Experiment No: 4

Measurement of Power Using CT & PT

Objective:

- To study the working of current transformer and potential transformer.
- To connect instrument transformer in electrical circuits for measurements of current, voltage and power.

Apparatus Used:

The following instruments are to be used for this experiment: -

Sl. No	Name of equipment's	Range
1	Current Transformer	30A / 5A
2	Potential Transformer	300V / 100V
3	M.I type Ammeter	Primary: (0 – 30A) Secondary: (0 – 5A)
4	M.I type Voltmeter	Primary: (0 – 230V) Secondary: (0 – 230V)
5	Dynamometer type Wattmeter	0 – 1.5kW
6	Loading arrangement	-

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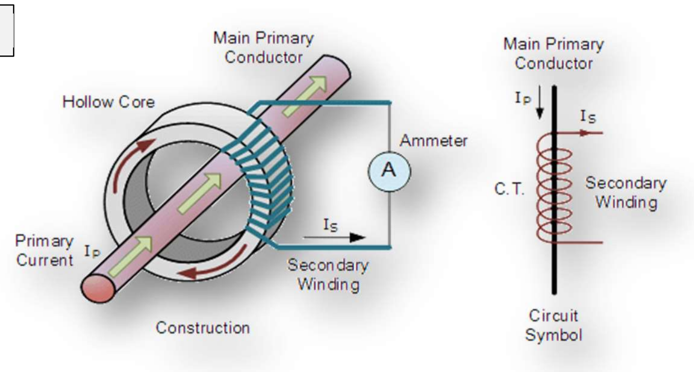
Theory:

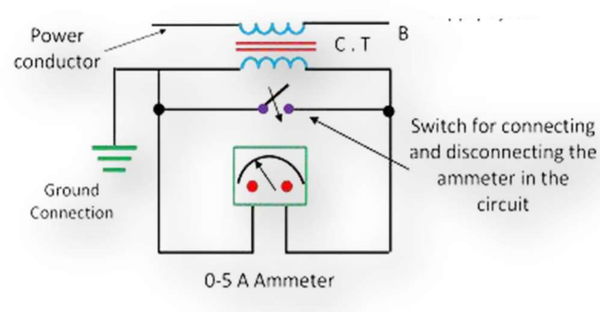
In dc circuits, large currents can be measured with the help of low range ammeters with appropriate shunts. For measuring high voltages, low range voltmeters are used in conjunctions with a high series resistance. Same methods cannot be used with ac circuits because of the presence if inductance and capacitance in the circuit. For this purpose, specially designed accurate ratio instrument transformers are used in conjunction with standard low range ac instruments. These instrument transformers are of two types: -

- **Current Transformers** for measuring large alternating currents and,
- **Potential Transformers** for measuring high alternating voltages.

Current Transformer



A Current Transformer (CT) is used to measure the current of another circuit. CTs are used worldwide to monitor high-voltage lines across national power grids. A CT is designed to produce an alternating current in its secondary winding that is proportional to the current that it is measuring in its primary. In doing so, the current transformer reduces a high voltage current to a lower value and therefore provides a safe way of monitoring electrical current flowing in an AC transmission line.



Current Transformer

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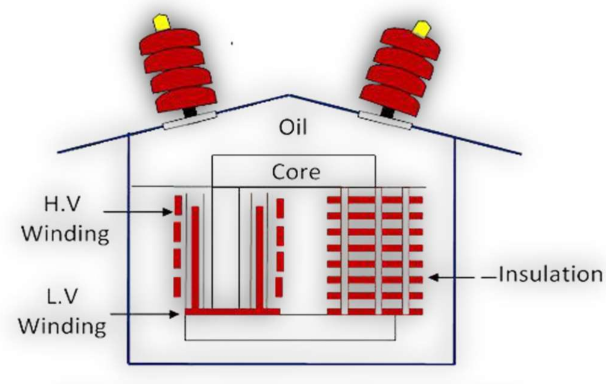
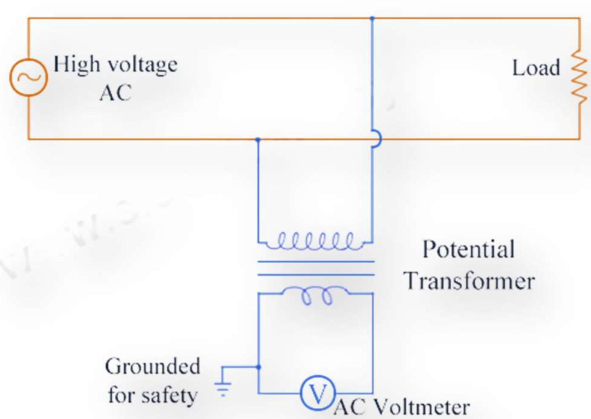
The current transformer is basically a step-up transformer and obviously the current in the secondary winding will be less than that in the primary winding. Thus, a current transformer having primary to secondary voltage transformation ratio of 1:20 will have a current transformation ratio of 100:5 (or 20:1). Hence if we know the current transformation ratio (I_1/I_2) then line current is obtained by multiplying the ammeter reading i.e., I_2 by the ratio I_1/I_2.

