

Disassemble the motor (Hand tool), Test and check the components (Hand tool / multimeter) Bring the replacement components (Hand tool), Assemble the motor / Test run / voltmeter / Ammeter - Recommended values.

- overall check, find damaged term out components.

The whole motor, Replace the term components

universal motor faulty scenario 2

153 W, 120 V, 8500 RPM

Hand button, view universal motor repair video 2

Warm out winding.

- Disassemble the motor (Hand tool), Test and check the winding (Hand tool, multimeter), winding resistance abnormal value, Rewind the winding (Hand tool, winding wire)

Assemble the components (Hand tool)

Test run - Volt meter, Ammeter, / specific values

- winding burnt out / Location - Armature, / Rewind winding

Different types of faults in 1 ϕ motor

- control circuit failure, Incorrect winding connection, motor bearing failure, open circuit winding, short circuit winding, insulation failure to frame.

- General locations where faults can occur

- Bearing and shafts, Brush, commutator (for universal motor)

- motor windings

Mechanical faults and consequence

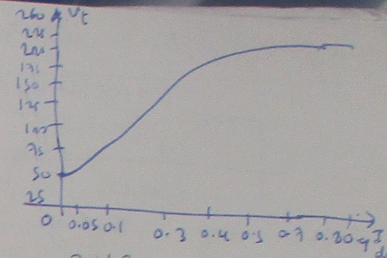
- Broken rotor bar (or) cracked rotor end ring causing vibration and mal-functioning of motor.

Static and dynamic airgap irregularities causing unstable operation of motor.

- Bent shaft which can result in a rub between rotor and stator causing heating and burning out of motor over

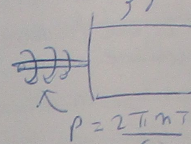
- Jammed shaft and heavy load causing motor over load and burning out.

3 ϕ Synchronous motor			
Br. 2	V _g		
0	50V	0.4	165V
0.05	50V	0.5A	290V
0.1	70V	0.7A	240V
0.3	140V	0.9A	260V
		0.9A	265V



$$P_{\text{Syn}} = \frac{3 V E_f}{X_s} \cos \delta, \quad T_{\text{Syn}} = \frac{3 V E_f}{2 \pi n_s X_s} \cos \delta$$

V = Terminal voltage / Ph, E_f = Excitation voltage / Ph
 I_a = Armature current, X_s = Synchronous reactance / Ph
 δ = Load angle between V and E_f operation



$P = 3 E_f I_a \cos \delta$
 * view the videos provided by Trainer
 * view the characteristics curves provided by Trainer

* view the practical instruction hand out provided by Trainer

- Excitation winding (field winding) of synchronous alternator is connected to dc supply

- Two types of rotors - salient / cylindrical

- Two methods of excitation

1. Excitation current flows into stationary field pole fitted on stator

2. Excitation current flows into rotating pole which are rotated by prime mover.

purpose of rheostat in the shaft field of dc exciter

- To adjust the field excitation current flows into field pole to regulate the built up voltage

4 Types of prime mover

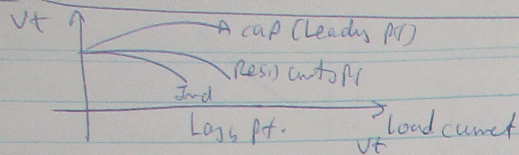
- Steam turbine, water turbine, diesel engine, petrol engine

Purpose of voltage regulator

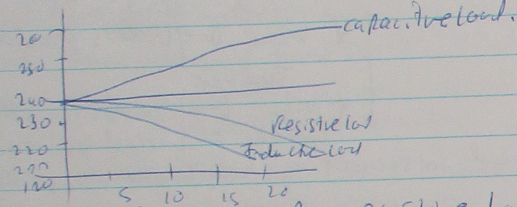
To regulate the terminal voltage when the alternator is supplying the load and the terminal voltage is varied due to load.

Advantages of operating synchronous generators in parallel
 - Repairing and periodical maintenance tasks can be performed easily
 - Depending on the load, the number of parallel machines can be added or reduced.

9.3 Generator connection and chara (characteristics)



LOAD %	Amp	Resistive Load	Inductive Load	capacitive Load
0	2	240	240	240
25	5	235	230	245
50	10	230	220	250
75	15	220	200	255
100	20	200	180	260



Generator is coil (inductor)
The resonance rise in the voltage across the inductor occurs resulting of power increase

Generator voltage drop with resistive load

When the resistive load is increased, voltage drop in resistance will reduce the terminal voltage.

Inductive load When inductive load is increased, the voltage drop in both resistive and inductive reactance part will reduce terminal voltage.

capacitive load Terminal voltage will increase.

Generator voltage coil is similar to inductor, when the capacitive load is connected, it will occur resonance. The resonance will reduce the impedance causing the current to increase and consequently terminal voltage rise up.

Excitation on output voltage more excitation will increase o/p voltage until saturation point.

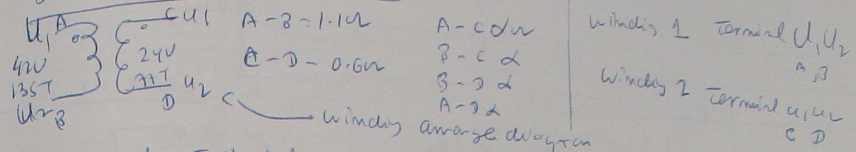
A/R A/R will automatically adjust the excitation current injected in to generator field coil depending on increase of load current to maintain the terminal voltage not to fall down.

common faults Exciter out of order / excitation cut fault, winding failure

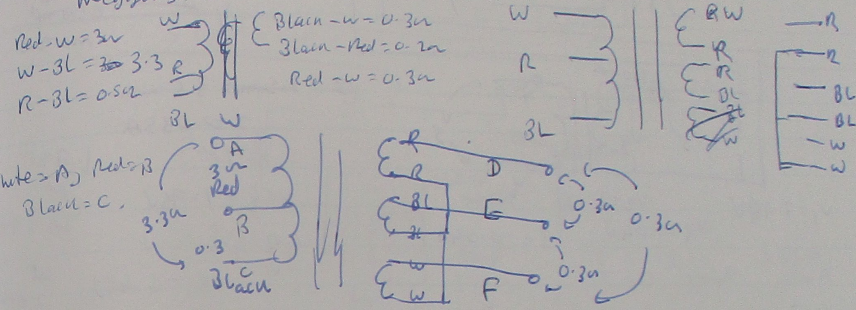
L-L / L-G fault, Prime mover fault, External fault, Disturbance in grid
Generator started with load, it will absorb more mech power impacting on prime mover. Gen: but when with load, sudden loss of excitation & Vt will increase

UEE EL 0025 Test and connect Transformer

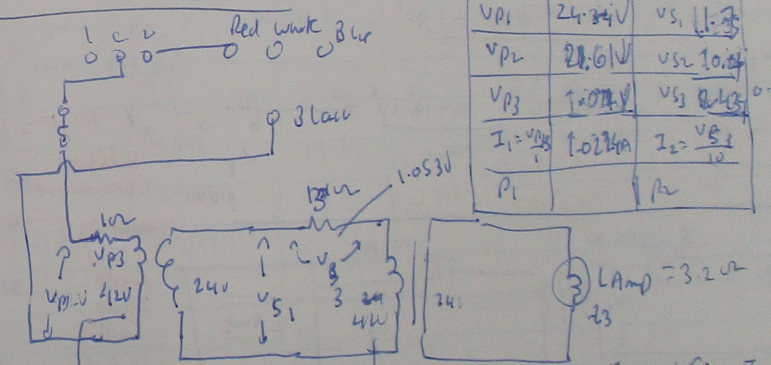
Double wound untapped Transformer



Insulation Test Wdg 1 - 2 & Wdg 1 - core & Wdg 2 - core
megger 500V



2.1 Transformation Ratio



V_{P1}	24.34V	V_{S1}	11.7V
V_{P2}	21.61V	V_{S2}	10.4V
V_{P3}	1.074V	V_{S3}	0.514V
$I_1 = \frac{V_{P1}}{R_1}$	1.0234A	$I_2 = \frac{V_{S1}}{R_2}$	
P_1		P_2	

$$P_1 = \frac{V_{P1}^2 - V_{P2}^2 - V_{P3}^2}{2R_1} = \frac{24.34^2 - 21.61^2 - 1.074^2}{2 \times 1} = 62.1W$$

$$P_2 = \frac{V_{S1}^2 - V_{S2}^2 - V_{S3}^2}{2R_2} = \frac{11.7^2 - 10.4^2 - 0.514^2}{2 \times 0.3} = 10.06W$$

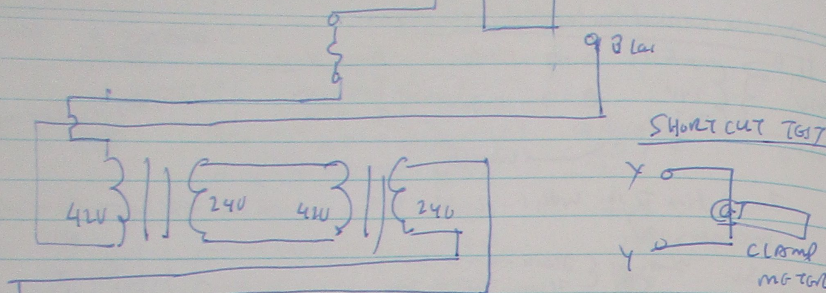
$$P_{loss} = 10.06 + \left(\frac{10.06}{3} \right) \times 3 = 12.07W$$

$$TR \text{ loss} = 12.07W$$

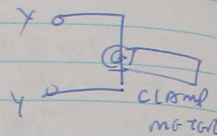
$$V_1 I_1 \approx V_2 I_2$$

3.2 OCT/SCOT

1 2 Red W 81
0 9 0 0



SHORT CIRCUIT TEST



$I = 3.5 \text{ mA}$ 3.5 mA
 $= 0.035 \text{ A}$
SCT $I = 1.7 \text{ A}$
 $V_S = 1.75 \text{ V}$
 $V_1 = 7.74 \text{ V}$ $V_2 = 7.72 \text{ V}$
 $V_3 = 0.04 \text{ V}$ $I = 0.04 \text{ A}$
 $V_S = 6.45 \text{ V}$ at 3.6 V

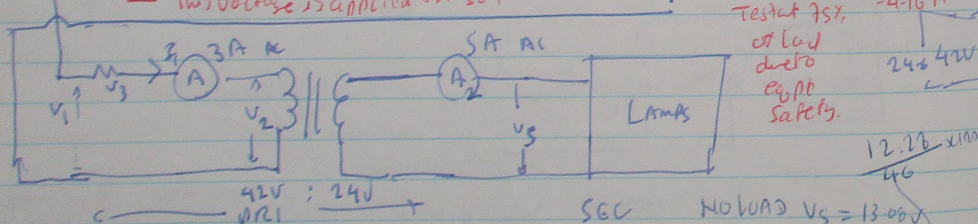
OCT $P = \frac{7.74^2 - 7.72^2}{2 \times 1} = 0.076 \text{ W}$, $I = 0.04 \text{ A}$ or 0.035 A

SCT $P = \frac{0.45^2 - 4.36^2}{1.75^2} = 7.16 \text{ W}$ $I = P_{in} = 1.7 \text{ A}$
 $I_{sec} = 2.99 \text{ A}$

	V_1	V_2	V_3	I_P	I_{sec}	P_W
OCT	7.74	7.72	0.04	0.04	0	0.076
SCT	6.45	4.36	1.75	1.7	2.99	7.16

Two voltage is applied for SCT

Full load $I_{sec} = \frac{100}{24} = 4.16 \text{ A}$
Test at 75%
at load due to R_{eq} safety.

