LABORATORY MANUAL

ON

ELECTRICAL MEASUREMENTS
LABORATORY

2018 – 2019

III B. Tech I Semester (JNTUA-R15)

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Department of Electrical and Electronics Engineering
Course Objective: The objectives of the course are to make the students learn about:

- Calibration of various electrical measuring/recording instruments.
- Accurate determination of resistance, inductance and capacitance using D.C and A.C Bridges.
- Measurement of parameters of choke coil

The following experiments are required to be conducted as compulsory experiments:
1. Calibration of Single Phase Energy Meter using Phantom loading method with RSS meter as standard
2. Calibration of Dynamometer Power Factor Meter
3. Crompton D.C. Potentiometer – Calibration of PMMC Ammeter and PMMC Voltmeter
6. Schering Bridge & Anderson Bridge for measurement of Capacitance and Inductance values.

In addition to the above eight experiments, at least any two of the experiments from the following list are required to be conducted:
10. Calibration of LPF Wattmeter – by Phantom Testing
12. Dielectric Oil Testing Using H.T. Testing Kit
13. LVDT and Capacitance Pickup – Characteristics and Calibration

Course Outcomes: At the end of the course, the student will be able to

- Calibrate various electrical measuring/recording instruments.
- Accurately determine the values of inductance and capacitance using a.c bridges
- Accurately determine the values of very low resistances
- Measure reactive power in 3-phase circuit using single wattmeter
- Determine ratio error and phase angle error of CT
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<tr>
<th>S. No</th>
<th>Name of the Experiment</th>
<th>Page No</th>
</tr>
</thead>
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<td>Anderson’s Bridge &amp; Schering Bridge</td>
<td>8-14</td>
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<td>Calibration And Testing of Single Phase Energy Meter</td>
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<td>Calibration Dynamometer Type of Power Factor Meter</td>
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<tr>
<td>5</td>
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<td>8</td>
<td>Energy Meter By Phantom Loading Method</td>
<td>34-36</td>
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<tr>
<td>9</td>
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<td>37-40</td>
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<tr>
<td>10</td>
<td>Measurement of 3 Phase Power With 2 Wattmeters</td>
<td>41-43</td>
</tr>
<tr>
<td>11</td>
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<td>44-46</td>
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</tbody>
</table>
EXPERIMENT – 1
3 AMMETERS AND 3 VOLTMETERS METHOD

AIM:
To measure the inductance and power factor of the choke coil using 3Ammeter and 3Voltmeter method.

APPARATUS:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ammeter</td>
<td>0-5A</td>
<td>AC</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Voltmeters 0</td>
<td>300V</td>
<td>AC</td>
<td>3 No’s</td>
</tr>
<tr>
<td>3</td>
<td>Resistor</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Choke coil</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Auto transformer</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

3 – Ammeter method:
From the pharos diagram
\[ I^2 = I R^2 + I L^2 + 2 I L I R \cos \phi L \]
\[ \cos \phi L = \frac{I^2 - I R^2 - I L^2}{2 I L I R} \]
Power drawn the load = \( VI L \cos \phi L \)
\[ = I R I L \cos \phi L \]
Since power = \( I R I L R \) \( I^2 - I R^2 - I L^2 / 2 I L I R \)
\[ = \left( I^2 - I R^2 - I L^2 \right) R/2. \]
From the power calculated the inductance of the choke can be calculated.

3 – Voltmeter method:
From the pharos diagram
\[ V = V R + V L + 2 V R V L \cos \phi, \quad 3 \text{ No’s} \]
\[ \cos \Phi_L = V - V_{RL} - V_L / 2V_{RL} \]

Power drawn by load = \( V_L I \cos \Phi_L \)

**CIRCUIT DIAGRAM:**

3 - VOLTMETER METHOD

![Circuit Diagram 1]

**figure: 1**

3 - AMMETER METHOD

![Circuit Diagram 2]

**figure: 2**

**3 Voltmeter method:**

1. Make connections as per circuit diagram.
2. Keep the auto transformer at zero position.
3. Switch on the power supply.
4. Increase the voltage gradually from or and note down the I/p voltage V1 voltage across R, V1 V2 and voltage across choke V3 at difference voltage levels.

3 Ammeter methods:

1. Make connections as per circuit diagram.
2. Keep the auto transformer at zero position.
3. Increase the voltage gradually from or and note down the current I1, I2, I3 at different steps.