Potential Transformer



Single Phase Potential Transformer

A Potential Transformer (PT) on the other hand is a step-down transformer used along with a low range voltmeter for measuring high voltage. The primary is connected across the high voltage supply and the secondary to the voltmeter or potential coil of the wattmeter. Since, the voltmeter (or potential coil) impedance is very high, the secondary current is very small and the potential transformer (PT) behaves as an ordinary two winding transformer operating on no-load. Potential transformer (PT) secondary is commonly designed for an output of 110 Volts.



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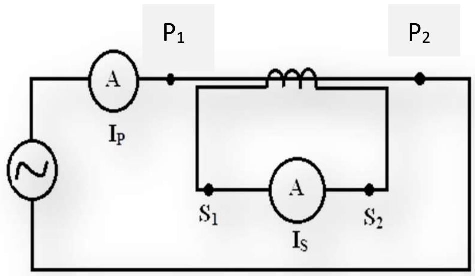
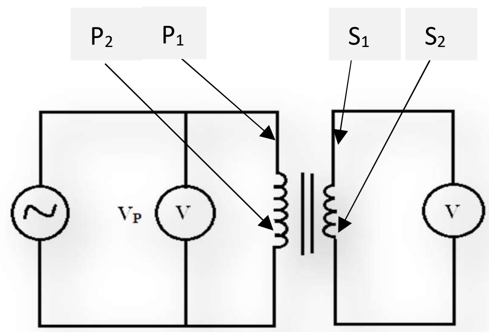
Since secondary load is either an instrument, a relay or a pilot lamp, the rating of PTs is 40W to 100W. For safety the secondary should be completely insulated from the high voltage primary and should be earthed.

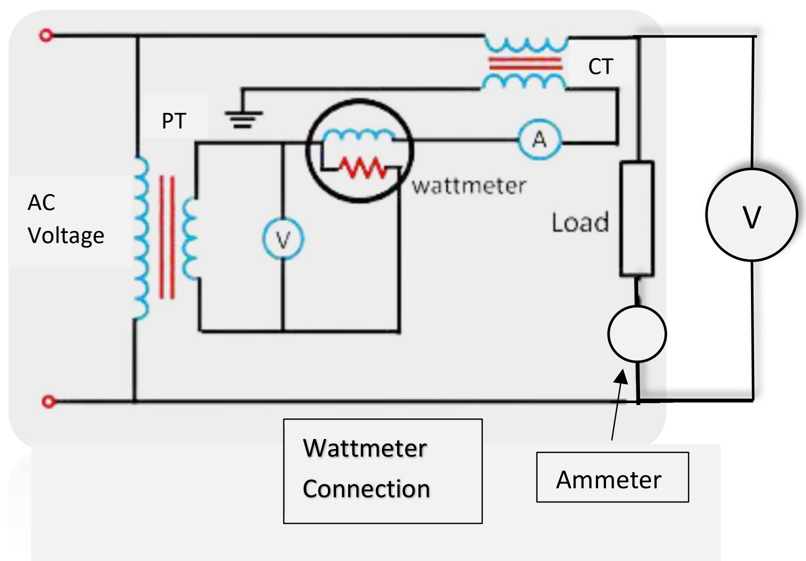
Circuit Diagrams:



CT Calibration



PT Calibration



CT Calibration: - By this method, the current circulating in the secondary windings of a CT is calculated using an ammeter of suitable range and then keeping in view of the Nominal ratio and Transformation ratio of CT, the actual Line current Is calculated.

