THREE PHASE POWER MEASUREMENT

OBJECTIVE

To measure power in a three phase circuit under

i) balanced resistive load condition

ii) balanced reactive load condition.

iii) unbalanced resistive load condition.

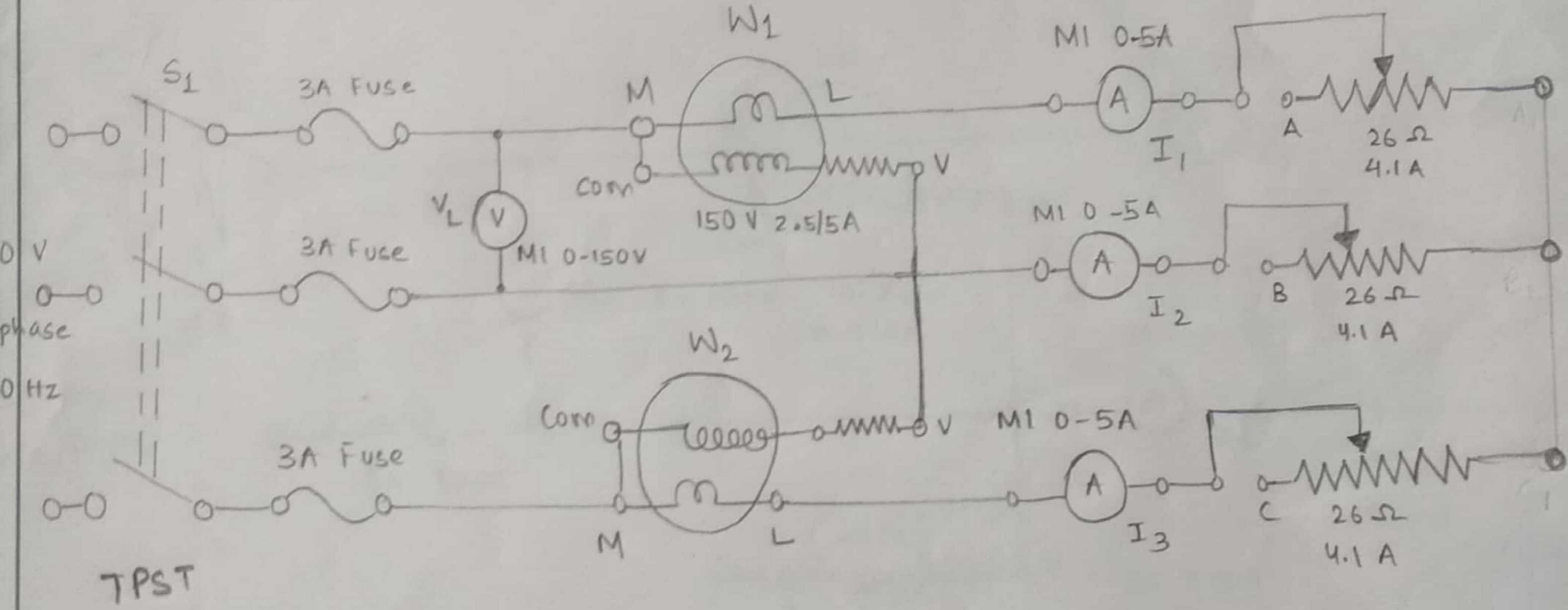
iv) Unbalanced reactive load condition.

APPARATUS REQUIRED

Apparatus / Instrument/ Device	Quantity	Range	Type
1. TPST Switch	1	–	–
2. Wattmeter	2	150 V 2.5/5 A	–
3. Voltmeter	1	0 - 150 V	MI
4. Ammeter	3	0 - 5 A	MI
5. Gang Rheostat	1	0 - 26 Ω	–
6. Capacitors	3	70 μF	–
7. Rheostats	3	0 - 26 Ω	–
8. SPST switch	1	–	–