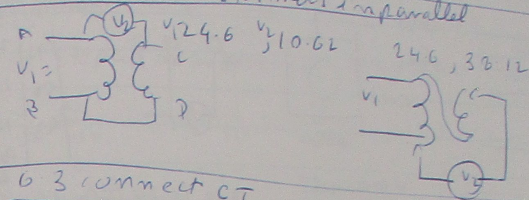


LOAD	V_1	V_3	V_2	P_{in}	I_1	A_2	V_S	P_{out}	$\%$
1	24.39	0.44	22.4	46	0.50	1A	12.28	12.29	26.37
2	24.26	0.41	21.11	71.1	0.2	2A	11.66	22.3v	32.37
4	24.19	0.312	21.62	56.6	0.0	2.4	11.69	26.95	49.57
3	24.39	0.312	21.76	58.6	0.0	2.4	11.66	28.9	49.67
5	24.33	0.322	21.70	59.45	0.0	2.6	11.66	30.3	50.967

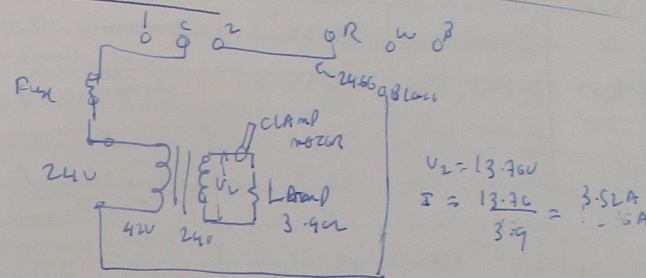
4.2 Transformer Regulation & Impedance

Refer 3.2, $V_{NL} = 13.08 \text{ V}$ $V_{FL} = 11.66 \text{ V}$

3.2.2 connect Transformer in parallel



3.3 connect CT



$V_2 = 13.76$

$R_S = 2.8$
 $R_6 = 3.2$
 $R_7 = 3$
 $R_8 = 2.7$

	V_1	R_t	I_{al}	$I_{meq.}$	R_{ATD}
R_S	13.76	2.8	4.91	0.58	8.44
$R_S R_6$	13.76	1.49	9.23	1.2	7.69
$R_S R_6 R_7$	13.76	0.997	13.8	1.8	7.66
$R_S R_6 R_7 R_8$	13.76	0.72	19.11	2.4	7.46

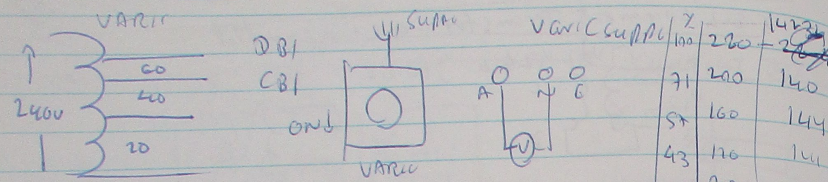
$R_S || R_6 = \frac{2.8 \times 3.2}{2.8 + 3.2} = \frac{8.96}{6} = 1.49$

$R_S || R_6 || R_7 = \frac{2.8 \times 3.2 \times 3}{2.8 \times 3.2 + 3.2 \times 3 + 2.8 \times 3} = \frac{26.88}{26.96} = 0.997$

$R_S || R_6 || R_7 || R_8 = \frac{2.8 \times 3.2 \times 3 \times 2.7}{2.8 \times 3.2 \times 3 + 3.2 \times 3 \times 2.7 + 2.8 \times 3 \times 2.7 + 2.8 \times 3.2 \times 2.7} = \frac{72.56}{94.6} = 0.72$

Note according to $R_t = R_0(1 + \Delta L)$ The lap resistance will change when they emit the light but it can be simulated to connect Transformer operation, because we don't have CT

6-1 Auto transformer connection & measurement



Vs	VARIAC	Vmeasured	
240	20	25.22	Due to safety concern
240	40	40.38	Sec. current measurement to be viewed video,
240	60	60.5	
240	100	90.7	
240	120	119.4	
240	160	159.4	
240	200	197.5	
240	240	237.2	

Due to safety concern
 Explored Terminal DIT
 Test terminal before turn
 cover exposed terminal
 wrong high voltage applied
 to burnt out of Tr. & M
 check Tr voltage before
 connection

2.1 The Transformation ratio (Transformer ratio)

$$\text{Transformer ratio} = \frac{V_p}{V_s} = \frac{24-34}{11.7} = 2.03 \approx 2$$

$$\text{Transformer ratio} = \frac{I_s}{I_p} = \frac{0.87}{0.46} = 1.89 \approx 2$$

① Secondary voltage is lower than the value from equation

Due to winding voltage drop due to winding resistance the secondary voltage value is less than the amount calculated by transformer ratio.

② 110V to 400V stepdown transformer ratio
 $a = \frac{110}{400} = 27.5$

③ 280V to 330V step up transformer transformer ratio
 $a = \frac{330}{280} = 1.1785$

230V to 10V step down transformer transformer ratio
 $a = \frac{230}{10} = 23$

④ 20:1 step down Tr, secondary winding 60 turns
 $a = \frac{N_1}{N_2} \rightarrow 20 = \frac{N_1}{60} \rightarrow N_1 = 20 \times 60 = 1200 \text{ turns}$

⑤ 1:10 step up transformer $N_2 = 140 \text{ turns}$
 $a = \frac{N_1}{N_2} \rightarrow \frac{1}{10} = \frac{N_1}{140} \rightarrow N_1 = 14$

⑥ 24:1 step down $N_2 = 200 \text{ turns}$
 $a = \frac{N_1}{N_2} \rightarrow 24 = \frac{N_1}{200} \rightarrow N_1 = 24 \times 200 = 4800$

⑦ $V_1 = ?$ 32:1 $V_2 = 400V$
 $a = \frac{V_1}{V_2} \rightarrow 32 = \frac{V_1}{400} \rightarrow V_1 = 32 \times 400 = 12800V$

⑧ $V_1 = ?$ $V_2 = 2.8kV$ 1:11 step up transformer
 $a = \frac{V_1}{V_2} \rightarrow \frac{1}{11} = \frac{V_1}{2.8kV} \rightarrow V_1 = \frac{2.8 \times 10^3}{11} = 254.5V$

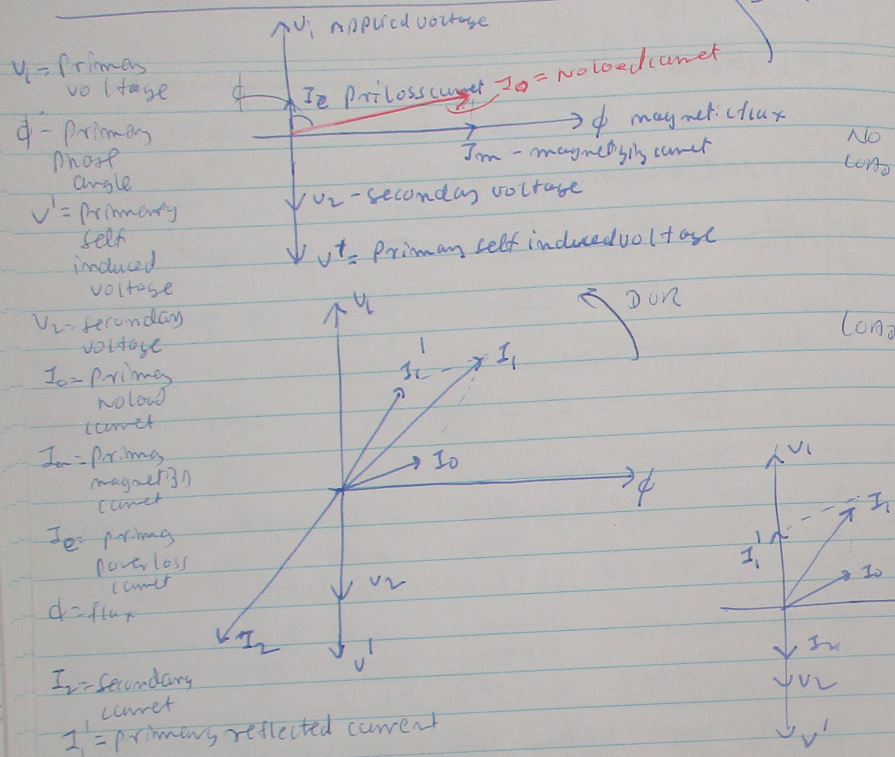
⑨ $N_1 = 281$, $N_2 = 1870$ $V_1 = 100V$ $V_2 = ?$
 $a = \frac{N_1}{N_2} = \frac{V_1}{V_2} \rightarrow \frac{281}{1870} = \frac{100}{V_2} \rightarrow V_2 = \frac{100 \times 1870}{281} = 665.48V$

⑩ $I_1 = ?$ 1:20 step up transformer
 $I_2 = 12 \text{ Amp}$
 $a = \frac{I_2}{I_1} \rightarrow I_1 = \frac{I_2}{a} = \frac{12}{20} = 0.6 \text{ Amp}$

⑪ $I_1 = ?$ $I_2 = ?$ 40:1 step down Tr. Resistive load 28W
 $V_1 = 230V$
 $a = \frac{V_1}{V_2} \rightarrow 40 = \frac{230}{V_2} \rightarrow V_2 = \frac{230}{40} = 5.75V$
 $I_2 = \frac{\text{Power}}{\text{voltage}} = \frac{28}{5.75} = 4.86 \text{ Amp}$
 $a = \frac{I_2}{I_1} \rightarrow 40 = \frac{4.86}{I_1} \rightarrow I_1 = \frac{4.86}{40} = 0.121A$

⑫ $I_1 = ?$ 230V to 12V step down Tr. low resistive load
 $I_2 = \frac{\text{Power}}{V_2} = \frac{70}{12} = 5.833 \text{ Amp}$
 $a = \frac{V_1}{V_2} = \frac{I_2}{I_1} \rightarrow \frac{230}{12} = \frac{5.833}{I_1} \rightarrow I_1 = \frac{5.833 \times 12}{230} = 0.305A$

2-2 Transformer Phasor Diagram



2-3 Transformer Applications

$$500 \text{ VA} \rightarrow 45 \text{ kW} \quad 45 \text{ kW} \rightarrow 500 \text{ VA}$$

$$500 \text{ VA} \rightarrow 1 = 50 \times \frac{50}{45} = 55.5$$

$$500 \text{ VA} \rightarrow 60 \text{ VA}$$

Scenario 1

500W, 120V down Light from 230V supply

Transformer Type - Shell, Power rating 600VA cooling system Air
 Insulation Type F, Primary voltage 230V, Secondary voltage 120V
 Primary current 0.217A, Secondary current = 4.16A

Installation conditions

4-5.2.1 Lamps, luminaires and their associated accessories shall be installed so as not to cause undue temperature rise follow Table 4-2 clause 4-5.2.3.3

Transformer 4-14.2.2 control and protection 2-3 control
 2-5 Protection against over current,
 Scenario 2

A transformer is required to provide a separated supply for a single 230V, 10A socket outlet.