TABULAR COLUMN:

3-Ammeter Method:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>I</th>
<th>IL</th>
<th>IR</th>
<th>COSΦ</th>
<th>PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>50</td>
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<td>75</td>
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<td>100</td>
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<td>125</td>
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<td>150</td>
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<td>175</td>
<td></td>
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</tr>
</tbody>
</table>

\[
\text{Cos } \Phi_L = I^2 - I R^2 - I L^2 / 2 I L I R
\]

Power drawn the load = VI L Cos Φ_L

\[
= I R R I L \cos \Phi_L
\]

Since power = I R I L R (I^2 – I R^2 – I L^2 / 2 I L I R)

\[
= (I^2 – I R^2 – I L^2) R/2.
\]
3-Voltmeter Method:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>I</th>
<th>VR</th>
<th>VL</th>
<th>COS Φ</th>
<th>PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>50</td>
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<td>125</td>
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<tr>
<td>150</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

\[
\text{COS } \Phi_L = \sqrt{V^2 - VR^2 - VL^2} / 2 VL VR
\]

**PRECAUTIONS:**

Instruments used should be of proper range.

All the connections should be tight.

**RESULT:**
ELECTRICAL MEASUREMENT LABORATORY

EXPERIMENT – 2
ANDERSON’S BRIDGE & SCHERING BRIDGE

AIM:

To determine the values of the inductance of a given decade inductance box.

APPARATUS:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anderson’s Bridge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Audio Oscillator</td>
<td>2V,1KHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>CRO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ohmmeter</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

This is modified version of Maxwell’s bridge in which self-inductance is measured in comparison with a capacitance. This method, using Anderson Bridge, is helpful in determining accurately inductance values over a wide range. The bridge network as shown in fig

L is the Unknown inductance and R1 its resistance.

C is a Standard capacitor.

R2, R3 and R4 are known non-inductive resistors.

r is the variable resistor.

The detector normally used is headphone.

The balancing of the bridge is done follows:
The bridge is first balanced using d.c supply and head phone as detector. Resistance R2, R3 and R4 are properly adjusted so that balance condition is obtained. And balancing of the bridge is again obtained by adjusting resistance r

\[ L = C \frac{r (R3R4) + (R3+R4)}{R4} \]

**PROCEDURE:**

1. Connect diagram of Anderson’s bridge for inductance measurement as shown in fig
2. Select any one standard inductance (unknown) from given inductance bank
3. Now plug in the headphone in to the socket adjust pot r and to get minimum sound on headphone.
4. Measure the Resistance of the r by using Ohmmeter.
5. After null position, unknown inductor L calculated by using standard formula which is given below.

The self-inductance is calculated using the formula:
R3

L = C ------ [r (R3xR4) + (R3+R4)]R4

CIRCUIT DIGRAM:

RESULT:
AIM:

To determine the value of given capacitor and to obtain its dissipation factor.

APPARATUS:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schering Bridge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CRO</td>
<td>AC</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>connecting wires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Digital Voltmeter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Probes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

Alternating current bridge methods are of outstanding importance for measurement of electrical quantities, measurement of Inductance, Capacitance, Storage Factor, Loss Factor, etc. may be made conveniently and accurately by employing AC bridge network.

The AC Bridge is a natural outgrowth of the Wheatstone bridge. An AC bridge, in its basic form, consists of four arms, a source of excitation and a balanced (Null detector). In an AC bridge each of the four arms is impedance, battery and the galvanometer of the Wheatstone bridge are replaced respectively by an AC source and a detector sensitive to small alternating potential difference.

SCHERING BRIDGE FOR LOW VOLTAGE:

The connection diagram for low voltage Schering Bridge is shown in below figure. It consists of the following components.
Let, $C_1$ = unknown Capacitor

$C_2$ = standard Capacitor

$r_1$ = Series resistance representing loss in capacitor $C_1$

$R_3$ & $R_4$ = A variable non inductive resistance

$C_4$ = Variable Capacitor

At balance condition, we obtain following equation.

$$\frac{C_1}{r_1} = \frac{C_2}{R_3}$$

and

$$\frac{C_1}{R_4} = \frac{C_2}{R_3}$$
Two independent balance equations are obtained if C and R4 are chosen as a variable element.

Dissipation factor \( D1 = \omega C1r1 = \omega CR4 \)

Values of capacitor C1 and its dissipation factor are calculated from the values of bridge element at balanced condition.