CIRCUIT DIAGRAM

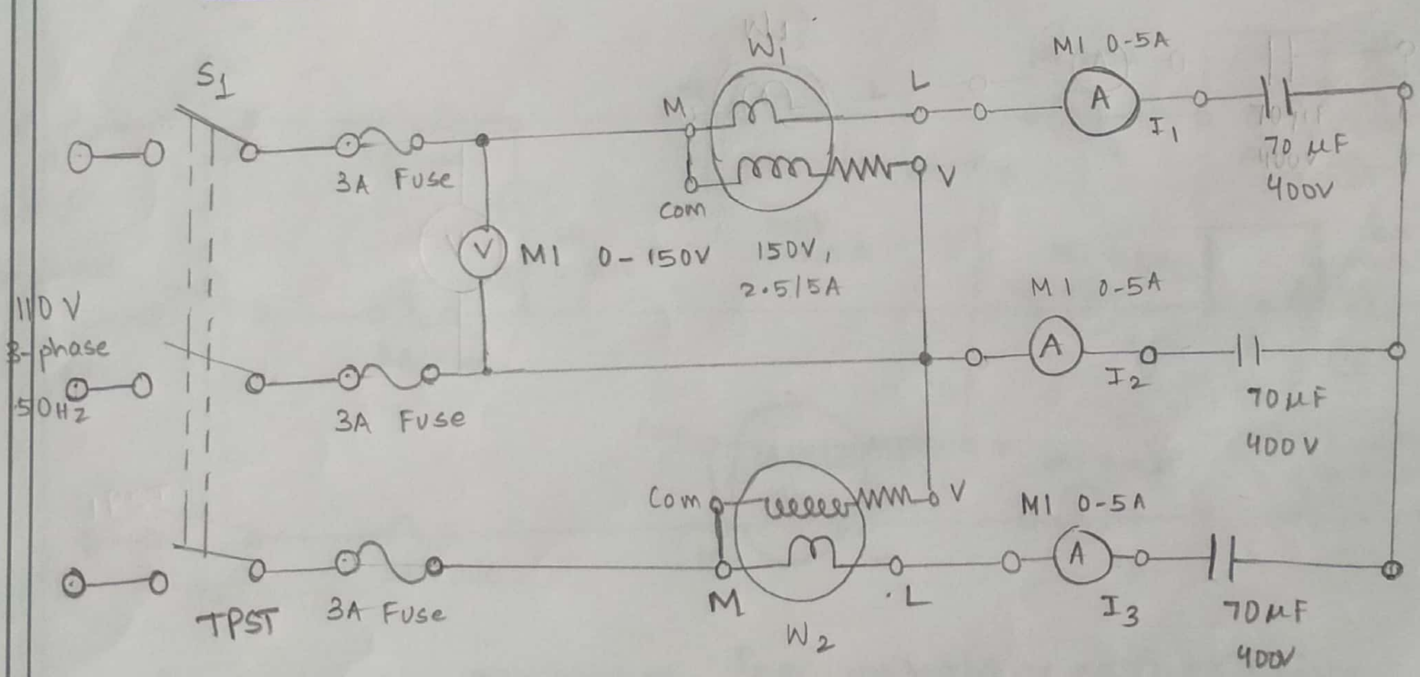
(A) RESISTIVE CIRCUIT



circuit diagram for balanced resistive load condition.

CIRCUIT DIAGRAM

(B) Balanced reactive (capacitive) load



Circuit diagram for balanced capacitive load condition

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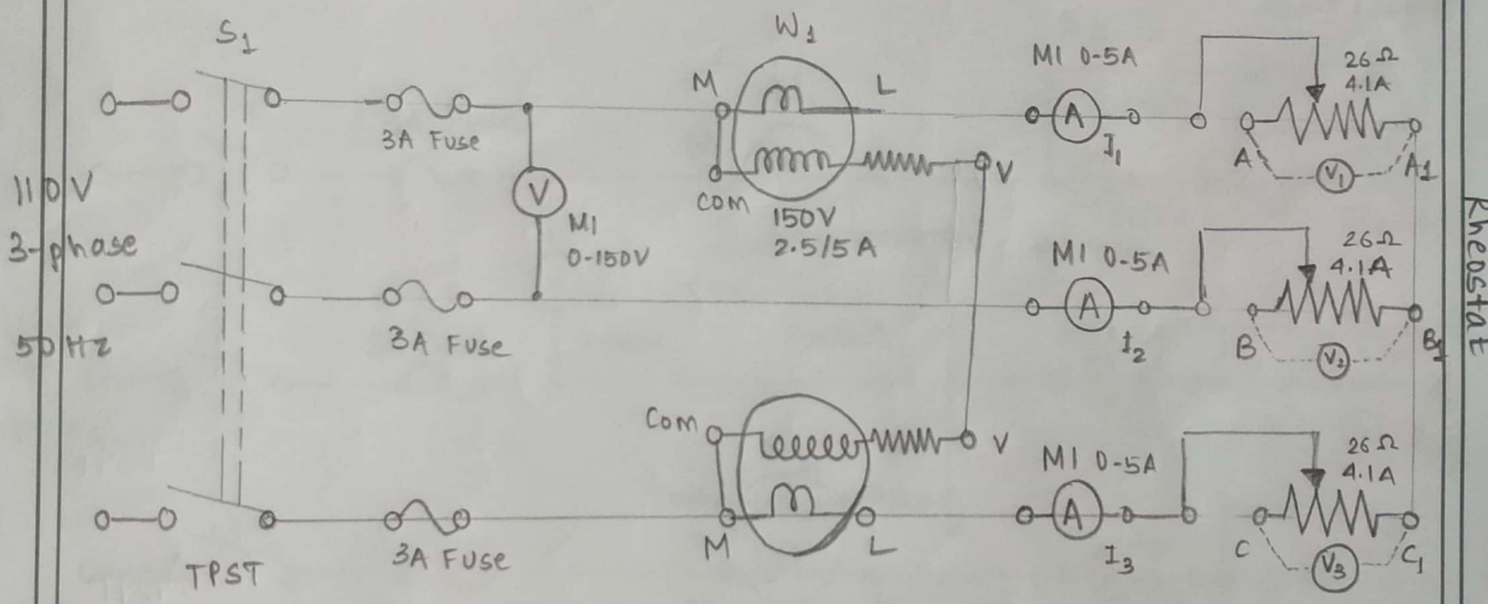
CIRCUIT DIAGRAM