Nominal Ratio (Turns Ratio) $= N = \frac{N_P}{N_S}$

Transformation Ratio $= R_{CT} = N + \frac{I_o}{I_S}$

Therefore, $I_P = I_o + NI_S$, P is Primary, S is secondary and I_o is the summation of core loss current and magnetizing current on the primary section.

PT Calibration: - By this method, the voltage in the secondary windings of the PT is calculated using a voltmeter of suitable range and then keeping in view of the Nominal ratio and Transformation ratio of PT, the actual phase voltage is calculated.

Nominal Ratio (Turns Ratio) $= N = \frac{N_P}{N_S}$

Transformation Ratio $= R_{CT} = N + \frac{I_S(R_P \cos\phi + X_P \sin\phi) + I_C R_P + I_M X_P}{N V_S}$, where R_P, X_P, I_C, I_M, I_S, V_S are Primary resistance, Primary reactance, Core loss component of exciting current, Magnetizing component of exciting current, Secondary current and Secondary voltage respectively.

Wattmeter Connection: - The Pressure coil is connected in parallel with the voltmeter, which is already connected with the S_1 and S_2 terminals of the PT secondary winding.

The Current coil is connected in series with the ammeter which was earlier connected to the S_1 and S_2 terminals of the CT secondary winding.

Observations:

Measurement of Current

Sl. No.	CT Nominal Transformation ratio N	Primary Current I_P(A)	Secondary Current I_S (A)	Actual Ratio $R_{CT} = I_P/I_S$	Ratio Error [(N – R_{CT}) / R_{CT}] * 100%
1	30/5 = 6	1.1	0.186	5.914	1.454%
2	30/5 = 6	1.9	0.303	6.270	-4.306%
3	30/5 = 6	2.9	0.46	6.304	-4.822%
4	30/5 = 6	3.7	0.632	5.854	2.494%
5	30/5 = 6	4.6	0.753	6.108	-1.768%

Measurement of Voltage

Sl. No.	PT Nominal Transformation ratio N	Primary Voltage V_P(V)	Secondary Voltage V_S(V)	Actual Ratio $R_{PT} = V_P/V_S$	Ratio Error [(N – R_{PT}) / R_{PT}] * 100%
1	300/100 = 3	17	6	2.833	5.895%
2	300/100 = 3	25	8	3.125	-4%
3	300/100 = 3	41	14	2.928	2.46%
4	300/100 = 3	55	18	3.055	-1.8%
5	300/100 = 3	67	22	3.045	-1.477%

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Measurement of Power

Sl. No.	CT Primary Current(A) I_P	CT Secondary Current(A) I_S	PT Primary Voltage(V) V_P	PT Secondary Voltage(V) V_S	Actual CT Ratio(I_P/I_S) R_{CT}	Actual PT Ratio(V_P/V_S) R_{PT}	Measured Power = Wattmeter Reading * 18 (W)	True Power $V_S I_S$ * R_{CT}*R_{PT}	% Error
1	0.95	0.154	220	73.4	6.168	2.997	11.1*18=199.8	208.95	-4.38
2	1.96	0.322	220	73.5	6.087	2.993	22.1*18=397.8	431.17	-7.74
3	2.98	0.485	220	73.2	6.144	3.005	32.9*18=592.2	655.46	-9.65
4	3.94	0.641	220	72.9	6.146	3.017	44.7*18=804.6	866.47	-7.14
5	4.95	0.811	220	73	6.103	3.013	54.8*18=986.4	1088.64	-9.39

Calculations:

Calculations for first set of readings:

Measurement of current:

