δ-Y connected power transformer is shown. Current transformers (CT) ratio is 150/5 on the 115 kV side and 2250/5 on the 13.2 kV side.

a. Identify the vector group of the Δ-Y connected transformer. (4pts)
b. Complete the three-phase wiring connection from current transformers to the differential relay. (9 pts)
c. Indicate on your completed schematic diagram the current distribution (both magnitude and direction of flow) on the power transformer and in the relay circuit. (6 pts)

Dy_n1 ⇒ for CT $Y_N d11$



$$I_{HV} = \frac{25\times10^6}{\sqrt{3}\times115\times10^3} = 125.5A$$

$$I_{LV} = \frac{25\times10^6}{\sqrt{3}\times13.2\times10^3} = 1093.5A$$

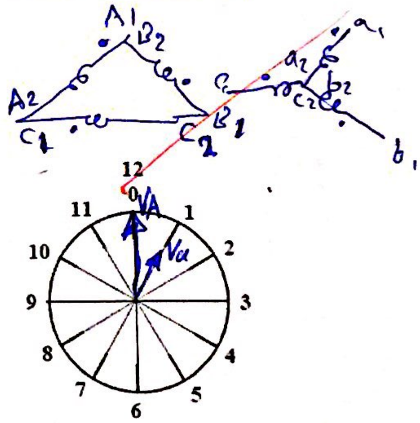
$$I'_{HV} = \frac{125.5}{150/5} = 4.183A$$

$$I'_{LV} = \frac{1093.5}{2250/5} = 2.43A$$

$$I_{PHV} = I'_{HV} = 4.183A$$

$$I_{PLV} = \sqrt{3}\, I'_{LV} = 4.21A$$

$$I_{op} = I_{PHV} - I_{PLV} \simeq \text{zero}$$



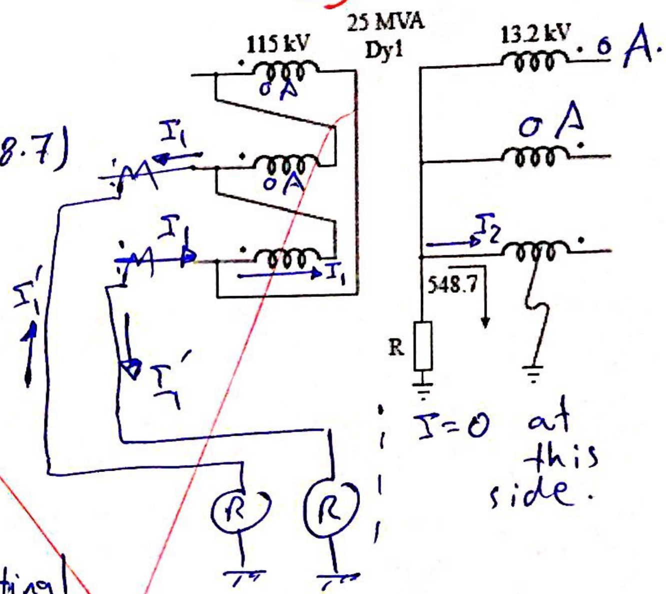
d. Calculate for full-load condition (7 pts)

	Item	115 kV Δ-Side	13.2 kV Y-Side
i.	the transformer HV and LV line currents (I_{HV} and I_{LV}) at both sides.	I_{HV} = 125.5 A	I_{LV} = 1093.5 A
ii.	the CT secondary phase currents I'_{HV} and I'_{LV}.	I'_{HV} = 4.183 A	I'_{LV} = 2.43 A
iii.	the pilot wire currents I_{PHV} and I_{PLV} on both left- and right-hand sides of the relay.	I'_{PHV} = 4.183 A	I'_{PLV} = 4.21 A
iv.	the operating current I'_{OP}	I'_{OP} = 0	A

e. A single-phase to earth fault at the middle of the LV winding, as indicated in the figure shown below, has resulted in a fault current of 548.7 A. The differential relay is set to operate at 5% of the CT rating. Calculate (8 pts)

i.	the relay secondary pickup current, $I_{pickup\text{-}sec}$	$I_{pickup\text{-}sec}$ =	0.6	A
ii.	the relay operating current, I_{Rop}	I_{Rop} =	0.6	A
iii.	state whether this earth fault could cause the relay to operate.	Yes		No