Unbalanced Resistive load



Circuit Diagram for unbalanced resistive load condition.

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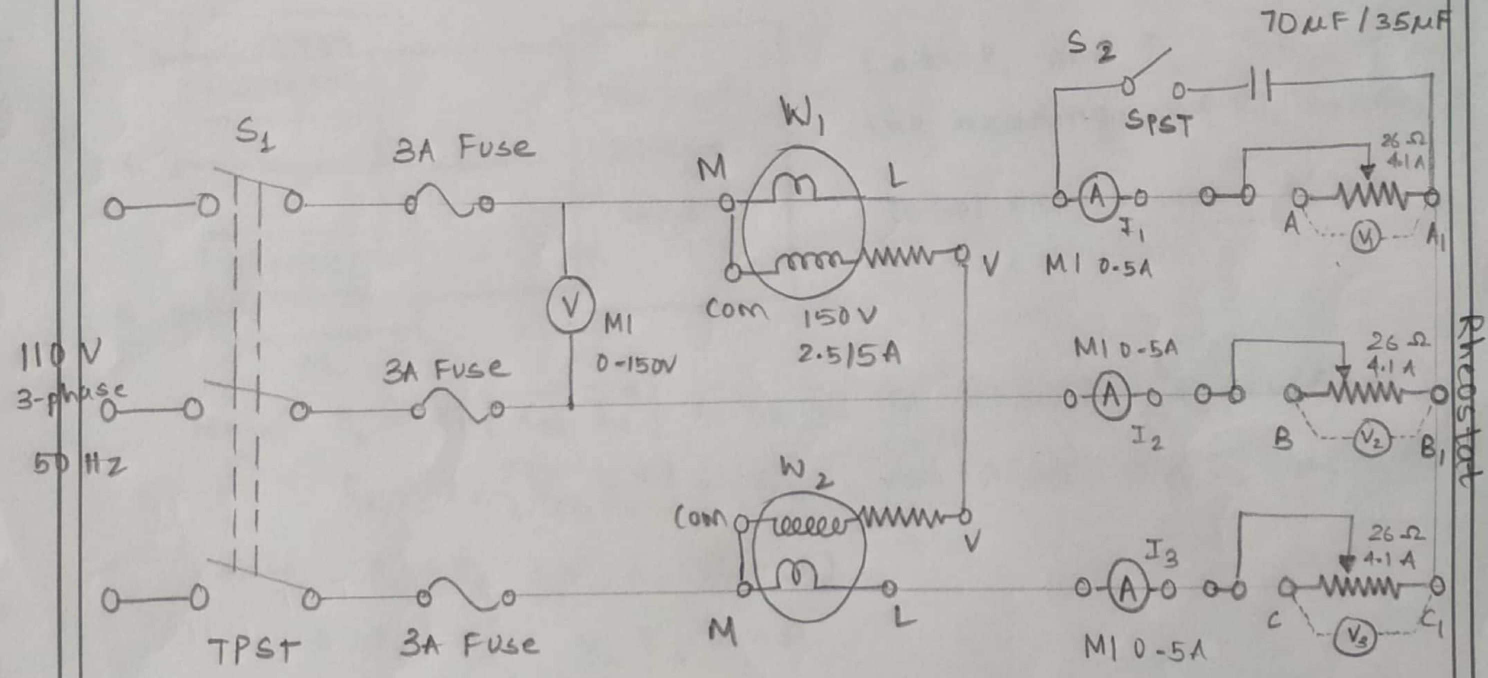
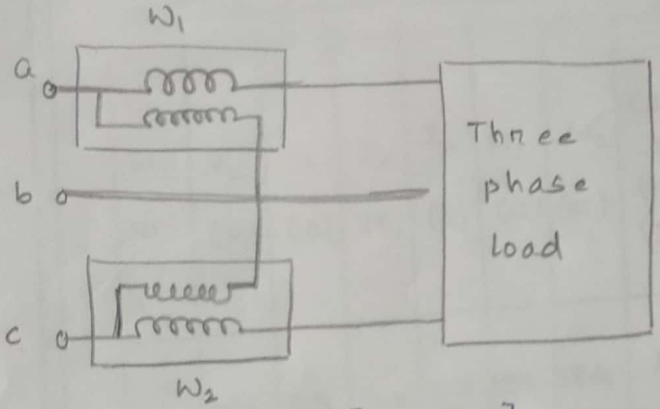
CIRCUIT DIAGRAM