**CIRCUIT DIAGRAM:**

![Circuit Diagram](image)

**PROCEDURE:**

1. Connect diagram of Schering bridge for capacitance measurement as shown in fig
2. Select any one standard capacitor (known) from given capacitor bank C
3. Standard capacitance C2 are given below:
   
   \[
   \begin{align*}
   CS1 &= 0.1 \mu f d \\
   CS2 &= 0.01 \mu f d \\
   CS3 &= 0.001 \mu f d 
   \end{align*}
   \]
4. Then connect any one unknown capacitance from bank Cx1, Cx2, Cx3 Now plug in the headphone in to the socket adjust pot R3 and R4 to get minimum sound on head phone.
5. Simultaneously connect to the multimeter terminals connect to the bridge as shown in the fig. Null detector and select the range 2 v AC to get minimum reading
6. Now remove the headphone and further adjust the resistance R3 and R4 till you get minimum reading. Measure resistance of R3 and R4 by using Ohm meter.

7. After null position, unknown capacitor C calculated by using standard formula which is given below

\[
\frac{C}{R3} = \frac{R4}{C} \times C \text{ (Standard Capacitor)}
\]

**LIST OF COMPONENTS:**

1. Standard Capacitor
   
   CS1 = 0.0011 µf
   CS2 = 0.01 µf
   CS3 = 0.1 µf

2. Helical pot R3 = 10 k

3. Helical pot R4 = 5 k
   
   r1 = 100 Ohm
   C = 0.1 µf
   C = 0.01 µf

Unknown Capacitors:

Cx1 = 0.001 µf
Cx2 = 0.01 µf
Cx3 = 0.1 µf

**RESULT:**
EXPERIMENT – 3

CALIBRATION AND TESTING OF SINGLE PHASE ENERGY METER

AIM:

To calibrate the given energy meter using a calibrated wattmeter.

APPARATUS:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Variac, single phase</td>
<td>10 A</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
<td>300 V</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ammeter</td>
<td>0-10A</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rheostat</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Wattmeter</td>
<td>LPF</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Single phase energy meter</td>
<td>10 A</td>
<td>AC</td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

The calibration of energy meter may become inaccurate during its vigorous use due to various reasons. It is necessary to calibrate the meter to determine the amount of error i.e. its reading so that same meter can be used for correct measurement of energy.

In this method precision grade indicating instruments are used as reference standard. These indicating instruments are connected in the circuit of meter under test. The current and voltages are held constant during the test. The numbers of revolutions made by the test are recorded. The time taken is also measured.

Energy recorded by meter under test = $RX / KX$ kWh.

Energy computed from the readings of the indicating instrument = $kW \times t$
Where \( RX \) = number of revolutions made by disc of meter under test.

\[
KX = \text{number of revolutions per kWh for meter under test,}
\]

\[
kW = \text{power in kilowatt as computed from readings of indicating instruments}
\]

\[
t = \text{time in hours.}
\]

Percentage Error \[ \frac{RX}{KX} - \frac{kW \times t}{X 100} \]

Before conducting any of these tests on a watt hour meter its potential circuit must be connected to the supply for one hour in order to enable the self heating of the potential coil to stabilize.

CIRCUIT DIAGRAM:

PROCEDURE:

1. Keep the Autotransformer at zero position.
2. Make connections as per the Circuit diagram shown below.
3. Switch on the 230 VAC, 50 Hz. power supply.
4. Increase the input voltage gradually by rotating the Auto transformer in clockwise direction.
5. Adjust the load rheostat so that sufficient current flows in the circuit. Please note that the current should be less than 4A.

6. Note down the Voltmeter, Ammeter, Wattmeter and power factor meter readings for different Voltages as per the tabular column.

7. Note down the time (by using stop watch) for rotating the disc of the Energy Meter for 10 times. Find out the percentage error by using above equations.

**TABULAR COLUMN**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Voltage (V)</th>
<th>Current (I)</th>
<th>R = No of revolutions of the disc</th>
<th>Time (t) in hours</th>
<th>Energy meter reading in KWh = No. revolution (R)/meter constant (K)</th>
<th>Wattmeter Reading in kW × t</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

**RESULT:**
EXPERIMENT – 4
CALIBRATION OF DYNAMOMETER TYPE POWER FACTOR METER

AIM:
To calibrate a given single phase power factor meter

APPARATUS:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Variac, single phase,</td>
<td>10A</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
<td>300V</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ammeter</td>
<td>0-10A</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rheostat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Wattmeter, LPF,</td>
<td>300V</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dynamometer type power factor meter</td>
<td>10A</td>
<td>AC</td>
<td></td>
</tr>
</tbody>
</table>

THEORY:
The error made by the Power factor meter can be calculated by nothing down the readings various meters and error can be calculated by using