0.25



$a = \frac{115}{13.2/\sqrt{3}} = 15.09$

$I_1 = \frac{I_2}{a} \times \frac{1}{2} = \frac{0.066}{2} \times (548.7)$

$= 18.2\,A$

$I_1' = \frac{18.2}{150/5} = 0.6\,A$

$I_{Rop} = I_1' = 0.6\,A$

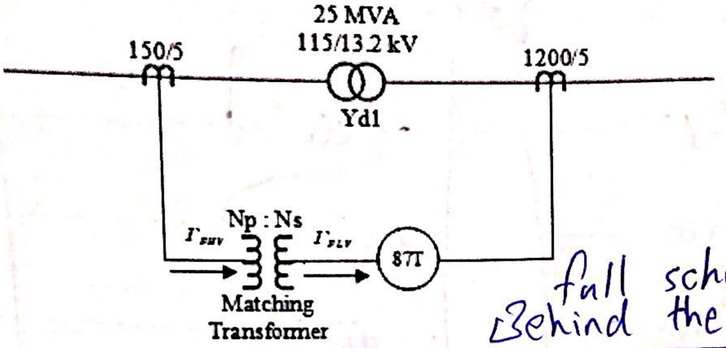
it will operate @ 5% (CT rating)

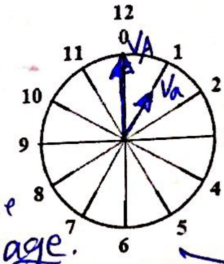
$= (0.05)(5) = 0.25\,A$

$0.6 > 0.25 \Rightarrow$ yes it will trip.

Question # 4 (12 points) **Show Your Calculations**

For the 25 MVA, 115/13.2 kV Yd1 transformer shown below, it is required to set the (87T) differential relay with matching transformer. If the **CTs** on both sides of the transformer are **Y-connected**,





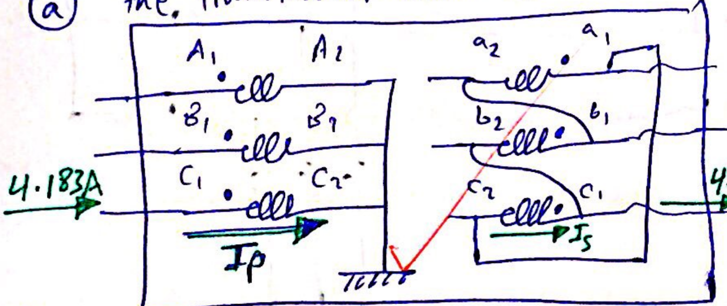
full scheme Behind the page.

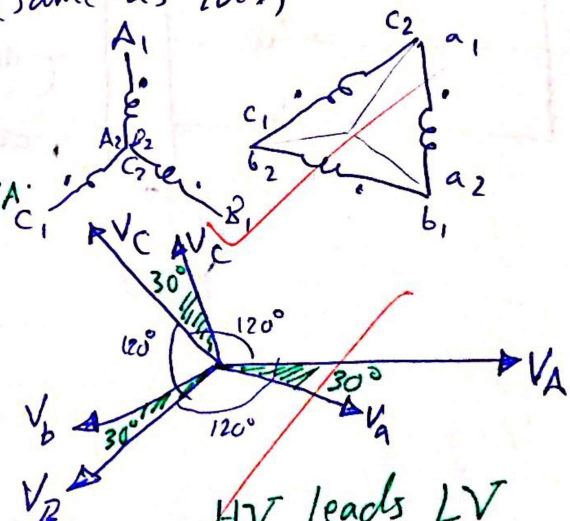
a. Identify the vector group of the matching transformer and draw its schematic diagram. Verify the vector group and transformer connections using phasor diagrams.

b. Calculate for full-load conditions:

i.	the pilot wire currents I'_{PHV} and I'_{PLV} on both left- and right-hand sides of the relay.	I'_{PHV} = 4.183 A	I'_{PLV} = 4.556 A
ii.	the appropriate turns ratio N_P/N_S of the matching transformer which can be installed in the primary circuit of 115 kV CT side to compensate the magnitude and phase difference.		$\frac{N_{P\text{-}match}}{N_{S\text{-}match}}$ = 0.6287

(a) the Matching transformer would be as follows: (same as Yd1)





(b)