Unbalanced Capacitive Circuit



RELEVANT THEORY

Power measurement using two wattmeter method



Let P_1 and P_2 be the readings of W_1 and W_2

Total real power $= P_1 + P_2$

Now $P_1 = Re[\bar{V}_{ab}\bar{I}_a^*] = V_{ab} I_a \cos(\theta + 30°) = V_L I_L \cos(\theta+30°)$

$P_2 = Re[\bar{V}_{cb}\bar{I}_c^*] = V_{cb} I_c \cos(\theta - 30°) = V_L I_L \cos(\theta - 30°)$

Now $P_1 + P_2 = V_L I_L (\sqrt{3}\cos\theta)$

and $P_2 - P_1 = V_L I_L \sin\theta$

$\therefore$ Real power $= P_1 + P_2 = P_T$

Reactive power $= \sqrt{3}(P_2 - P_1) = Q_T$

$\tan\theta = \dfrac{Q_T}{P_T} = \dfrac{\sqrt{3}(P_2 - P_1)}{P_2 + P_1}$, θ is the power angle

Now, 1. $P_2 = P_1$, load is resistive

2. $P_2 > P_1$, load is inductive

3. $P_2 < P_1$, load is capacitive

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OBSERVATION TABLE

Balanced Resistive Circuit

Sl. No.	V_L (V)	I_1 (A)	I_2 (A)	I_3 (A)	W_1 (W)	W_2 (W)	Calculated power (W_c) = $(V_L/\sqrt{3}) \times (I_1+I_2+I_3)$	$W_m = (W_1+W_2)$	Error $\frac{W_m - W_c}{W_c} \times 100\%$
1	101	2.4	2.4	2.4	204	224	419.85	428	1.9%.
2	99	2.76	2.8	2.8	228	264	477.84	492	2.96%.
3	100	2.9	2.9	2.9	252	260	502.29	512	1.93%.

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OBSERVATION TABLE

Balanced Capacitive Circuit

Sl. No.	V_L (V)	I_1 (A)	I_2 (A)	I_3 (A)	W_1 (W)	W_2 (W)	Error $= (W_1+W_2)$ (W)
1	103.5	1.4	1.36	1.4	72	-76	-4

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OBSERVATION TABLE

Unbalanced Resistive Circuit

Sl. No.	V_1 (V)	V_2 (V)	V_3 (V)	I_1 (A)	I_2 (A)	I_3 (A)	W_1 (W)	W_2 (W)	Calculated Power $W_c = V_1 I_1 + V_2 I_2 + V_3 I_3$	$W_m = (W_1 + W_2)$	Error $= \frac{W_m - W_c}{W_c} \times 100\%$
1	39.34	62.90	71.3	4.5	3.9	3	400	252	613.74	652	6.2%
2	59.75	58.04	55.45	2.56	2.7	2.79	216	260	464.37	476	2.50%
3	59.5	58.5	54.90	2.7	2.8	2.92	220	276	484.76	496	2.32%

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OBSERVATION TABLE

Unbalanced Capacitive Circuit

Capacitance	V_1 (V)	V_2 (V)	V_3 (V)	I_1 (A)	I_2 (A)	I_3 (A)	W_1 (W)	W_2 (W)	Calculated Power $W_c = V_1I_1 + V_2I_2 + V_3I_3$ (W)	$W_m = (W_1 + W_2)$ (W)	Error $\frac{W_m - W_c}{W_c} \times 100\%$
35 μF	58.7	64.62	52.44	2.18	2.4	2.04	52	45	389.95	388	-0.5%
	59.32	65.42	51	2.38	2.6	2.4	55	53	433.67	432	-0.4%
	53.4	65.86	55.57	2.65	2.55	2.38	62	50	438.42	448	2.18%
70 μF	52.56	70.1	53.04	2.61	2.75	2.27	69	45	450.36	456	1.25%
	55.50	66.6	53.52	2.48	2.9	2.44	68	45	461.37	452	-2.03%
	60.21	64.21	51.24	2.4	3.2	2.2	68	50	462.7	472	2%

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RESULT

1. From the given experiment it can be concluded that power of any balanced or unbalanced 3-star or delta connected load can be found out by using two wattmeters.