Transformer Type - Shell, Power rating 2-3 kVA, cooling system - Air, Insulation type F

Primary voltage 230V Secondary voltage 230V Primary current 10A secondary current 10A

Installation condition

2-3 control of electrical installation shall be provided with device to prevent (or) remove hazards.

2-5 It needs to be provided with protection against over current.

4-14.2.1 The wiring and electrical equipment connected to be secondary winding of a transformer shall comply with the requirements of the standard for extra low, low and high voltage appropriate to secondary voltage.

① Types of factors affecting the selection of transformer

- Primary and secondary voltage, kVA, winding connection, Power factor, cooling method, winding conductor material, Types, mounting, arrangement, Efficiency, frequency of operation, Environment, specific level of protection, The operation

② Purpose of using 1:1 Isolation transformer to supply a circuit

- To protect against electric shock, to suppress electrical noise in sensitive device, to improve safety, to transfer power between two circuits which must not be connected.

③ Use of step up transformer with an installation that increases the voltage above that at the point of supply

4-14.5 where a transformer is used to raise the voltage above that at which electricity is supplied at the point of supply, no connection shall be made between the primary and secondary windings.

1.2 Identify and Test Transformer Windings

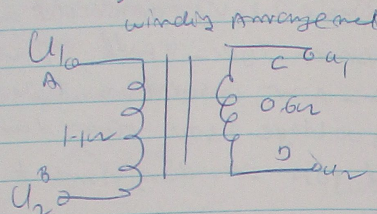
meter - multimeter, Range - ohm

Test Result A-B = 1.1k, A-C = 2k, A-D = 2k, B-C = 2k

B-E 2k C-D 0.6k

Double wound untapped winding

	Terminal
1	U _{1A} U _{2B}
2	U _{1C} U _{2D}



Continuity - IR Tester 500V, multimeter - ohm

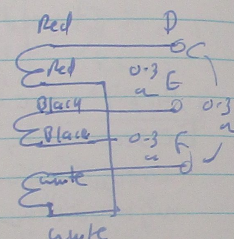
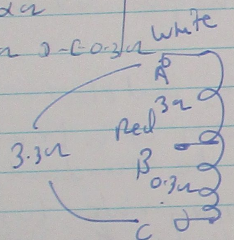
A-B 3k, A-C 3.3k A-D 2k

A-E 2k B-C 0.3k B-E 2k

B-F 2k C-D 2k C-E 2k D-F 0.3k

Double wound untapped winding

	Terminal
1	A, B, C
2	D, E, F



IR Tester - 500V

wdg 1 - 2 2k

wdg 1 - core 2k

wdg 2 to core 2k

Black

Double wound untapped

meter selected - multimeter ohm

Test Result

A-B 3k, A-C 3.3k A-D 2k, A-E 2k A-F 2k

B-C 0.3k, B-E 2k B-F 2k C-D 2k

C-E 2k C-F 2k D-F 0.3k D-E 0.3k E-F 0.3k

Double wound untapped winding

meter - multimeter ohm range

A-B 3k, A-C 3.3k A-D 2k, A-E 2k, A-F 2k

B-C 0.3k, B-E 2k, B-F 2k, C-D 2k

C-E 2k, C-F 2k, D-E 0.3k, D-F 0.3k, E-F 0.3k

Double wound untapped winding

wdg 1 ABC, wdg 2 DEF

IR Tester 500V

wdg 1 - 2 2k
1 - 3 2k
2 - 3 2k

wdg 1 to core 2k
2 - 2k
3 - 2k

Insulation Resistance

6.3.6.3 The insulation resistance between (a) the conductor of consumer main (b) Live earthed parts of an electrical installation or parts thereof including consumer main and submain shall not be less than 1M

2/ Identify which is higher voltage wdg

A-B (U₁ - U₂) is higher voltage wdg (higher resistance)

C-D (U₁ - U₂) is lower voltage wdg (lower resistance)

3 Types of core

- Air core
- Iron core
- Ferrite core

Core type
Shell type
Toroidal (C-type)

4/ Two materials commonly used to construct transformer

- Silicon steel (Low frequency)
- Ferrite (High frequency)

5/ 4 types of insulation used in 1kV and 3kV Transformer

Cellulose insulation
Enamel
Polymer film

Epoxy Resin
Oil impregnated paper/cloth

6/ Test 2 eqpt to identify transformer terminal

winding identification test

eqpt - ohmmeter continuity Tester / Multimeter ohm range

7/ 6 types of information on nameplate

Serial number
Type
Rating
Nominal voltage

Current
Impedance
Weight
Cooling

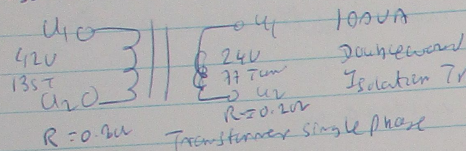
Insulation

3.2 Transformer losses and efficiency

Q Imp High voltage and limit injected in transformer short circuit test and burnt out of transformer.

m) caution - Follow the steps suggested in connection diagram without teacher's supervision, do not touch the VMC.

ISOLATION TRANSFORMER



Electric motor
Education Astor (CME)
electric motor reduction camera
model 4204-1-5200
ser no 1304 3011 4.35V

$420V = 24V$
 $I_{pri} = 2.35A$ $I_{sec} = \frac{100}{24} = 4.16A$ now test at 50% FL

copper loss $P_c = I^2 R = 2.99^2 \times 0.8 + 2.99^2 \times 0.2 = 4.32W$

Primary Power - variable loss $7.46 - 4.32 = 3.13W$

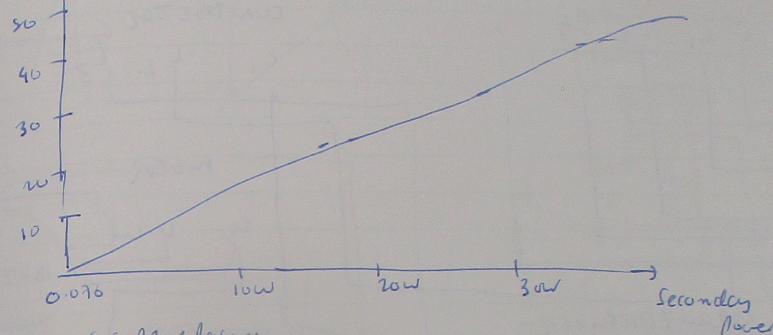
$a = 1.7$	I_{sec}	I_{pri}	copper loss	$a \approx 1.7$
	2.99	1.78	2.42 $1.78^2 \times 0.8 + 2.99^2 \times 0.2$	
	2	1.176	3.44 $1.176^2 \times 0.8 + 2^2 \times 0.2$	
	1	0.588	0.663 $0.588^2 \times 0.8 + 1^2 \times 0.2$	
	4	2.35	7.618 $2.35^2 \times 0.8 + 4^2 \times 0.2$	

I_{sec}	I_{pri}	P	copper loss
1	0.588	0.476	1
2	1.176	1.906	2
2.99	1.78	4.2	3
4	2.35	7.618	4

Point = 30.3W $P_{in} = 59.45W$
Total losses = $59.45 - 30.3 = 29.15W$

$I_1 = 0.8$ $I_2 = 2.6$ I_{sec}
cotton = $0.8^2 \times 0.8 + 2.6^2 \times 0.2 = 1.864W$

% efficiency



cause of copper losses

The current flows in winding resistance causes copper loss in a transformer

Why copper losses can be disregarded during open circuit test

Very small amount of current flows in to winding

what are the causes of iron losses in a transformer

When transformer core is energized, eddy current flows in transformer core causing the losses which is called as iron loss