Actual reading = Power factor meter reading

Theoretical reading Cos Φ = P /VI

Actual reading - Theoretical reading

Since percentage of error = --------------------------- X 100
Theoretical reading
CIRCUIT DIAGRAM

PROCEDURE:

1. Keep the Auto transformer at zero position.
2. Make connections as per the Circuit diagram shown below.
3. Switch on the 230 VAC, 50 Hz. power supply.
4. Increase the input voltage gradually by rotating the Auto transformer in clockwise direction.
5. Adjust the load rheostat so that sufficient current flows in the circuit. Please note that the current should be less than 4A.
6. Note down the Voltmeter, Ammeter, Wattmeter and power factor meter readings for different voltages as per the tabular column.
7. Find out the percentage error by using above equations.

TABULAR COLUMN:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>V AC</th>
<th>I AC</th>
<th>Wattmeter reading</th>
<th>Power Factor meter Reading</th>
<th>Theoretical P/VI</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
PRECAUTIONS:

1. Instruments used should be of proper range.
2. All the connections should be tight.

RESULT:
EXPERIMENT – 5

CALIBRATION OF DYNAMOMETER TYPE WATTMETER BY PHANTOM LOADING

AIM:

To calibration of dynamometer type wattmeter by phantom loading.

APPARATUS REQUIRED FOR AC WATTMETER:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Voltmeter, 300v AC</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ammeter, 0-10A, AC</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Variac, single phase, 0-230 V, 10A</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Variac, Single Phase, 0 – 230V, 2 A</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rheostat</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Wattmeter</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Power factor meter</td>
<td>AC</td>
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</tr>
</tbody>
</table>

APPARATUS REQUIRED FOR DC WATTMETER:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Voltmeter</td>
<td>300V</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ammeter</td>
<td>0-10A</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Power Supply</td>
<td>0-30V</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Power Supply</td>
<td>0-200 V</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rheostat</td>
<td></td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Wattmeter</td>
<td></td>
<td>DC</td>
<td></td>
</tr>
</tbody>
</table>
THEORY:

When the current rating of a meter under test is high a test with actual loading arrangements would involve a considerable waste of power. In order to avoid this “Phantom” or Fictitious” loading is done.

Phantom loading consists of supplying the pressure circuit from a circuit of required normal voltage, and the current from a separate low voltage supply as the impedance of this circuit very low. With this arrangement the total power supplied for the test is that due to the small pressure coil current at normal voltage, plus that due to the current circuit current supplied at low voltage. The total power, therefore, required for testing the meter with phantom loading is comparatively very small.

Wattmeter reading = Actual reading

Theoretical reading $P = VI \cos \Phi$

$P = \text{Voltmeter reading} \times \text{Ammeter reading} \times \text{power factor reading}$

Actual reading - Theoretical reading

Since percentage of error $= \frac{\text{-------------}}{\text{-------------}} \times 100$
CIRCUIT DIAGRAM: (for AC wattmeter)

![Figure 1: Circuit Diagram for AC Wattmeter](image)

CIRCUIT DIAGRAM (for DC wattmeter)

![Figure 2: Circuit Diagram for DC Wattmeter](image)

PROCEDURE (For AC Wattmeter):

1. Keep the Autotransformer at zero position.
2. Make connections as per the Circuit diagram shown below.
3. Switch on the 230 VAC, 50 Hz. power supply.
4. Increase the input voltage gradually by rotating the Autotransformer in clockwise direction.
5. Adjust the load rheostat so that sufficient current flows in the circuit. Please note that the current should be less than 4A.
6. Note down the Voltmeter, Ammeter, Wattmeter and power factor meter readings for different voltages as per the tabular column.
7. Find out the percentage error by using above equations.

PROCEDURE (For DC Wattmeter):

1. Make connections as per the Circuit diagram shown below.
2. Switch on the 230 VAC, 50 Hz. power supply.
3. Increase the input voltage of the power supply
4. Adjust the load rheostat so that sufficient current flows in the circuit.
5. Note down the Voltmeter, Ammeter, and Wattmeter meter readings for different voltages as per the tabular column.
6. Find out the percentage error by using above equations.