2. In case of balanced load there is no potential difference between neutral and center of star connected load.

3. In case of unbalanced load there is potential difference between neutral and center of star connected load.

DISCUSSION :

1. What do you understand by a balanced three phase load?

A balanced three phase load refers to a set up of three equal and identical impedances in a Wye or Delta connection.

2. How would you measure power using:
   a) Three wattmeters
   b) One wattmeter for balanced/unbalanced load?

(a) By connecting the current coil in series with the transmission line and voltage coils across transmission line and neutral points for all three loads, we can make use of the three wattmeters to find out the average power consumed by each phase.

(b) For balanced load, connecting one wattmeter across any phase will give exactly one third of total average power. For unbalanced load, we can fix one terminal to neutral point of the voltage coil and then shift connections

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accordingly for each phase to read the power consumed by that phase.

3. Is it possible to measure power factor of the balanced (three-phase load by two-wattmeter method)?

Yes, it is possible.

Let P_1 and P_2 be the readings of W_1 and W_2, then $P_T = P_1 + P_2$

$$Q_T = \sqrt{3}(P_2 - P_1)$$

and $\tan\theta = \dfrac{Q_T}{P_T} = \dfrac{\sqrt{3}(P_2 - P_1)}{P_2 + P_1}$, where θ is power angle

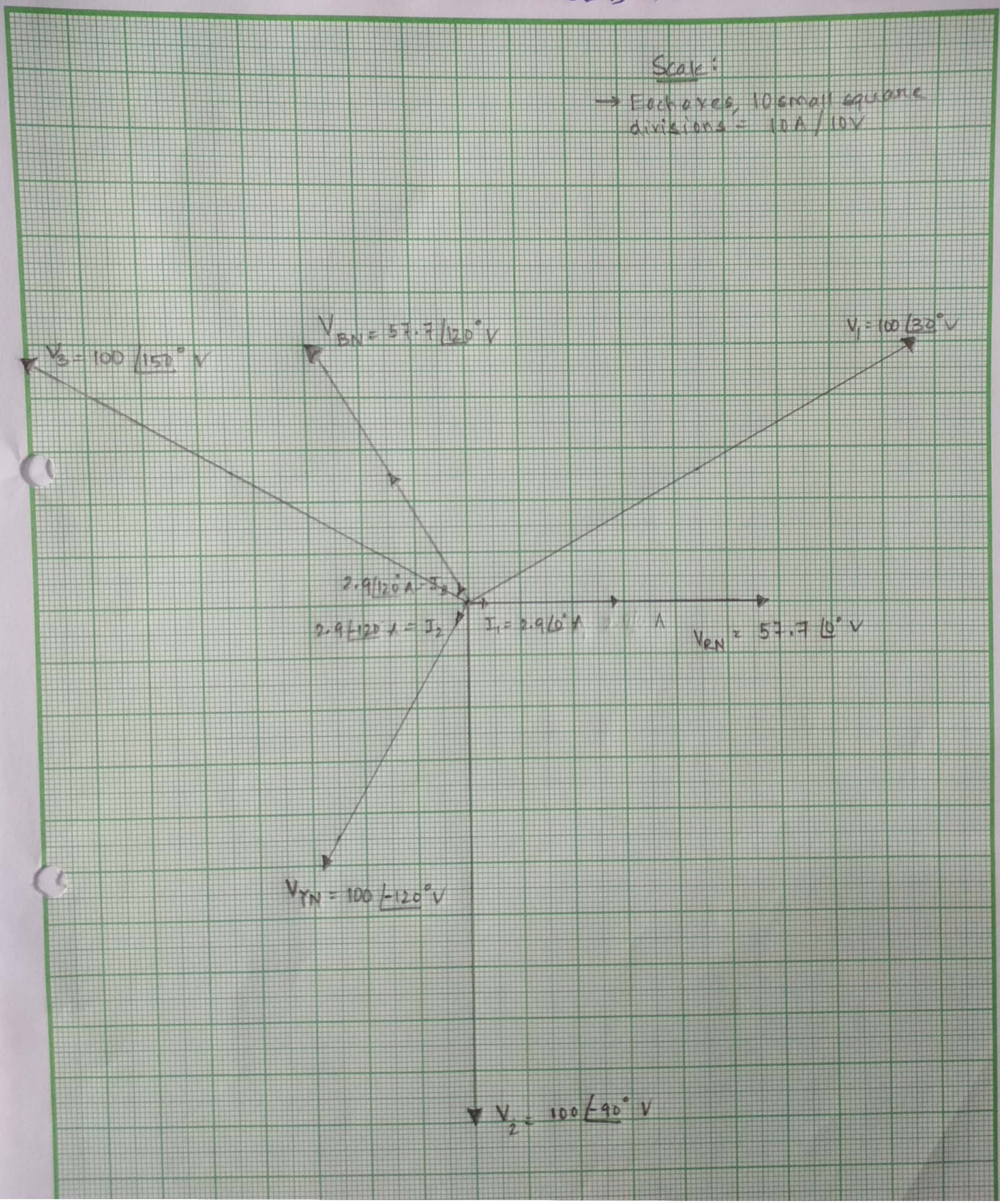
$$\therefore \text{p.f.} = \cos\theta = \frac{1}{\sqrt{1+\tan^2\theta}}$$