CT Nominal transformation ratio $= N = \frac{30}{5A} = \frac{6}{1} = 6$

Actual ratio $= R_{CT} = \frac{I_P}{I_S} = \frac{1.1A}{0.186A} = 5.914$

Ratio Error $= \frac{N-R_{CT}}{R_{CT}} \times 100\% = \frac{6.000-5.914}{5.914} \times 100\% = \frac{0.086}{5.914} \times 100\%$

$$= 0.01454 \times 100\% = 1.454\%$$

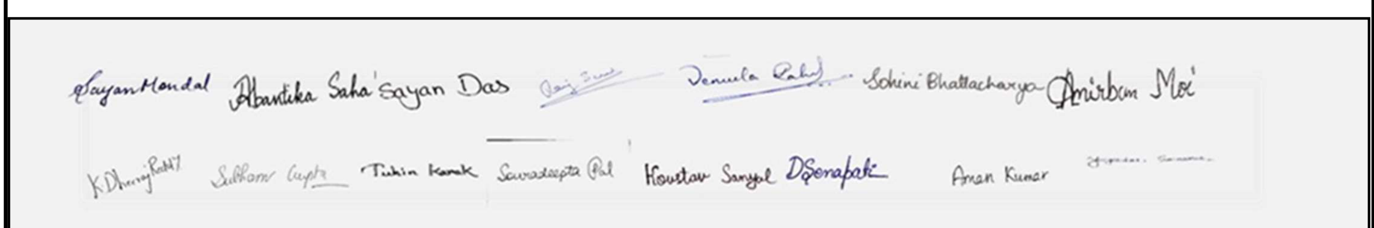
Measurement of voltage:

PT Nominal transformation ratio $= N = \frac{300V}{100V} = \frac{3}{1} = 3$

Actual ratio $= R_{PT} = \frac{V_P}{V_S} = \frac{17V}{6V} = 2.833$

Ratio Error $= \frac{N-R_{PT}}{R_{PT}} \times 100\% = \frac{3.000-2.833}{2.833} \times 100\% = \frac{0.167}{2.833} \times 100\%$

$$= 0.05895 \times 100\% = 5.895\%$$



Measurement of power:

Actual CT ratio $= R_{CT} = \frac{I_P}{I_S} = \frac{0.95A}{0.154} = 6.168$

Actual PT ratio $= R_{PT} = \frac{V_P}{V_S} = \frac{220V}{73.4V} = 2.997$

Measured Power $(W_M) =$ Wattmeter reading $\times 3 \times 6 = 11.1 \times 18 = 199.8W$

True Power $(W_T) = (V_S I_S) \times R_{CT} \times R_{PT} = (73.4 \times 0.154) \times 6.168 \times 2.997 = 208.95W$

Ratio Error $= \frac{W_M - W_T}{W_T} \times 100\% = \frac{199.8-208.95}{208.95} \times 100\% = \frac{-9.15}{208.95} \times 100\%$

$$= -0.0438 \times 100\% = -4.380\%$$

Calculations using mean values:

Actual Transformation ratios (I_P/I_S) of the **Current Transformer** came out to be: -

- $\frac{1.1A}{0.186A} = 5.914$
- $\frac{1.9A}{0.303A} = 6.270$
- $\frac{2.9A}{0.46A} = 6.304$
- $\frac{3.7A}{0.632A} = 5.854$
- $\frac{4.6A}{0.753A} = 6.108$

So, the mean value of the Transformation ratio of this particular **Current transformer** is: -

$$\frac{(5.914 + 6.270 + 6.304 + 5.854 + 6.108)}{5} = 6.09$$

Turns Ratio $= N = \frac{30A}{5A} = \frac{6}{1} = 6$

So, Ratio Error is $\frac{6-6.09}{6.09} \times 100\% = -1.4778\%$

Actual Transformation ratios (V_P/V_S) of the **Potential Transformer** came out to be: -

- $\frac{17V}{6V} = 2.833$
- $\frac{25V}{8V} = 3.125$
- $\frac{41V}{14V} = 2.928$
- $\frac{55V}{18V} = 3.055$
- $\frac{67}{22V} = 3.045$

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So, the mean value of the Transformation ratio of this particular **Potential transformer** is: -

$$\frac{(2.833\ +\ 3.125\ +\ 2.928\ +\ 3.055\ +\ 3.045)}{5} = 2.9972$$

Turns Ratio $= N = \frac{300V}{100} = \frac{3}{1} = 3$

So, Ratio Error is $\frac{3-2.9972}{2.9972} \times 100\% = 0.093\%$

Power Calculation for different values of I_P and Constant value of V_P = 220V yields different values of I_S and V_S: -