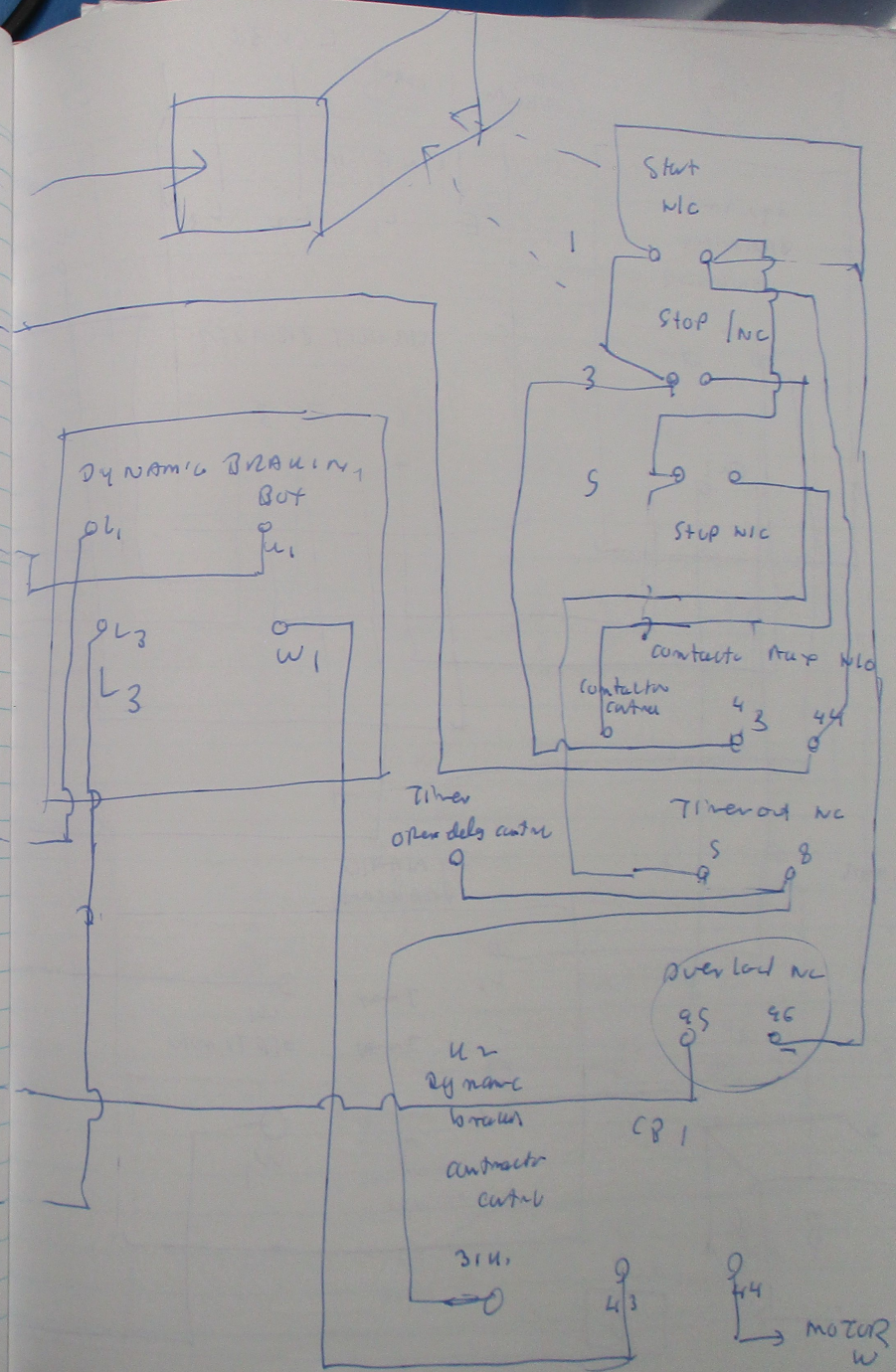
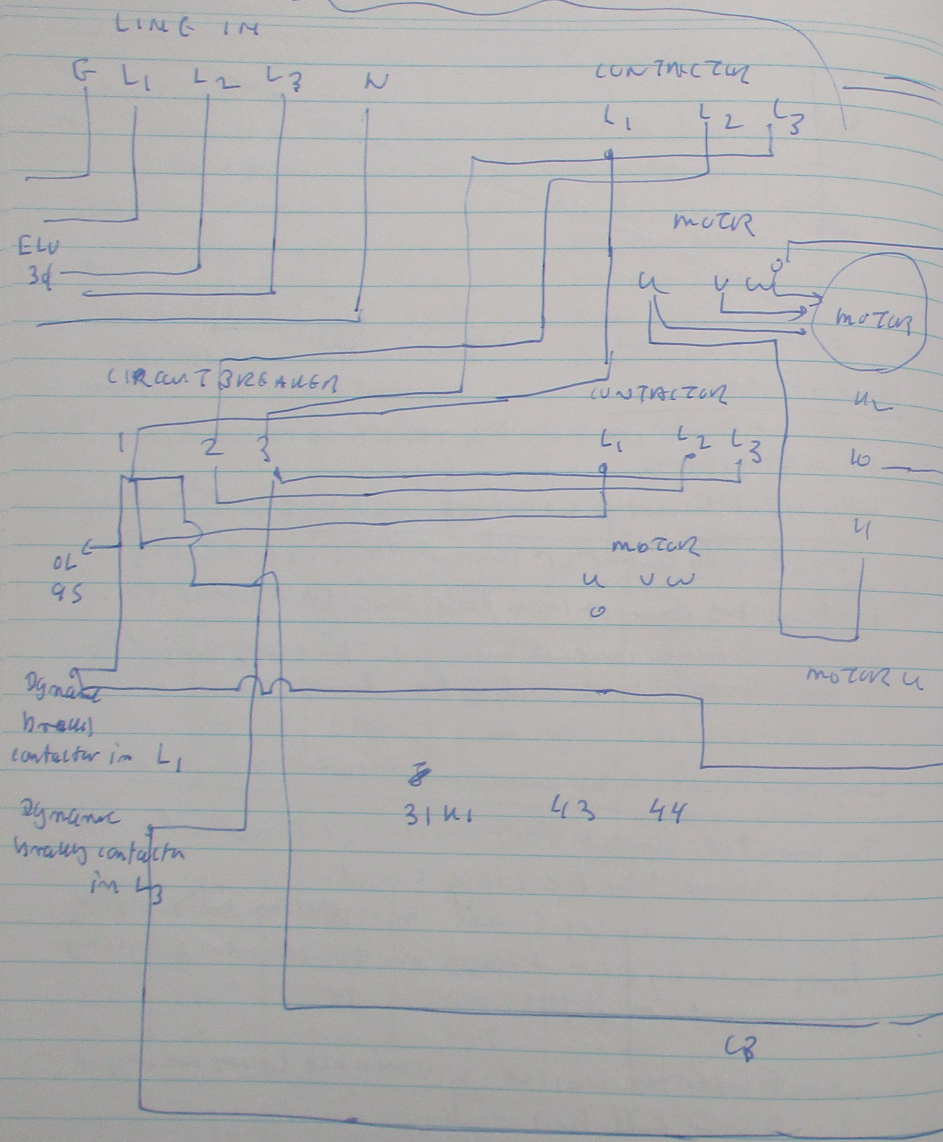
Why iron losses can be disregarded during a short circuit test

The amount of current flow in transformer coils are much higher than the eddy current. Iron losses are very small by comparing with copper losses caused by current flow in transformer winding during short circuit test.

When transformer constant in variable losses are equal it give full best results

Dynamic brake contactor control

Q109



(A)

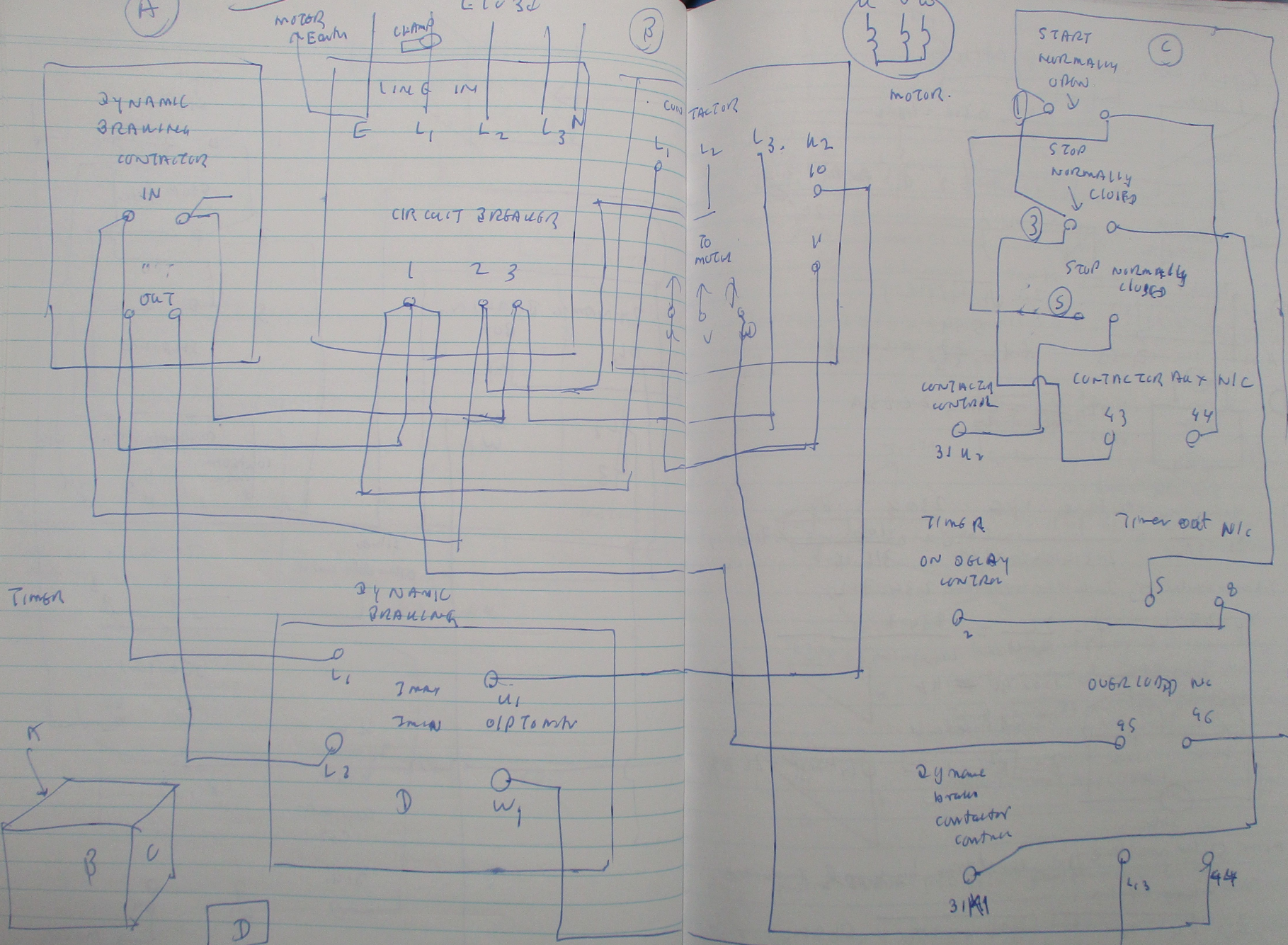
Q109

E1036

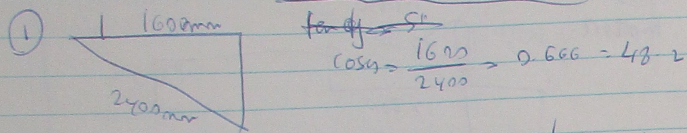
(B)

(C)

(D)