$$= \frac{1}{\sqrt{1 + \dfrac{3(P_2-P_1)^2}{(P_2+P_1)^2}}}$$

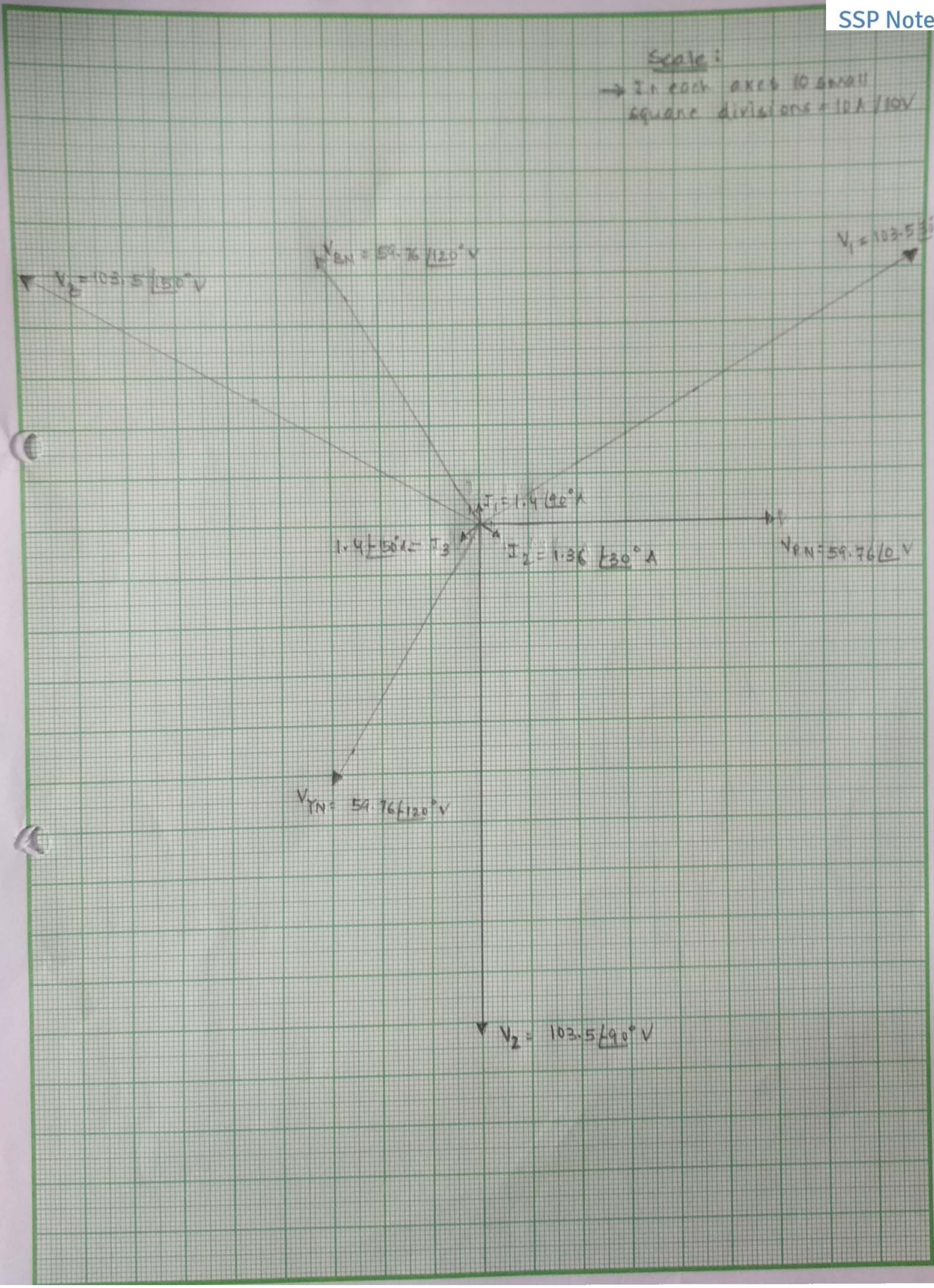
4. Draw the phasor diagrams for the four situations in the experiment.