I_P	I_S	V_P	V_S	$R_{CT} = I_P/I_S$	$R_{PT} = V_P/V_S$	True Power $(V_S I_S) * R_{CT}*R_{PT}$ (W_t)
0.95A	0.154A	220V	73.4V	0.95A/0.154A = 6.168	220V/73.4V = 2.997	73.4V * 0.154A * 6.168*2.997 = 208.95W
1.96A	0.322A	220V	73.5V	1.96A/0.322A = 6.087	220V/73.5V = 2.993	73.5V * 0.322A * 6.087*2.993= 431.17W
2.98A	0.485A	220V	73.2V	2.98A/0.485A = 6.144	220V/73.2V = 3.005	73.2V * 0.485A * 6.144*3.005 = 655.46W
3.94A	0.641A	220V	72.9V	3.94A/0.641A = 6.146	220V/72.9V = 3.017	72.9V * 0.641A * 6.146*3.017 = 866.47W
4.95A	0.811A	220V	73V	4.95A/0.811A = 6.103	220V/73V = 3.013	73V * 0.811A * 6.103 * 3.013 = 1088.64W

And the deviation of the wattmeter reading from the true power is: -

True Power $(V_S I_S)*R_{CT}*R_{PT}$ (W_t)	Measured Power = Wattmeter Reading * 18 = W_m	Percentage Error = $[(W_m-W_t)/W_t]*100\%$
73.4V * 0.154A * 6.168*2.997 = 208.95 W	11.1 * 18=199.8 W	-4.38%
73.5V * 0.322A * 6.087*2.993 = 431.17 W	22.1 * 18=397.8 W	-7.74%
73.2V * 0.485A * 6.144*3.005 = 655.46 W	32.9 * 18=592.2 W	-9.65%
72.9V * 0.641A * 6.146*3.017 = 866.47 W	44.7 * 18=804.6 W	-7.14%
73V * 0.811A * 6.103 * 3.013 = 1088.64 W	54.8*18=986.4 W	-9.39%

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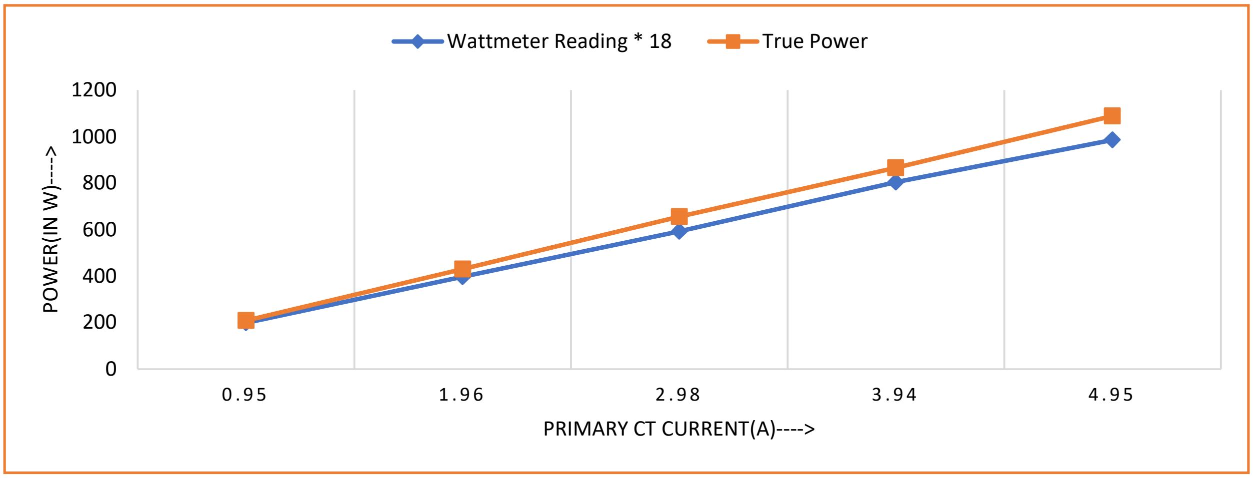
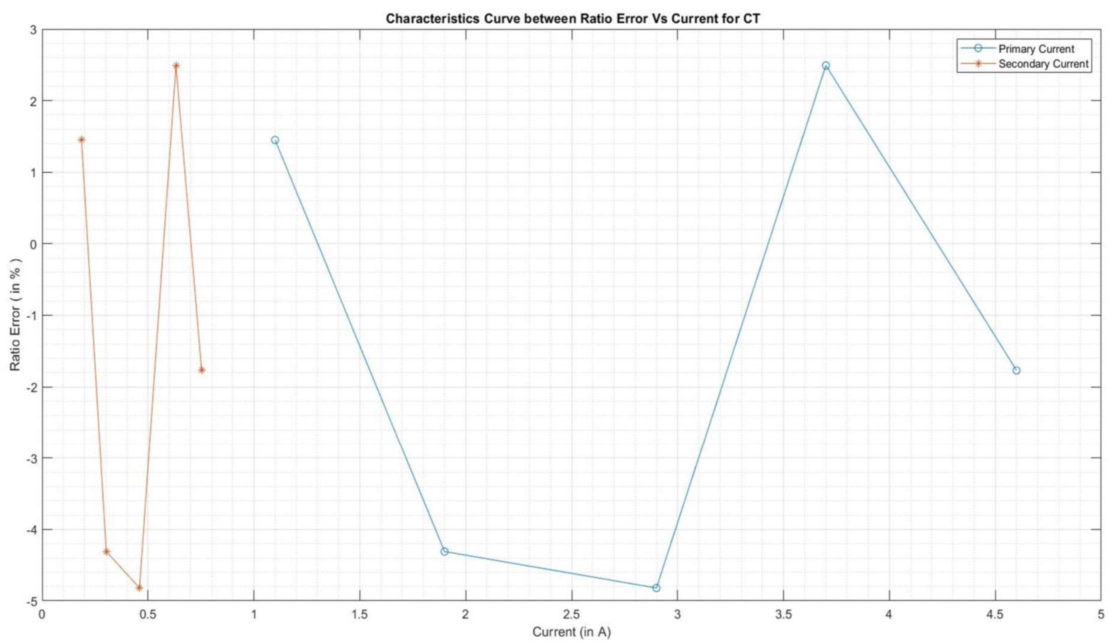
True Power & Measured Power VS I_S