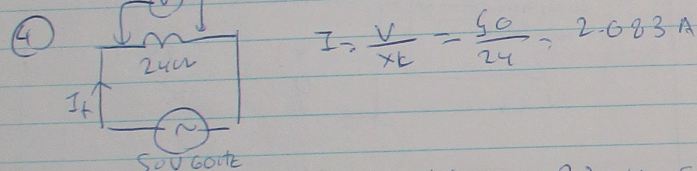
Q102 A Gap Training 27/09/2023



$\tan \phi = \frac{5^\circ}{1600}$
 $\cos \phi = \frac{1600}{2400} = 0.666 = 48.2$

② $I_t = \sqrt{I_1^2 + I_2^2} = \sqrt{6^2 + 3.2^2} = 6.8$ $\phi = \tan^{-1} \frac{3.2}{6} = 28.6^\circ$

③ $I_t = \sqrt{5.3^2 + 2.7^2} = 5.94$
 $\tan \phi = \frac{2.7}{5.3} = 0.509$ $\phi = \tan^{-1} 0.509 = 28.9^\circ$

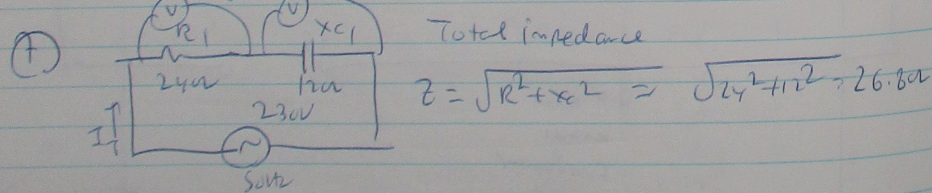


$I = \frac{V}{R} = \frac{50}{24} = 2.083 \text{ A}$

⑤ Capacitive reactance $1 \mu\text{F}$ 230 V 50 Hz
 $X_c = \frac{1}{2\pi fC} = \frac{1}{2 \times 3.1416 \times 50 \times 1 \times 10^{-6}} = \frac{10^6}{314.16} = 3183.09 \Omega$

⑥ 2.4 mH inductor, Inductive reactance 234.7Ω
 $X_L = 2\pi fL$ $f = \frac{X_L}{2\pi L} = \frac{234.7}{2 \times 3.1416 \times 2.4 \times 10^{-3}}$

$= \frac{234.7 \times 10^3}{2 \times 3.1416 \times 2.4} = 1583.46 \text{ Hz}$



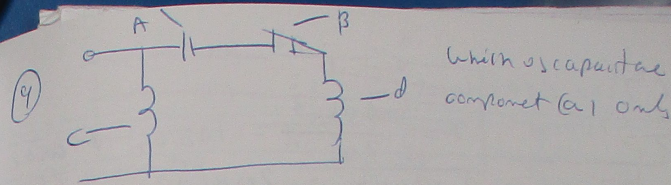
Total impedance

$Z = \sqrt{R^2 + X_c^2} = \sqrt{24^2 + 1^2} = 26.8 \Omega$

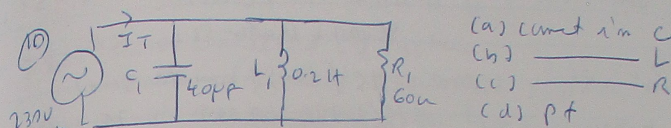
⑧ motor stator resistance 37Ω , current drawn by supply Inductive reactance 49.7Ω

$Z = \sqrt{R^2 + X_L^2} = \sqrt{37^2 + 49.7^2} = 61.96 \Omega$

$I = \frac{230}{61.96} = 3.712 \text{ A}$



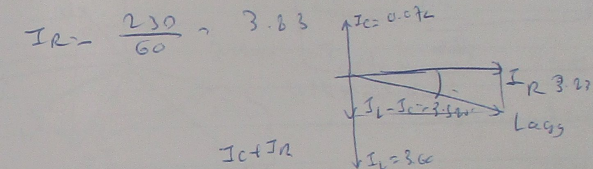
Which is capacitive component (a) only



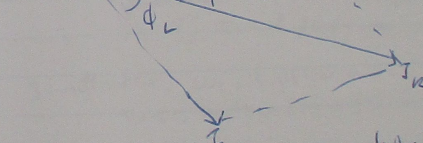
- (a) current in C
- (b) L
- (c) R
- (d) pf

$X_c = \frac{1}{2\pi fC} = \frac{1}{2 \times 3.1416 \times 50 \times 10^{-6}} = \frac{10^6}{314.16} = 3183.09 \Omega$
 $I_c = \frac{230}{3183.09} = 0.072 \text{ A}$

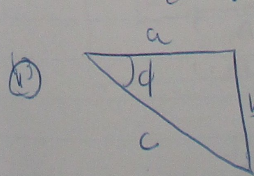
$I_L = X_L = 2\pi fL = 2 \times 3.1416 \times 50 \times 0.2 = 62.832 \text{ A}$ $I_L = \frac{230}{62.83} = 3.66 \text{ A}$



- (a) $\text{Lag} = \text{pf}$
- (b) $I_L =$ current flow in inductor



- (a) What type of power is consumed by purely resistive load represented by (a)
- True power (P) measured in watts (W)



- (a) Side (c) - volt Amp (VA)

⑬ motor 750 W $\text{pf} = 0.8$ $P = 75 \times 0.8 = 63.75 \text{ kW}$

⑭ Voltmeter 230 V Ammeter 12.5 A $\text{pf} = \frac{2156}{230 \times 12.5} = 0.749 = 41.49^\circ$

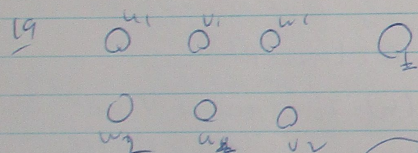
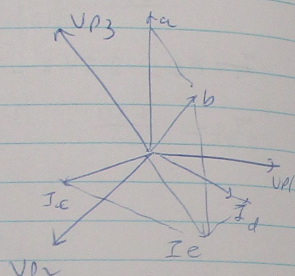
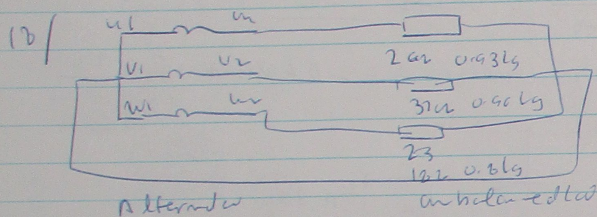
6 15kW 1φ load 230V pf=0.6 lag

$$Ratio = \frac{15}{0.6} = 25 \text{ kVA} \quad I = \frac{25 \times 10^3}{230} = 108.69 \text{ A} \quad \phi = \cos^{-1} 0.6 = 53.1^\circ$$

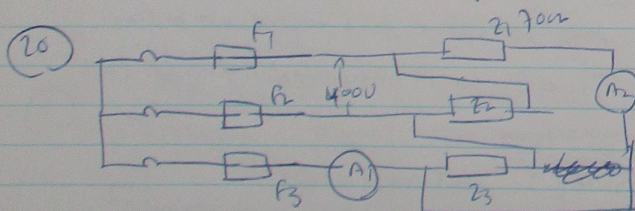
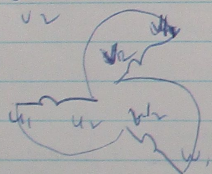
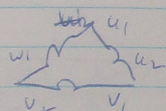
$$W_{VAR} = \sqrt{W^2 - kW^2} = \sqrt{25^2 - 15^2} = 20 \text{ kVAR} \quad W_{VAR} = W_{VAR} \sin 53.1^\circ = 15 \tan 53.1^\circ$$

pf=0.8 $\phi = \cos^{-1} 0.8 = 36.8^\circ$ $W_{VAR} = 15 (\tan 53.1^\circ - \tan 36.8^\circ) = 15 (1.33 - 0.75) = 8.7 \text{ kVAR}$

17 Δ system The line current is 10A.



34 Inductor delta



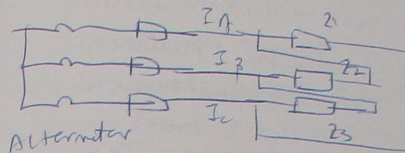
line voltage 400V

$A_1?$
 $A_2?$

$$A_2 = \frac{E}{Z} = \frac{400}{70} = 5.71 \text{ A}$$

$$A_1 = \sqrt{3} A_2 = 1.732 \times 5.71 = 9.897 \text{ A}$$

21

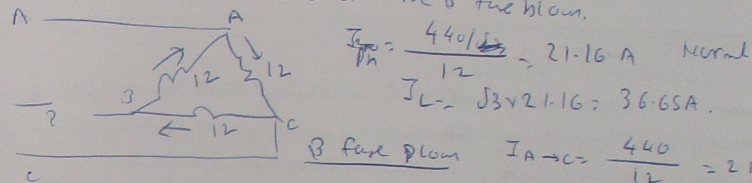


Line current = 50A
Earthed system

$$I_{ph} = \frac{2L}{\sqrt{3}} = \frac{50}{1.732} = 28.86 \text{ A}$$

22

Interconnected 3φ system
Balanced 1φ load $Z_p = 12\Omega$ supply 440V
current in each wire when Line B fuse blown.

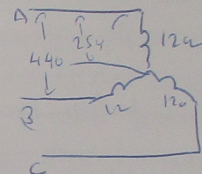


$$I_{ph} = \frac{440/\sqrt{3}}{12} = 21.16 \text{ A Normal}$$

$$I_L = \sqrt{3} \times 21.16 = 36.65 \text{ A}$$

B fuse blown $I_A \rightarrow C = \frac{440}{12} = 36.65 \text{ A}$

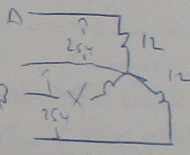
22



$$I_{ph} = \frac{440/\sqrt{3}}{12} = 21.16$$

$$I_A = 2I_{ph} = 42.32 \text{ A}$$

$$I_3 = 0, I_A = I_C = \frac{254}{12} = 21.16 \text{ A}$$

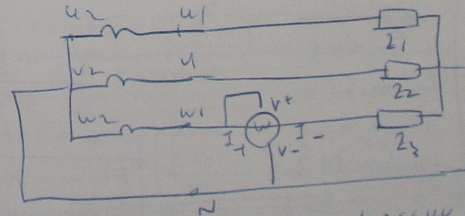


23

One wattmeter is used to measure power delivered from balanced 4 wire supply wattmeter reads 1.75kW
Ph P_3 Total power = $3 \times 1.75 = 5.25 \text{ kW}$

3 wattmeter, $W_1 = 5.05 \text{ kW}$, $W_2 = 6.15 \text{ kW}$, $W_3 = 5.83 \text{ kW}$ Total power
 $W_T = W_1 + W_2 + W_3 = 5.05 + 6.15 + 5.83 = 17.03 \text{ kW}$