TABULAR COLUMN (for AC wattmeter):

<table>
<thead>
<tr>
<th>S. No.</th>
<th>I in AMPS</th>
<th>V in volts</th>
<th>Wattmeter Reading</th>
<th>Power factor</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABULAR COLUMN (for DC wattmeter):

<table>
<thead>
<tr>
<th>S. No.</th>
<th>I in AMPS</th>
<th>V in volts</th>
<th>Wattmeter Reading</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PRECAUTIONS:

1. Instruments used should be of proper range.
2. All the connections should be tight.

RESULT:
EXPERIMENT – 6

SILSBEE’S METHOD OF TESTING CURRENT TRANSFORMERS

AIM:

To determine the percentage ratio error and the phase angle error of the given current transformer by comparison with another current transformer whose error are known.

APPARATUS:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard CT</td>
<td>0-5A</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Testing CT</td>
<td>0-300V</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Wattmeter</td>
<td></td>
<td>LPF</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Ammeter</td>
<td>MI type</td>
<td>AC</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Rheostat</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Phase shifting transformer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

This is a comparison type of test employing deflect ional methods. Here the ratio and phase angle of the test transformer x are determined in terms of that of a standard transformer s having same nominal ratio.

The errors are as follows say:

<table>
<thead>
<tr>
<th>Error</th>
<th>Ratio Error</th>
<th>Phase Angle Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The primaries of the two CTs are connected in series and the current through them is say IP. The pressure coils of two wattmeters are supplied with constant voltage V from a phase shifting transformer.

The current coil of wattmeter W1 is connected to S through an ammeter. The current coil of wattmeter W2 is connected as shown in fig and carriers a current SI.

\[ SI = \text{Iss} - \text{Isx} \text{ (Victorian difference)} \]

Where in is the current in the current coil of W1 and Isx is the current flowing through the burden. The phase shifting transformer is adjusted so that the wattmeter W1 reads zero.

\[ W1q = V_{pcq} \text{Iss} \cos 90 = \theta \]

\[ W2q = V_{pcq} SI \cos (\theta X - \theta s) \]

\[ = V \text{Isx} \sin (\theta X - \theta s) \]

Where \( V_{pcq} \) is the voltage from the phase shifting transformer, which is in quadrature with the Iss in is current coil of W1.

Then the phase of the voltage from to phase shifting transformer is shifted through \( 90^\circ \).

Therefore, now V is in phase with the current Iss.

\[ W1p = V \text{Iss} \]

\[ W2p = VSI \sin (\theta X - \theta s) \]

\[ = V [\text{Iss} - \text{Isx} \cos (\theta X - \theta s)] \]

\[ = W1p - VISX \cos (\theta X - \theta s) \]

As \( (\theta X - \theta s) \sim 0 \)

Therefore \( V\text{Isx} = W1p - W2p \)
\[
\begin{align*}
Ip \\
RX &= \frac{Ip}{ISX} \\
Ip \\
RS &= \frac{Ip}{ISS} \\
RX &= RS (1 + \frac{W2p}{W1p})
\end{align*}
\]

Now to obtain the Phase Angle Errors

\[
\begin{align*}
\sin(\theta X - \theta s) &= \frac{W2q}{V Isx} \\
\cos(\theta X - \theta s) &= \frac{W1p - W2p}{V Isx} \\
\tan(\theta X - \theta s) &= \frac{W2Q}{W1p - W2p}
\end{align*}
\]

OR

\[
\theta X = \frac{W2\theta}{W1p - W2p}
\]

\[\text{+}\theta_s \text{ radius}\]
CIRCUIT DIAGRAM:

Figure: 1

TABULAR COLUMN:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Iss</th>
<th>Wiq</th>
<th>W2q</th>
<th>W1p</th>
<th>W2p</th>
<th>Rx</th>
<th>Θx</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PROCEDURE:

1. The connections are made as per the circuit diagram. The burden is adjusted to have a suitable current In. the phase angle is adjusted using the phase shifting transformer will wattmeter W1 reads zero. Reading of the other wattmeter (W2q) is noted.
2. A phase shift of 90° is obtained by the phase shifting transformer. The two wattmeter readings W1p and W2p are then observed.
3. The ratio error is calculated using the formula \( Rx = Rs \)
4. The phase angle error is calculated using the formula
5. The experiment is repeated by varying the burden and setting different values for Iss.
6. The average values of Rs and are then obtained.

PRECAUTIONS:

1. W2 is sensitive instrument. Its current coil may be defined for small values. It is normally designed to carry about 0.25 A for testing CTs having a secondary current of 5 Amps

RESULT:
EXPERIMENT – 7

CALIBRATION OF PMMC VOLTMETER USING CROMPTON D.C POTentiOMETER

AIM:

To Determine Error given by voltmeter with DC potentiometer.