P.R.E.

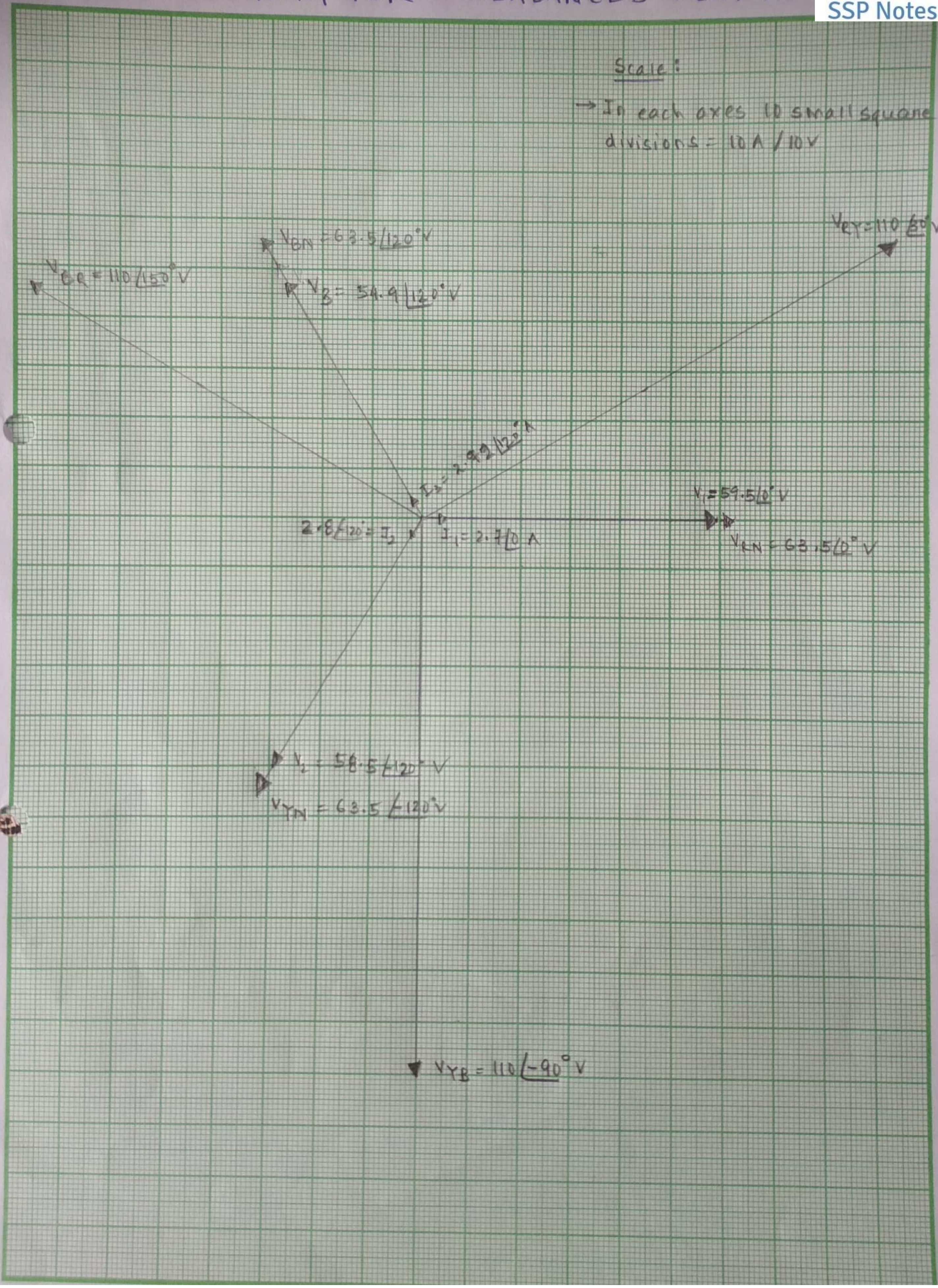
PHASOR DIAGRAM FOR BALANCED RESISTIVE CIRCUIT



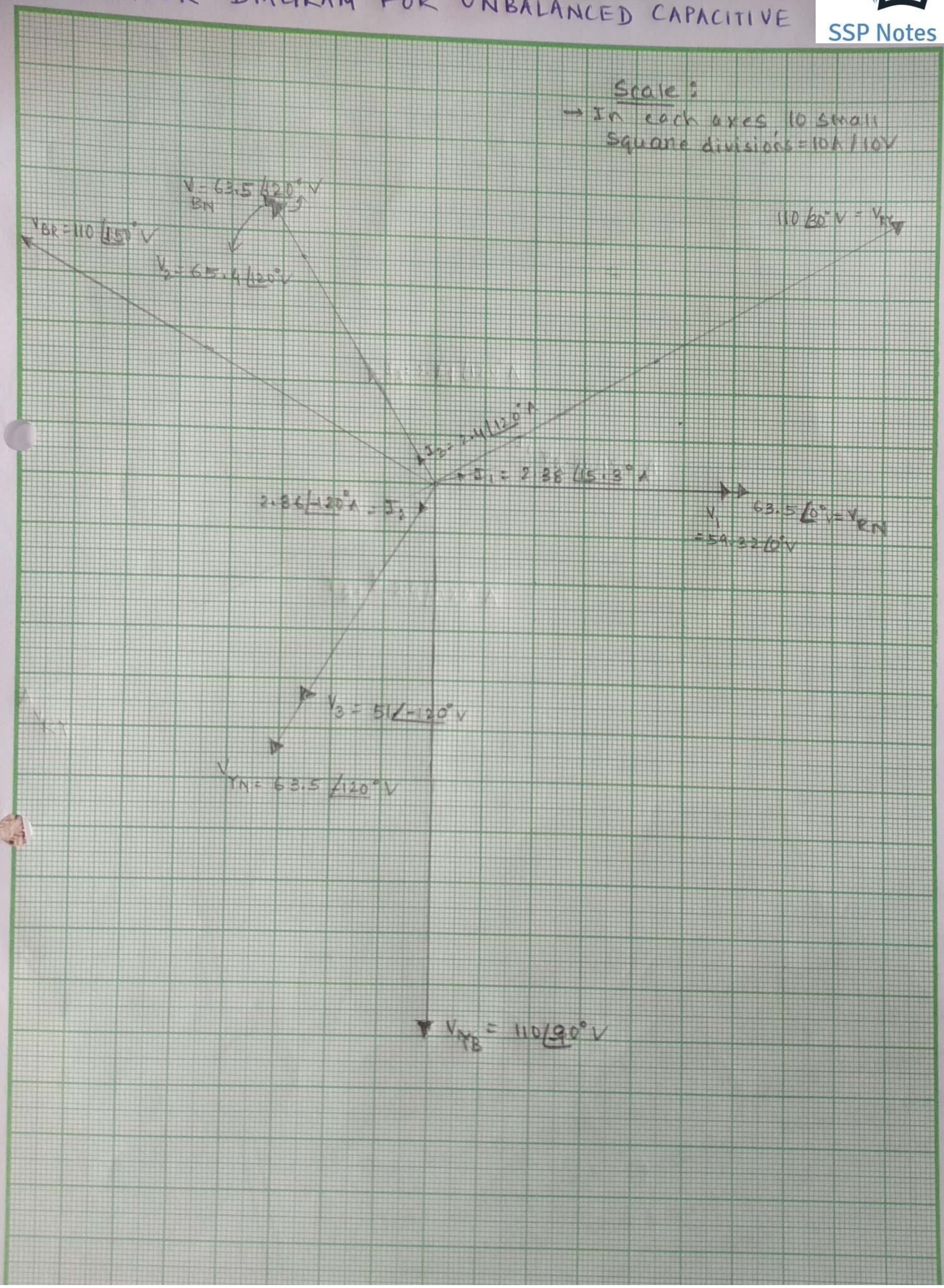
PHASOR DIAGRAM FOR BALANCED CAPACITIVE C



PHASOR DIAGRAM FOR UNBALANCED RESISTIVE



PHASOR DIAGRAM FOR UNBALANCED CAPACITIVE



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5. In case S_2 is open in Fig. 4 for case 1 (70μF), with the S_2 open, will the wattmeter readings change? Discuss.

Whenever we connect a reactance in a circuit, no real power is dissipated and the power is only exchanged between the reactance and the source. Hence, when we disconnect one 70μF capacitor by keeping the switch S_2 open, the net impedance across the AabBA loop increases and current decreases, so the wattmeter reading reduces.

6. Comment on the neutral to start point voltage for each case.

In case of the balanced resistive load and reactive load, the neutral to start point voltage was found to be near about 0.1 V which ideally should be zero. The error observed is due to instrumental malfunctioning. In a balanced condition the currents are equal in magnitude and exactly 120° out of phase with each other and at the starpoint-

$$\sum_{a,b,c} \vec{I_n} = 0 \qquad \therefore \quad \overline{V}_{Nn} = Z_N \cdot (\Sigma I_n) = 0$$

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But in case of unbalanced load, voltages of about 50 & 60 V were measured between the neutral and star point. This happens because now the currents are no more equal in magnitude and an excess current can be drawn from the star point.

For unbalanced $\sum_{a,b,c} \vec{I_n} \neq 0$.