24



Total power = 12.8kW
Line current, Line voltage = 400V

$$\text{One Phase Power} = \frac{3 \phi \text{ power}}{3} = \frac{12.8}{3} = 4.266 \text{ kW}$$

$$\cos \phi = 1 \text{ Resistive}$$

$$\sqrt{3} E I_L \cos \phi = 12.8 \times 10^3 \text{ W}$$

$$I_L = \frac{12.8 \times 10^3}{1.732 \times 400} = 18.47 \text{ A}$$

25

3φ A meter full load
current = 75A pf = 0.75 lagging Terminal voltage = 400V

$$(a) \text{ Apparent power } S = \sqrt{3} V I = 1.732 \times 400 \times 75 = 51963 = 51.963 \text{ kW}$$

$$W = \sqrt{3} V I \cos \phi = 51.963 \times 0.75 = 38.972 \text{ kW}$$

26 PS/MS 3002.1.1 Reactance at 50Hz Flexible
conductor 2.5mm² multicore elastomer cord

Spec Temp = 90°C

Flexible Elastomer multicore Table 31
Elastomer MS 3002

2.5mm² → 0.118 Reactance = 0.118Ω

EL005 Sample 3.3 Sample Test Transformer oil

Power transformation ratio, Power Rating = 25kVA

Primary voltage 11kV, Secondary voltage 0.433kV

Primary current = 1.31A, secondary current 33-33A

cooling system on air cooling main tap 35C

View to oil cool transformer frame plate provided by
Trainer

View Transformer oil inspection video provided by Trainer

Flash point > 140°C, test, 0.25-0.29 g/cc

Interfacial Tension mN/m

dielectric strength Resistivity 90°C

24°C 160000 > 12 mΩ·cm 3 SX10 > 12 mΩ·cm

Sign of water X Sign of foreign body X

Transformer oil breakdown test

view 30V Test video and Data Sheet provided by

Teacher	Same oil	Average =
Different oil	1 - 64.5	64.5 + 53.4 + 46.1 + 70.3 + 65.8
1 62 (30min)	2 - 53.4	3
2 21.47 (Red palms)	3 - 46.1	= 60.02 kV
3 44.75 (RBDPA)	4 - 70.3	
4 52.64 (PEAE)	5 - 65.8	

Furum - degree
of degradation
of transformer
paper insulation

1/ Not to draw the oil from negative tank pressure

The negative pressure in oil tank will absorb the outside
air containing dust

2/ Routine Tests for Transformer oil

Dissolved gas analysis
Dielectric strength test
Interfacial testing

Acid Number Testing
Water content Testing
P-f Testing

PCB Analysis
Furum Analysis
Visual Inspection

PCB - polychlorinated Biphenyls

Sufficient dielectric strength - Yes

Relationship between transformer power rating & cooling system

- The more effective cooling system decreases transformer

internal power losses due to heat and increase the output power

- 3 common Transformer cooling medium:

oil natural Air natural cooling

oil natural Air forced cooling

oil forced Air forced cooling

oil forced water forced cooling

oil, Air, water

AF Air forced (Forced Air)

ONAF oil natural air forced.

oil immersed transformer tank design

The core and coil are cooled by surrounding in oil.

The oil acts as a cooling agent and insulator. convection

moves the oil through the winding, coils and core

keeping the transformer from over heating. oil is further

cooled externally at lower voltage and in air cooled radiator

with higher voltage

4.2 Transformer Regulation and Impedance

This practical combine concurrently with Practical 3.2

No load VS = 13.03V, Full load = 11.66V

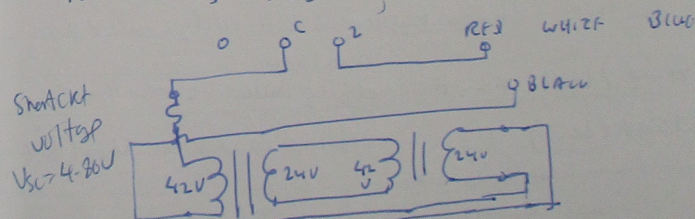
$$\% \text{Reg} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

$$= \frac{13.03 - 11.66}{11.66} \times 100 = 11.75\%$$

$$\% Z = \frac{V_{SC}}{V_P} \times 100$$

V_{SC} = Primary voltage
in volt causes
short circuit secondary
V_P = Rated primary
voltage in volt

$$= \frac{4.86}{42} \times 100 = 11.57\%$$



Short circuit
voltage
V_{SC} = 4.86V

V₃ = 4.35V
Two voltmeters
is applied
for SCT

7.5V 4.86V at short
circuit

Rated primary voltage = 42V

Effect of transformer impedance on voltage regulation

The higher the impedance, the lower the voltage regulation over the transformer's load range.

Team G102

$$\begin{aligned} X/R &= 2.1, X/X = 3.9 \text{ p.u. lag} \\ \cos \phi &= 0.82 \quad \phi = \cos^{-1} 0.82 = 34.9^\circ, \sin \phi = 0.572 \\ X/R &= 2.1 \times 0.82 + 3.9 \times 0.572 = 3.912 \end{aligned}$$

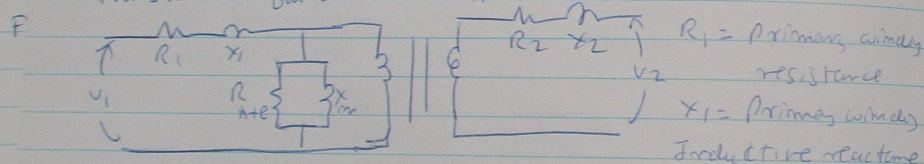
The higher the impedance, the lower the voltage regulation over transformer's load range.

- % impedance - The percent voltage required to circulate rated current flow through one transformer winding when another winding is short circuited at the rated voltage but at rated frequency.

X-Z Test

Short circuit test, the secondary winding of the transformer is shorted and the voltage on primary is increased until rated current flows in transformer.

Transformer equivalent circuit.



R_1 = Primary winding resistance

X_1 = Primary winding Inductive reactance

R_2 = Secondary winding resistance, X_2 = secondary winding inductive reactance

V_1 = Primary voltage

V_2 = Secondary voltage R_{h+e} = Hysteresis and eddy current loss resistance

% Reg = $\frac{V_1 R_{h+e}}{V_2} + \frac{V_1 X_m}{V_2} \left\{ \begin{array}{l} \text{lagg} \\ \text{lead} \end{array} \right\}$ X_m magnetizing inductive reactance.

% Reg = $\frac{V_1 R_{h+e}}{V_2} - \frac{V_1 X_m}{V_2}$ lead

$V_{NL} = 412, 500V \text{ 3\phi}$

$V_{FL} = 400V$

$$\begin{aligned} \% \text{ Reg} &= \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100 \\ &= \frac{412 - 400}{400} \times 100 \\ &= 3\% \end{aligned}$$

1000kVA $V_{NL} = 11, V_{FL} = 10.92$

$$\begin{aligned} \% \text{ Reg} &= \frac{11 - 10.92}{10.92} \times 100 \\ &= 0.732\% \end{aligned}$$

$V_{NL} = 404, \% \text{ Reg} = 3.29$

$\% \text{ Reg} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$

$$3.29 = \frac{404 - V_{FL}}{V_{FL}} \times 100$$

$$V_{FL} + \frac{3.29}{100} V_{FL} = 404$$

$$V_{FL} = \frac{404}{1.0329}$$

$$= 388.87V$$

33/11kV 1000 kVA $V_{SC} = 1.96V$

% Z = ?

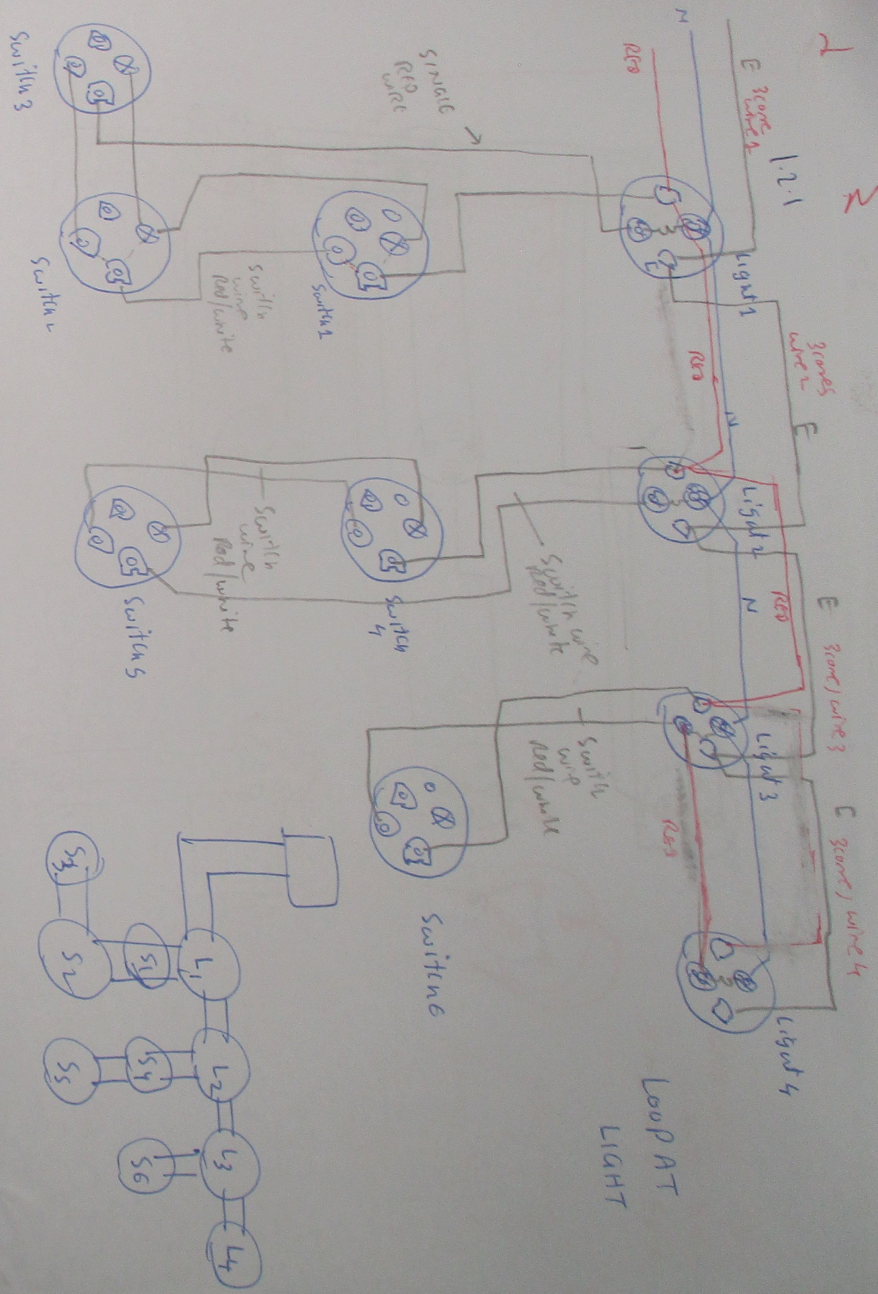
$$\% Z = \frac{V_{SC} \times 100}{V_P} = \frac{1.96}{33} \times 100 = 5.939\%$$