$$I_{HV} = \frac{25\times10^6}{\sqrt{3}\times115\times10^3} = 125.5\text{A}$$

$$I_{LV} = \frac{25\times10^6}{\sqrt{3}\times13.2\times10^3} = 1093.5\text{A}$$

HV leads LV By 30°

$$I'_{HV} = \frac{125.5}{150/5} = 4.183\text{A} \equiv I'_{PHV}$$

$$I'_{LV} = \frac{1093.5}{1200/5} = 4.556\text{A} \equiv I'_{PLV}$$

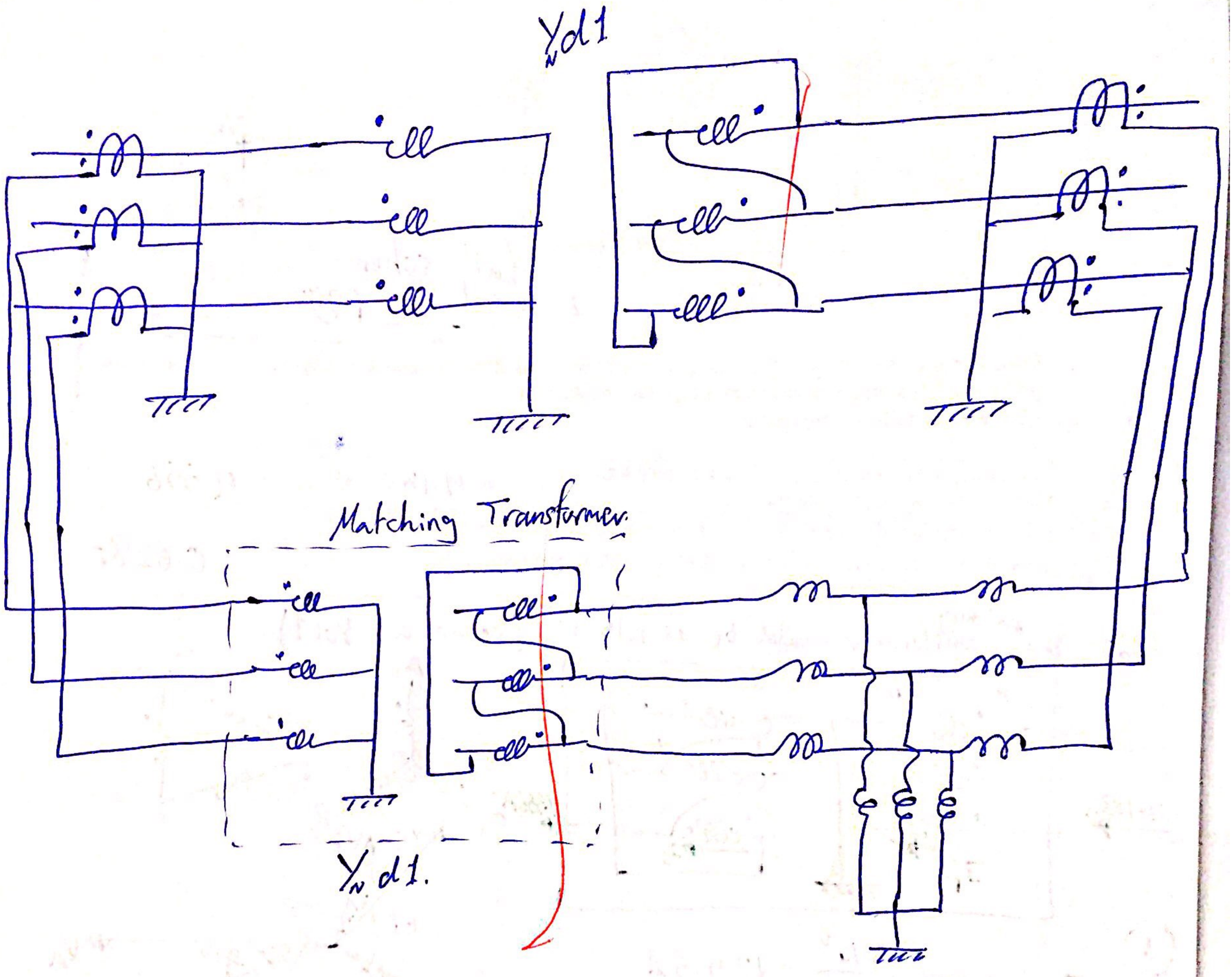
} since CT's Both Y connected

$$I_p = 4.183\text{A}$$

$$\Rightarrow \frac{N_p}{N_s} = \frac{I_s}{I_p} = \frac{2.63}{4.183} = 0.6287$$

$$I_s = \frac{4.556}{\sqrt{3}} = 2.63\text{A}$$

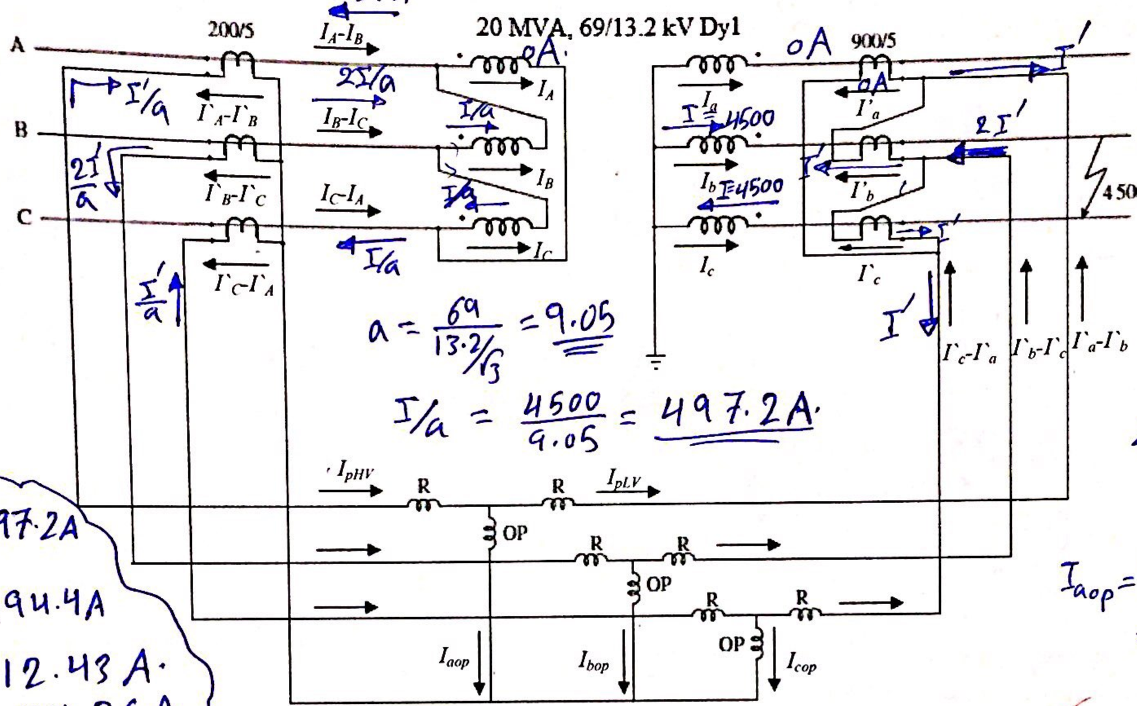
Q4 :



Question # 5 (22 points)

Show Your Calculations

Consider the 20-MVA, 69/13.2-kV, Dy1 transformer whose connections are shown below. The CTs on the 69-kV side of the transformer have a ratio of 200/5, and those on the 13.2-kV side a ratio of 900/5. The differential relays operate for a current equal to 20% of nominal current. If a line-line fault of 4500 A occurs between phases (*b*) and (*c*) in the secondary windings of the transformer, determine:



$a = \frac{69}{13.2/\sqrt{3}} = 9.05$

$I/a = \frac{4500}{9.05} = 497.2A$

$\frac{I}{a} = 497.2A$, $\frac{2I}{a} = 994.4A$, $\frac{I'}{a} = 12.43A$, $\frac{2I'}{a} = 24.86A$