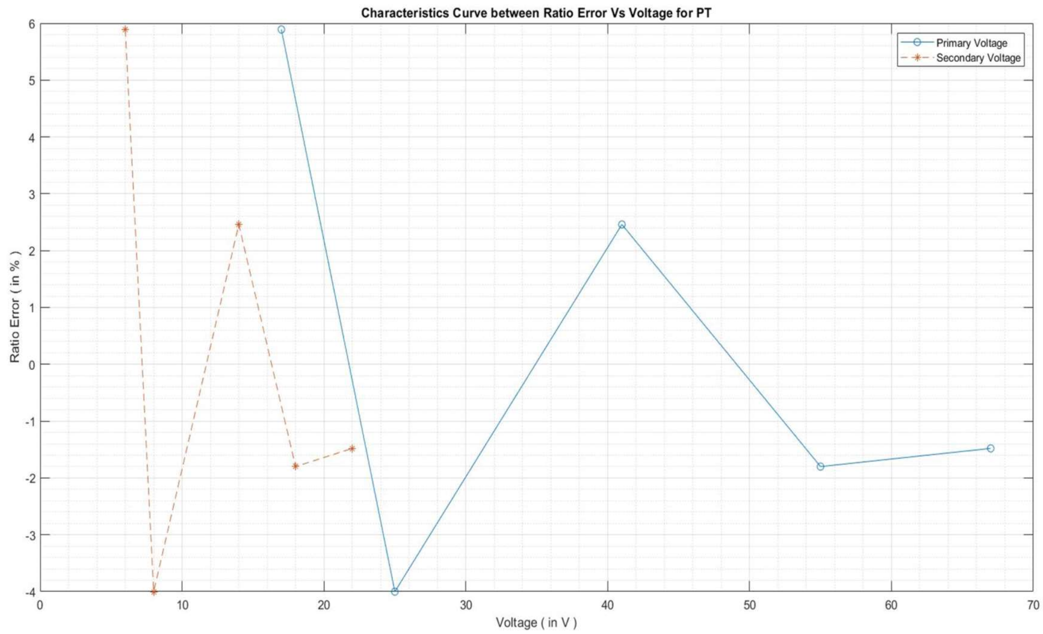
Here, we can see there is a very slight difference between the True power and Measured power curves due to instrumental errors.