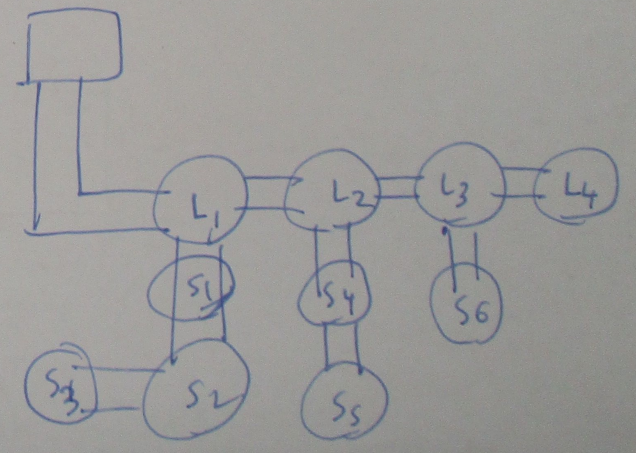
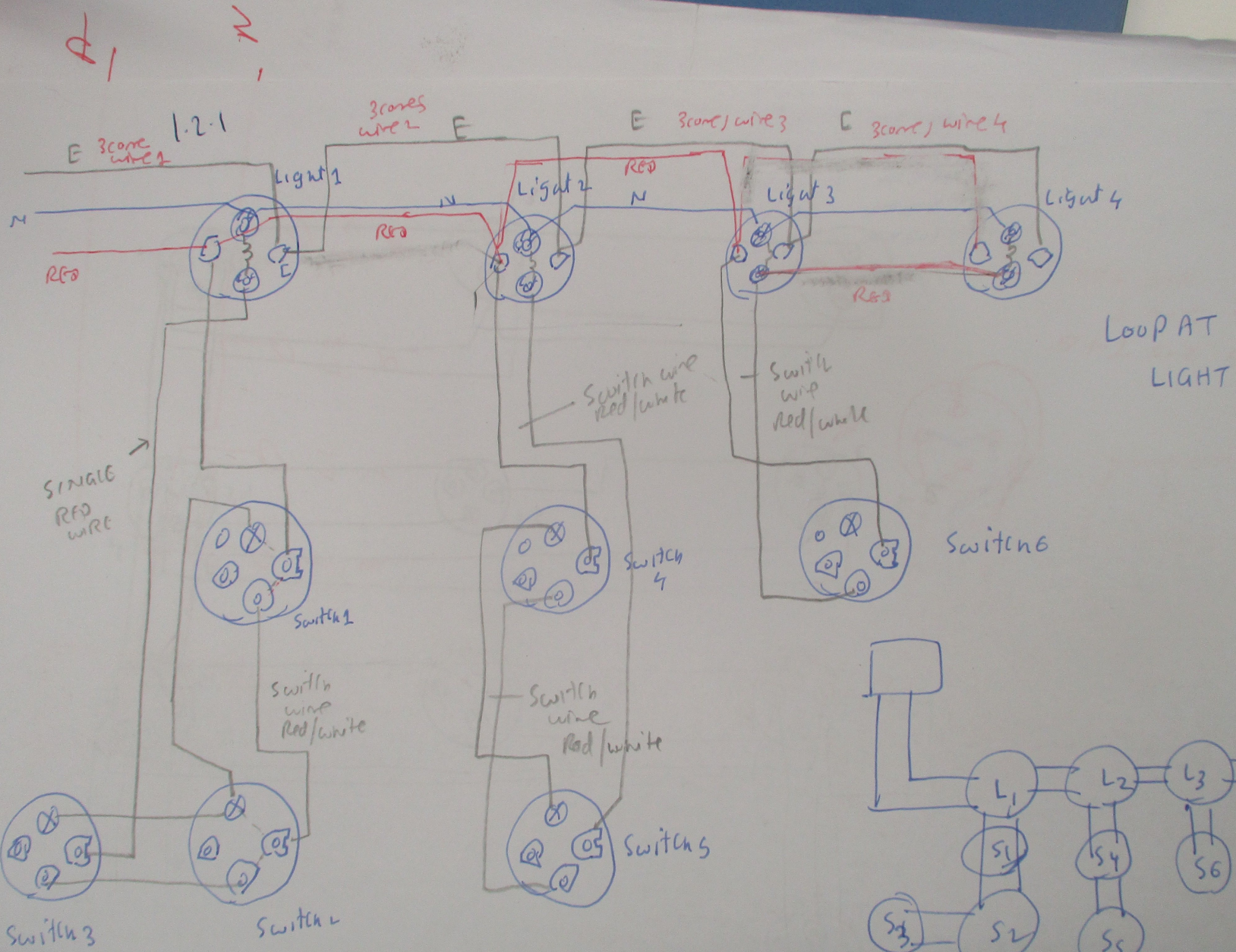
11kV, 400V, 500kVA $V_P = 796V$

$$\% Z = \frac{V_{SC} \times 100}{V_P} = \frac{796 \times 100}{11000} = 7.24\%$$

330/33kV $V_{BC} = 47.39$

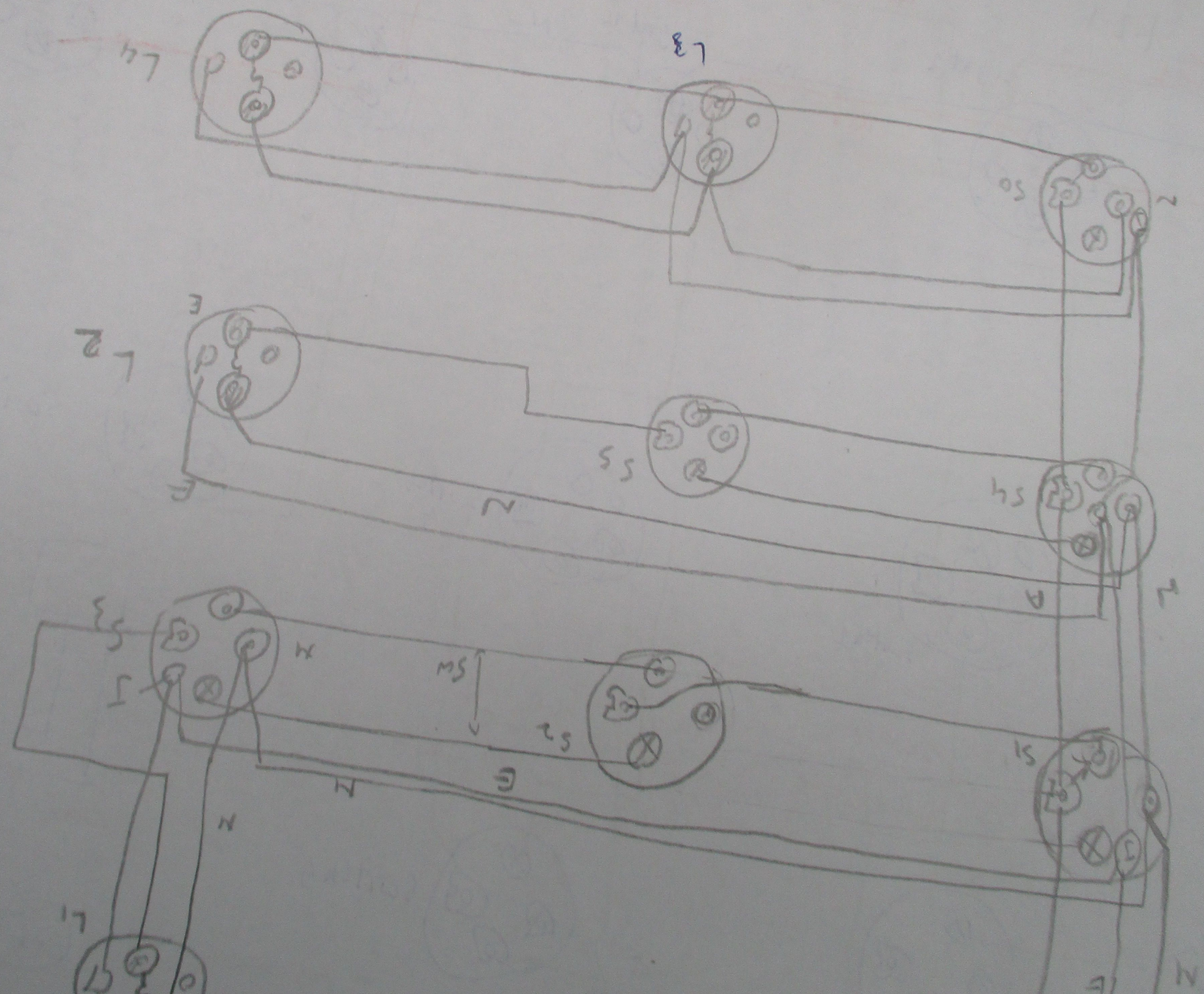
$$\% Z = \frac{V_{SC} \times 100}{V_P} = \frac{47.39 \times 100}{330} = 14.36\%$$