APPARATUS:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RPS</td>
<td>(0-30)v</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
<td>(0-30)v</td>
<td>MC</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Volt Ratio box</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Standard cell</td>
<td>0.0186</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Connecting wires</td>
<td></td>
<td></td>
<td>set</td>
</tr>
<tr>
<td>6</td>
<td>Potentiometer</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

THEORY:

There are two types of potentiometers.

1. D.C potentiometer
2. A.C Potentiometer.

The potentiometer is extensively used for a calibration of voltmeters and ammeters and has infect became the standard for the calibration of these instrument. The principle of operations of all potentiometers is based on the circuit, all the resistors in a potentiometer with the exception of slide wires are made of manganin. This is because manganin has a high stability a low temperature coefficient and has freedom from thermo electric effect against copper.

The slide wire is usually made of platinum sliver alloy and the sliding contacts are of a copper gold sliver alloy. this combination of materials for slide wire and sliding contacts results in a good contact, freedom from thermo electric emf and minimum wear of slide wire.
CIRCUIT DIAGRAM:

![Circuit Diagram](image1)

**figure:1**

**figure:2**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Voltmeter(V)</th>
<th>Potentiometer output</th>
<th>Potentiometer input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PROCEDURE:
1. Connect the circuit elements as per the circuit diagram.
2. Standardize the given potentiometer.
3. Apply the voltage to potentiometer terminal.
4. Adjust the dial resistor for zero deflection of galvanometer.
5. Compare the obtained value.

\[ \% \text{Error} = \frac{\text{Instrument reading} - \text{actual reading}}{\text{Actual reading}} \]

PRECAUTIONS:
1. Avoid loose connections.
2. Avoid Parallax Errors.

RESULT:
EXPERIMENT – 8

CALIBRATION OF ENERGY METER BY PHANTOM LOADING

AIM:

To calibrate a given single phase energy meter by phantom loading.

APPARATUS:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Variac, single phase</td>
<td>2 A, 0-230V</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
<td>0-300V</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ammeter</td>
<td>0-10A</td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rheostat</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Wattmeter</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Single Phase Energy Meter</td>
<td>300V, 10A</td>
<td>AC</td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

The calibration of energy meter may become inaccurate during its vigorous use due to various reasons. It is necessary to calibrate the meter to determine the amount of error i.e. its reading so that same meter can be used for correct measurement of energy.

In this method precision grade indicating instruments are used as reference standard. These indicating instruments are connected in the circuit of meter under test. The current and voltages are held constant during the test. The numbers of revolutions made by the test are recorded. The time taken is also measured.

Energy recorded by meter under test = RX / KX kWh.

Energy computed from the readings of the indicating instrument = kW × t
Where RX = number of revolutions made by disc of meter under test.

KX = number of revolutions per kWh for meter under test,

kW = power in kilowatt as computed from readings f indicating instruments

t = time in hours.

Percentage Error = \( \frac{RX}{KX} - kW \times t \),

----------------------- X 100

kW \times t

Before conducting any of these tests on a watt hour meter its potential circuit must be connected to the supply for one hour in order to enable the self heating of the potential coil to stabilize.

CIRCUIT DIAGRAM:

![Circuit Diagram](figure:1)

PROCEDURE:
1. Keep the Autotransformer at zero position.
2. Make connections as per the Circuit diagram shown below.
3. Switch on the 230 VAC, 50 Hz. power supply.
4. Increase the input voltage gradually by rotating the Auto transformer in clockwise direction.
5. Adjust the load rheostat so that sufficient current flows in the circuit. Please note that the current should be less then 4A.
6. Note down the Voltmeter, Ammeter, Wattmeter and power factor meter readings for different voltages as per the tabular column.
7. Note down the time (by using stop watch) for rotating the disc of the Energy Meter for 10 times.
8. Find out the percentage error by using above equations.

TABULAR COLUMN:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Voltage (V)</th>
<th>Current (I)</th>
<th>R = No of revolutions of the disc</th>
<th>Time (t) in hours</th>
<th>Energy meter reading in KWh= No. revolution (R)/meter constant (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RESULT
AIM:

To determine the value of the resistance of the given wire using Kelvin’s Double Bridge

APPARATUS:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kelvin’s Double Bridge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DC Power supply</td>
<td>AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Rheostat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Standard resistance boxes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Galvanometer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Connecting Wires</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

The KDB is a modification of the Wheatstone Bridge (WB) and provides increased accuracy in the measurement of low resistance’s. The resistance’s of the lead and contact resistance of which is a major source of error in the WB is overcome in this method.