Experimental Graphs:

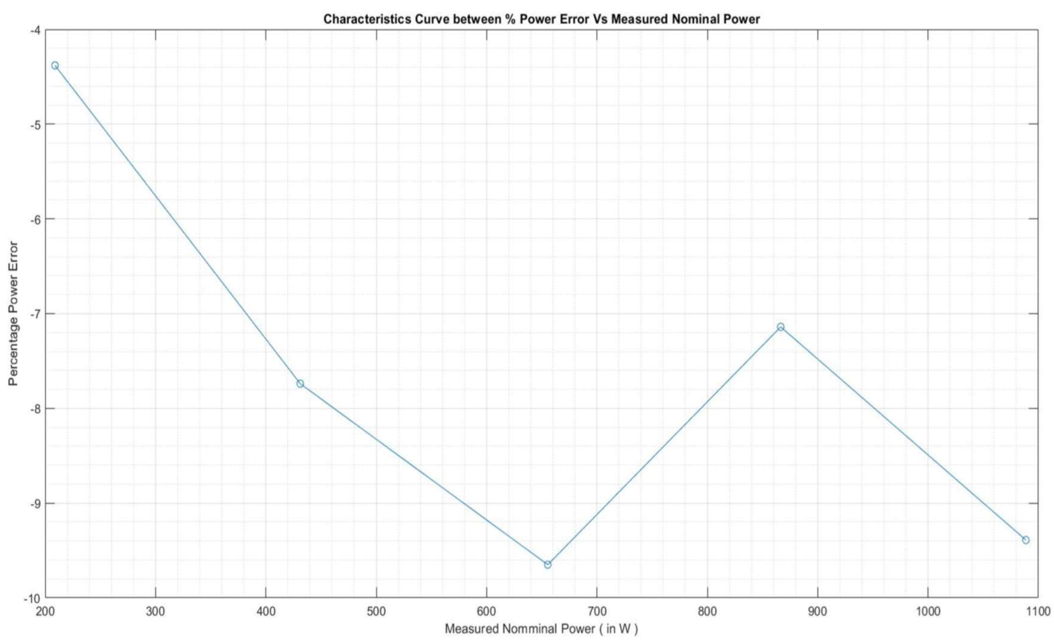
Ratio Error vs Current for CT (I_S & I_P)

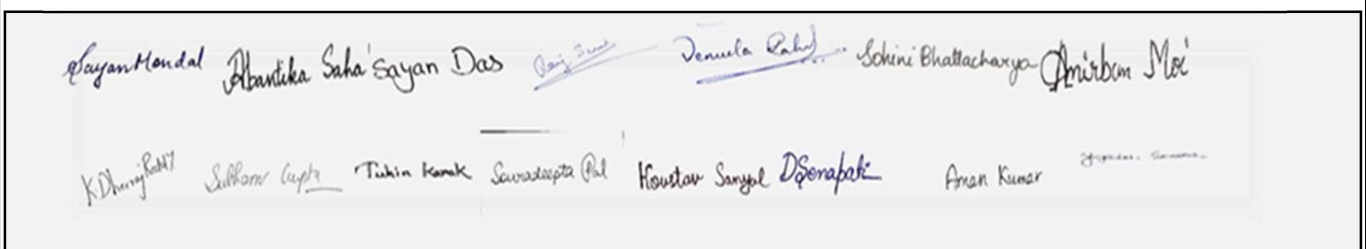


Ratio Error vs Voltage for PT (V_S & V_P)



% Power Error vs Measured Nominal Power





Conclusion:

From the experiment and the results above we conclude that -

The mean transformation ratio of the CT is 6.09

The mean transformation ratio of the PT is 2.9972

The mean percentage error is -7.66%.

Using a CT, we can easily step down the high current across any load and measure it safely with normal instruments.

Using a PT, we can easily step down the high voltage across any load and measure it safely with normal instruments.

Thus, a combination of CT and PT can be used to measure the power across a load. They effectively step down the high voltage or current and the readings can be taken safely with instruments in the normal range.

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