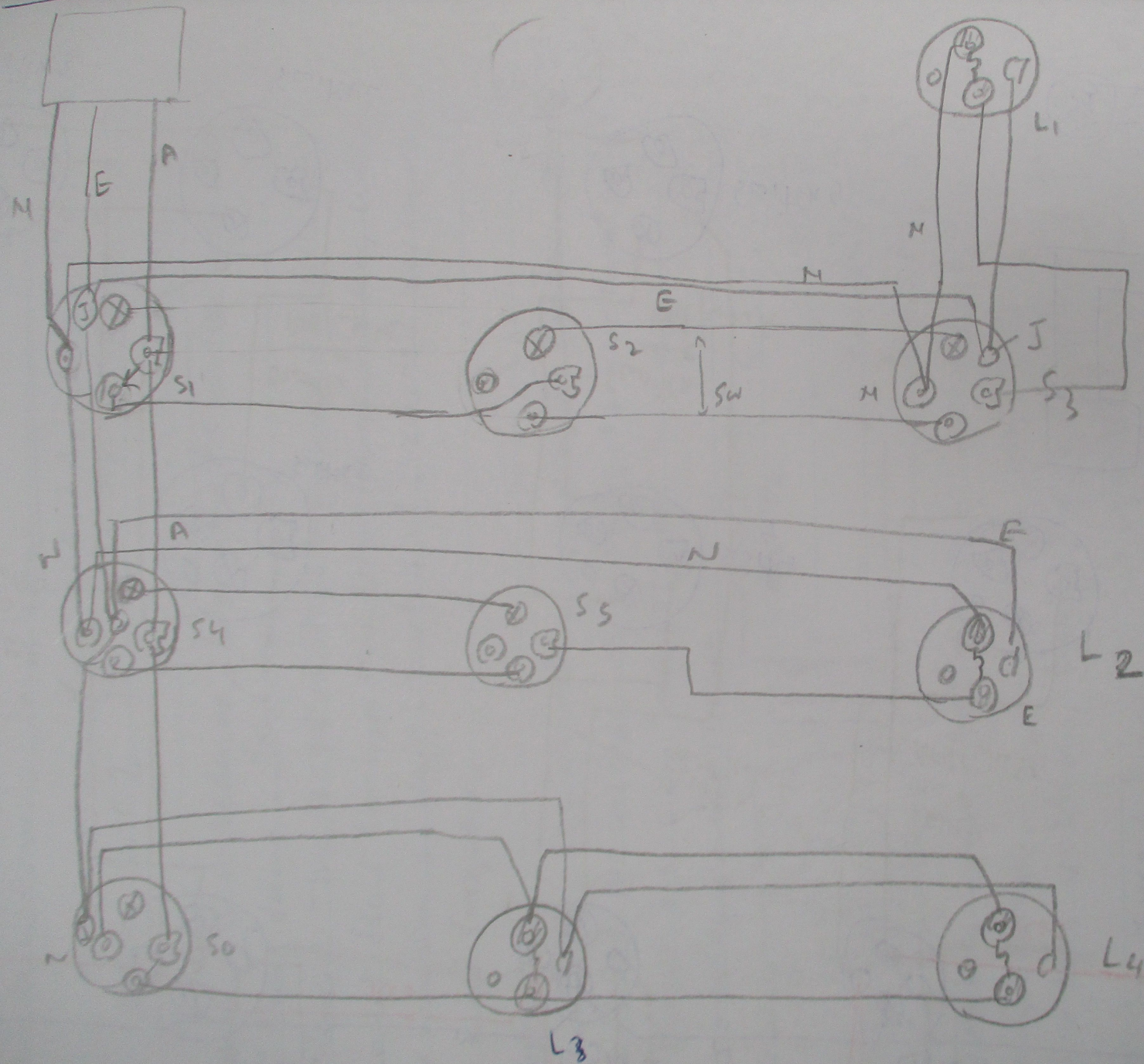




1/5/20

The

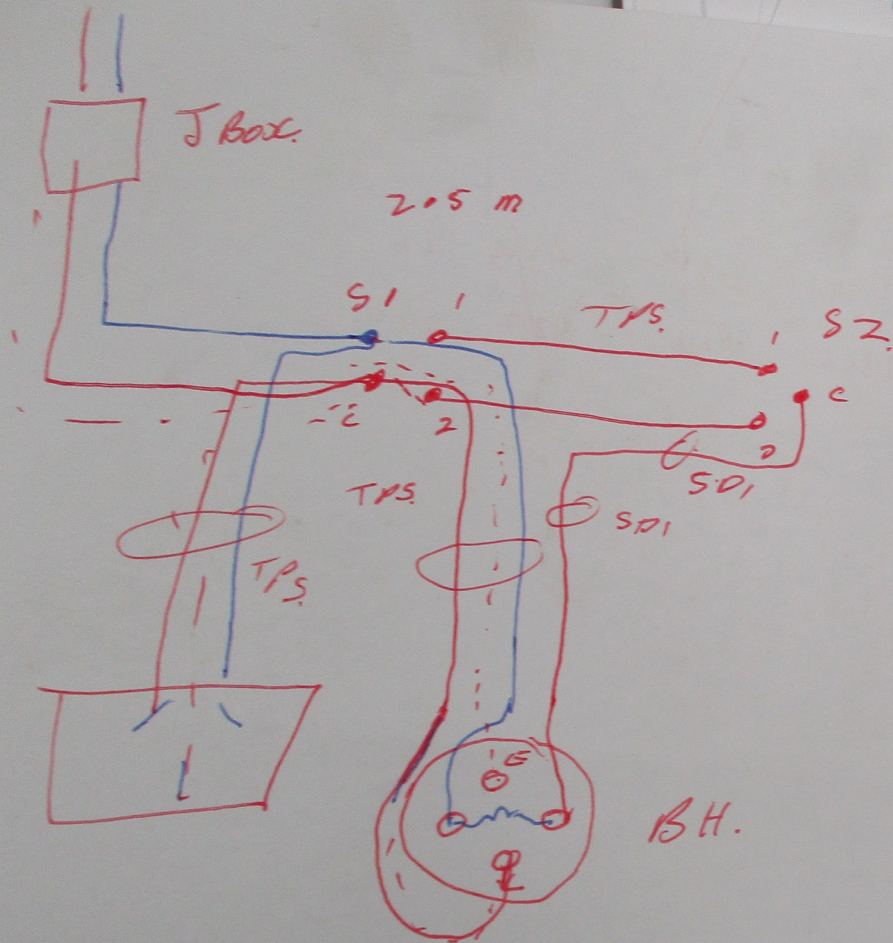




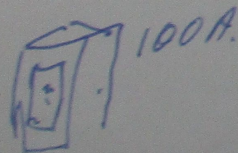
PV Array operating parameters

Type of PV Array - REC TWING P6AN x2 mono SER

Output voltage 38.3 → 40.2V



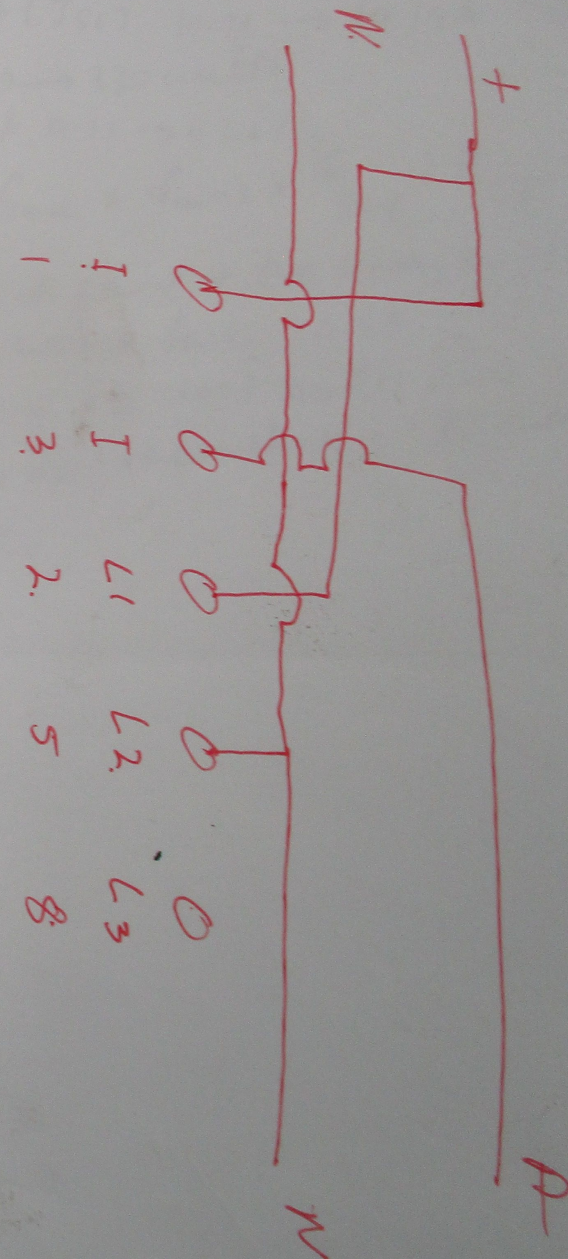
TPS 2.5 T+E
TPS 2.5 T
TPS 2.5 SDI



MAINS

80A 100A ←

1 mm = 10 A
1.5 mm = 16 A
2.5 mm = 20 A
4.0 mm = 25 A
6.0 mm = 32 A
8.0 mm = 50 A
16 mm = 63 A



PV Array operating parameters

Type of PV Array - REC TWINE P6AN x 2 mono series

open circuit voltage $38.3 \rightarrow 40.2V$

maximum power voltage $33 \rightarrow 34.3V$

Short circuit current (I_{sc}) $10.01 \rightarrow 10.19A$

maximum power $305 \rightarrow 330 \text{ watts}$

maximum power current $9.11 \rightarrow 9.02A$

$$E_{sys} = P_{array STC} \times f_{men} \times f_{dirt} \times f_{temp} \times H_{Tilt} \times \eta_{inv} \times \eta_{cabo}$$

$P_{array STC}$ = Rated output power of the array under STC

f_{men} = manufacturing tolerance factor = 0.97

f_{dirt} = Derating factor for dirt buildup = 0.96

f_{temp} = Derating factor for temperature = To calculate

H_{Tilt} = Total hours

ETC Topic Skills Practice Cover Sheet

Unit Name:	UEERE0022 Solve basic problems in photovoltaic energy apparatus and systems
Topic Title:	PV module characteristics

Skill Practice Number:	3.1
Skill Practice Name:	PV cell equivalent circuit and operating characteristics

Student Name:	
Student ID:	
College/Campus:	
Group:	

Results	
Planning:	
Carryout:	
Completion:	
Overall Results:	
Comments:	

Topic Skills Practice 3.1

UEERE0022 Solve basic problems in photovoltaic energy apparatus and systems

Topic 3. PV module characteristics

Skills Practice 3.1: PV cell equivalent circuit and operating characteristics

Task:

To draw and label the equivalent circuit of a PV cell, and to draw and label the I-V curves for a PV module under various operating conditions.

Objectives:

At the completion of this skills practice, you should be able to:

- Draw the equivalent circuit of a PV cell.
- Identify and label the elements of a PV cell equivalent circuit.
- Draw the I-V curves for a PV module under varying levels of irradiance.
- Draw the I-V curves for a PV module under varying levels of operating temperatures.
- Identify and label the major points on PV module I-V curves.

1. Planning the Unit

1.1 Research PV Cell

1.1.1 Research re
Commonwealth
PV cell.

1.1.2 Research
characterist

1.1.3 On
material

2.0

2