The KDB incorporates the idea of a second set of ratio arms – hence the name Double Bridge – and the use of four – terminal resistor for the law resistance arms. As shown in the figure the first of ratio arms is P & Q. The second set of ratio arms, P and V, is used to connect the galvanometer to point D at the appropriate potential between points M and N to eliminate the
effect of connecting lead of resistance $R$ between the known resistance $R$ and the Standard resistance $S$.

The ratio $P/Q$ is made equal to $p/q$. Under balance conditions there is no current through the galvanometer, which means that the voltage drop between $a$ and $b$, $E_{ab}$ is equal to the voltage drop $E$ and $I$ between $a$ and $c$.

The last equation indicates that the resistance of connecting lead, $r$ has no effect on the measurement. Provided that the two sets of ratio arms equal ratios. The last but one equation above, shows that the error that is introduced in case the ratios are not exactly equal it indicates that it is desirable to keep as possible in order to minimize the errors in case there is a difference between ratios. $P/Q$ and $p/q$.

The effect of thermo electric emfs can be eliminated by making another measurement with the battery connections revered. The true value of $R$ being the mean of the two readings.

**CIRCUIT DIAGRAM:**
P, p, Q, q – Known decade resistances

R – Unknown resistance whose value is to be determined.

S – Standard resistance.

R_{b} – Regulating resistance.

G – Galvanometer.

K – Key switch.

PROCEDURE:

1. The connections as per the circuit diagram.
2. Keep Q = q = 1000 ohms and S = 1 ohm. The ratio P/Q should
   a. always be kept equal to p/q, as Q = q, we must keep P = p.
   b. To start with P and p may be kept at zero position.
3. Switch on the DC power supply and adjust the voltage to about 2
   a. volts with the regulating resistance cut in fully.
4. Adjust P and p simultaneously to get balance. If a light spot
5. Galvanometer is used, then increases the sensitivity in steps and
   a. get exact balance in the direct portion. Bring back the sensitivity
   b. Knob of the galvanometer to the starting position.
6. Note the value of P.
7. Repeat steps (3) and (4) reversing the DC power supply polarity.
8. Repeat steps (3) to (5) above for
9. Q = q = 100 ohms, 10 ohms, 1 ohms choosing suitable values for S
   a. So that the value of p at balance is obtained in hundreds.
10. The unknown resistance is calculated in each case using the Formula R = P/Q.S
TABULAR COLUMN:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Main dial</th>
<th>Slide wire</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PRECAUTIONS:

1. In the case of a light spot galvanometer, the sensitivity knob of the galvanometer should be in the shorted position when the bridge is unbalanced. It should be brought back to shorted position from the direct position, immediately after obtaining balance.

2. The DC power regulating resistance (R_b) should be cut in fully to start with and adjusted later if necessary to get larger deflection.

VIVA-VOCE:

1. What are the advantages of the Kelvin Double Bridge when compared to Wheaton’s Bridge for measurement of small resistance?

2. Why are low resistance standards provided with four terminals?

3. Why is the ratio P/Q in this bridge?

4. What is the sensitivity of the commercial Kelvin’s Double Bridge?

5. Why is every measurement repeated after reversing the DC power polarity?

6. What precautions should be exercised for the safety of the galvanometer?

RESULT:
EXPERIMENT – 10

MEASUREMENT OF 3-PHASE REACTIVE POWER USING TWO WATTMETER

AIM:

To measure 3-phase power using two wattmeters.

APPARATUS:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single Phase Wattmeter</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Three Phase Resistive Load</td>
<td></td>
<td>AC</td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

Three phase reactive power can be measured by two wattmeter method which is universally adopted Method. The difference between higher reading wattmeter and lower wattmeter reading yields $VL \cdot IL \sin \phi$. so, the total 3 reactive power is $\sqrt{3} V L I L \sin \phi$

Reactive power in a balance 3-$\phi$ load can also be calculated by using single wattmeter. In this method, the current coil of the wattmeter is connected in any one line and the pressure coils across the other two lines. Let us assume that the Current coil is connected in R phase and pressure coil is connected across ‘Y’ and ‘B’ phases. Assuming phases. Assuming phase sequence RYB and an inductive load of an angle ‘$\phi$’ the phasor diagram for the circuits is as follows.

Here current through current coil = $IR$

Voltage across pressure coil = $VYB$
The phase current lag the corresponding phasor voltages by an angle $\hat{\theta}$

The current through wattmeter P1 is I and a voltage across its pressure coil is V I leads V

By an angle $(30 - \hat{\theta})$.