$I' = \frac{4500}{900/5} = 25A$, $2I' = 50A$

$I_{aop} = (-\frac{I'}{a}) + I' = 25 - 12.43 = 12.57A$

a.	the magnitude and direction of the phase currents in the LV–side windings.	I_a=	0	A
		I_b=	4500	A
		I_c=	−4500	A
b.	the magnitude and direction of the phase currents in the CT secondary of the LV–side windings.	I'_a=	0	A
		I'_b=	25	A
		I'_c=	−25	A
c.	the magnitude and direction of the line currents in the CT secondary of the LV–side windings.	$I'_a - I'_b$ =	−25	A
		$I'_b - I'_c$ =	50	A
		$I'_c - I'_a$ =	−25	A
d.	the magnitude and direction of the phase currents in the HV–side windings.	I_A=	0	A
		I_B=	497.2	A
		I_C=	−497.2	A
e.	the magnitude and direction of the line currents in the HV–side windings.	$I_A - I_B$ =	−497.2	A
		$I_B - I_C$ =	994.4	A
		$I_C - I_A$ =	−497.2	A
f.	the magnitude and direction of the phase currents in the CT secondary of the HV–side windings.	$I'_A - I'_B$ =	−12.43	A
		$I'_B - I'_C$ =	24.86	A
		$I'_C - I'_A$ =	−12.43	A
g.	the relay operating currents	I_{aop}=	12.57	A
		I_{bop}=	−25.14	A
		I_{cop}=	12.57	A
h.	the fault between phases *b* and *c* causes relay:	(Operation)	No Operatio	

$I_{bop} = (2\frac{I'}{a}) + (-2I') = 24.86 - 50 = -25.14A$

$I_{cop} = (-\frac{I'}{a}) + I' = 25 - 12.43 = 12.57A$