Reading of P1 wattmeter, $P = VI \cos (30 - \hat{\theta}) = \sqrt{3}VI \cos (30 - \hat{\theta})$

The current through wattmeter P2 is I and voltages across its pressure coil is V I lags V by an angle $(30 + \hat{\theta})$

Reading of P2 wattmeter, $P = VI \cos (30 + \hat{\theta}) = \sqrt{3}VI \cos (30 + \hat{\theta})$

Sum of reading of two Wattmeters

$$P1+P2 = \sqrt{3}VI \left[ \cos (30 - \hat{\theta}) - \cos (30 + \hat{\theta}) \right]$$

$$= 3VI \cos \hat{\theta}$$

this is total power consumed by load $P = P1 + P2$

Difference of readings of two Wattmeters

$$P1 - P2 = \sqrt{3}VI \left[ \cos (30 - \hat{\theta}) - \cos (30 + \hat{\theta}) \right]$$

$$= \sqrt{3}VI \sin \hat{\theta}$$

$$\frac{P1 - P2}{P1 + P2} = \frac{\sqrt{3}VI \sin \hat{\theta}}{\sqrt{3}VI \cos \hat{\theta}} = tan \hat{\theta}$$

Power factor $\cos \hat{\theta} = \frac{cos \hat{\theta}}{\sqrt{3}}$

Current through the current coil = I

Voltage across the pressure coil = V

$$Q = 3VI \sin \hat{\theta} = -\sqrt{3} \times \text{reading of wattmeter}$$
Phase angle $\theta \tan^{-1} \frac{Q}{P}$

CIRCUIT DIAGRAM:

![Circuit Diagram]

PROCEDURE:

1. Connect the circuit as shown in fig.
2. Switch ‘ON’ the supply.
3. Note down the corresponding there reading and calculate 3-φ reactive power.
4. Now increase the load of three phase Inductive load steps and note down the corresponding meter readings.
5. Remove the load and switch ‘off’ the supply.

TABULAR COLUMN:

<table>
<thead>
<tr>
<th>3 Phase Resistive Load</th>
<th>Wattmeter Reading</th>
<th>3 Phase Reactive Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RESULT:
EXPERIMENT – 11

MEASUREMENT OF 3-PHASE REACTIVE POWER USING SINGLE WATTMETER

AIM:

To measure 3-phase reactive power using single phase wattmeter

APPARATUS:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Equipment</th>
<th>Range</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single Phase Wattmeter</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>Three Phase inductive load</td>
<td>AC</td>
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</tr>
</tbody>
</table>

THEORY:

Three phase reactive power can be measured by two wattmeter method which is universally adopted Method. The difference between higher reading wattmeter and lower wattmeter reading yields $VLIL\sin\phi$. so, the total 3 reactive power is $\sqrt{3} V L I L \sin\phi$

Reactive power in a balance 3-\(\phi\) load can also be calculated by using single wattmeter. In this method, the current coil of the wattmeter is connected in any on line and the pressure coils across the other two lines. Let us assume that the Current coil is connected in R phase and pressure coil is connected across ‘Y’ and ‘B’ phases. Assuming phases. Assuming phase sequence RYB and an inductive load of an angle ‘\(\phi\)’ the phasor diagram for the circuits is as follows.

Here current through current coil = $IR$

Voltage across pressure coil = $VYB$
The phase angle between VYB and IR from the phasor diagram is 90°-φ

Wattmeter reading is VYB IR Cos (90°-φ)

\[ W = VYB \text{ IR } \cos(90° - \phi) \]

\[ W = VYB \text{ IR } \sin(90° - \phi) \]

In terms of line current and voltage

\[ W = VYB \text{ IR } \cos(90° - \phi) \]

Items of line current and voltage

\[ W = VL \text{ IL } \sin \phi \]

The total 3-φ reactive power is \( \sqrt{3} VL \text{ IL } \sin \phi \)

**CIRCUIT DIAGRAM**

![Circuit Diagram](image1)

**figure: 1**
PROCEDURE:

1. Connect the circuit as shown in fig.
2. Switch ‘ON’ the supply.
3. Note down the corresponding there reading and calculate 3-φ reactive power.
4. Now increase the load of three phase Inductive load steps and note down the corresponding meter readings.
5. Remove the load and switch ‘off’ the supply.

TABULAR COLUMN:

<table>
<thead>
<tr>
<th>3 Phase Load</th>
<th>Wattmeter Reading</th>
<th>3 Phase Reactive Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A</td>
<td></td>
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<tr>
<td>2 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 A</td>
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<td>5 A</td>
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RESULT: