رقم 128 / ق.هـ.ك / ك.ت/2026

المسيلة في : 2026/06/23

شهادة إدارية

بخصوص مطبوعة الدروس الخاصة بالأستاذ

بلة سعد

بناءً على محضر اللجنة العلمية لقسم الهندسة الكهربائية تحت رقم: /46/ق.هـ.ك/2026 المنعقد بتاريخ 04 افريل 2026 والمتضمن تعين الخبراء: الأستاذ غضبان اسماعيل أستاذ بجامعة المسيلة، الأستاذ زيق عصام أستاذ محاضر - أ- بجامعة المسيلة، والأستاذ رابحي بوعلاقة أستاذ بالمدرسة العليا للاساتذة - بوسعادة وذلك لتقييم مطبوعة الاعمال التطبيقية المقدمة **باللغة الانجليزية**، الخاصة بالأستاذ **بلة سعد** أستاذ محاضر "ب" بالقاعدة المشتركة – كلية التكنولوجيا – جامعة المسيلة تحت عنوان :

" Electrotechnics Lab "

وبعد إطلاع رئيس اللجنة العلمية ورئيس القسم على التقارير الواردة و التي كانت كلها ايجابية، وعليه فإن اللجنة لا ترى مانعا أن تتخذه سندا في تدريس طلبة السنة الثانية مهندس تخصص هندسة الانظمة الالكتروتقنية و أن تعتمد في أي تقييم للمسار العلمي للأستاذ المعني.

رئيس اللجنة العلمية
أ .د فؤاد برابح

رئيس القسم

ملاحظة: سلمت هذه الشهادة للمعني(ة) لاستعمالها في حدود ما يسمح به القانون

People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

University of Mohamed Boudiaf - M'Sila

Faculty of Technology

Department of Electrical Engineering

Polycopié

Electrotechnics Lab

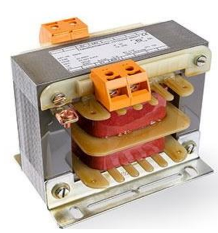
2nd Year Engineering Student
Code: **UEM 3.1** | Credit: **1** | Coeff: **1** | Semester: **S3**

Prepared by

Saad BELLA

Maître de conférences classe B

Electrical Engineering Department



AY: 2025 / 2026

Semestre: 3
Unité d'enseignement: UEM 3.1
Matière 2: TP électrotechnique fondamentale 1
VHS: 22h30 (TP: 1h30)
Crédits: 1, Coefficient: 1

Objectifs de l'enseignement:

Consolidation des connaissances acquises dans la matière d'électrotechnique 1 fondamentales pour mieux comprendre et assimiler les lois fondamentales de l'électronique et de l'électrotechnique.

Connaissances préalables recommandées

. Electrotechnique fondamentale.

TP 1 : Mesure de tensions et courants en monophasé
TP 2 : Mesure de tensions et courants en triphasé
TP 3 : Mesure de puissances active et réactive en triphasé
TP 4 : Circuits magnétiques (cycle d'hystérésis)
TP 5 : Essais sur les transformateurs
TP 6 : Machines électriques (démonstration).

Mode d'évaluation :

Contrôle continu : 100 %

Preface

This Electrotechnics Lab (UEM 3.1) manual is dedicated to 2nd-year Electrical Engineering students; it provides them practical comprehension and gets them into electrotechnics fundamentals.

To properly ensure a comprehensive systemic view, three-phase measurements (Voltage, Current, and Power) are integrated into a single extensive session (Lab 2), reflecting real-world industrial monitoring practices.

Laboratory Program:

Lab 1: Measurement of Voltage, Current, and Power in a Single-Phase System.

Lab 2: Measurement of Voltage, Current, and Power in a Three-Phase System.

Lab 3: Magnetic Circuits and Hysteresis Loop.

Lab 4: Single-phase Transformer.

Lab 5: Direct Current Machines.

Evaluation Mode: 100% Continuous Assessment (Lab performance and reports)

Finally, I hope this manual serves as a valuable asset for students. Any feedback and suggestions for improvement from peers and readers are highly welcome.

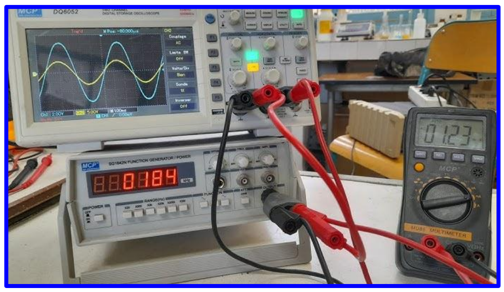
All sessions were conducted at the Electrical Engineering Laboratory, University of M'sila

Contents

Lab 01

Measurement of Voltage, Current, and Power in Single-Phase System

Prepared by Dr. Saad Bella



Experiment progression:

This report prepared by:

Full name		Remarks	Group
01			
02			
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07			
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Lab 01: Measurement of Voltage, Current, and Power in Single-Phase System

1. Objectives

i. To **study** and measure electrical quantities in a single-phase system: Voltage, Current, and Power.
ii. To **measure** power factor PF
iii. To **draw** phasor diagram in ac circuit.

2. Required equipment

- AC voltage supply
- Electrical loads (R, L, C)
- Measurement instruments (voltmeter, ammeter, wattmeter)

3. Background

a. Single-phase system

Let's consider the RLC circuit shown in Fig. 1

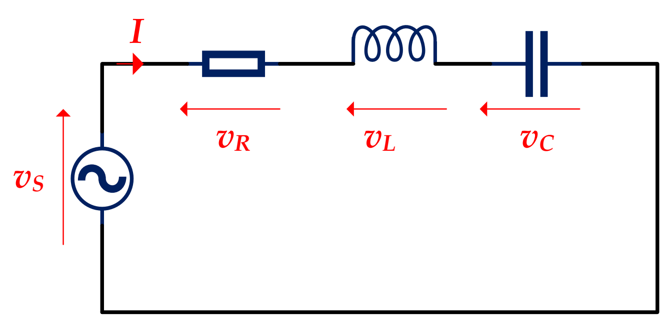


Fig. 1 Series RLC circuit

By using Kirchhoff's law, the electrical equation can be given:

$$\underline{V_s} = \underline{I}\left(R + jL\omega - j\frac{1}{C\omega}\right)$$

i.e.

$$\underline{V_s} = \underline{Z}.\underline{I}$$

Hence, the total impedance of the circuit is deduced as:

$$\underline{Z} = R + jL\omega - j\frac{1}{C\omega}$$

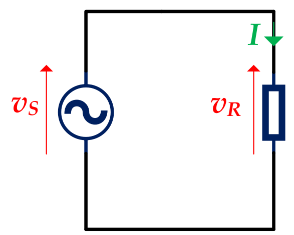
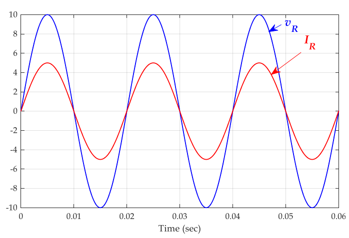
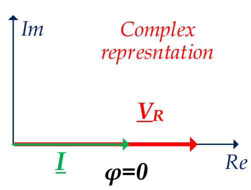
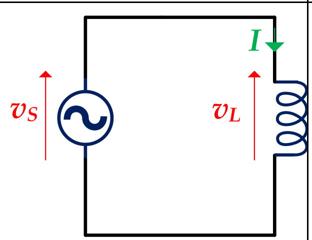
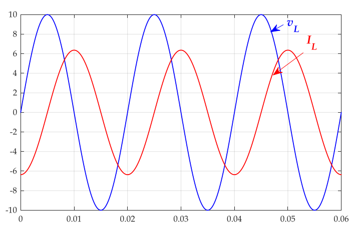
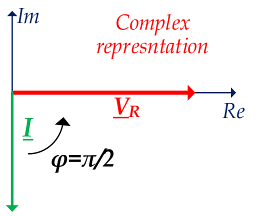
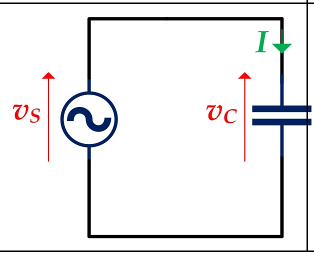
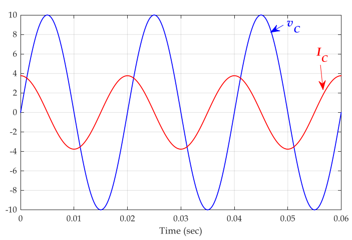
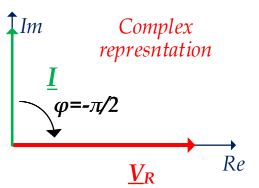
The magnitude of Z is

$$Z = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$$

The argument:

$$\varphi = \tan^{-1}\frac{L\omega - \frac{1}{C\omega}}{R}$$

This table represents a summary about ac current behavior with different passive loads.

			$\underline{V_R} = R.\underline{I}$ $\varphi = \tan^{-1}\frac{0}{R}$
			$\underline{V_L} = jL\omega.\underline{I}$ $\varphi = \tan^{-1}\frac{L\omega}{0}$
			$\underline{V_C} = -j\frac{1}{C\omega}.\underline{I}$ $\varphi = \tan^{-1}\frac{-\frac{1}{C\omega}}{0}$

In this work, the goal is to measure voltage across load, current through load, and power consumed by it. So, it is needed to give a summary about electric voltage, current and power measurements.

b. Voltage Measurement

It is the potential difference between two points v_a, and v_b; this difference can be written as:

$$v = v_{ab} = v_a - v_b$$

As shown in Fig. 2., the **voltmeter** is used to measure this voltage **(in units of volt 'V')**; it can be a **digital** or **analog** device. This Fig. 2 shows that the voltmeter should be **connected in parallel** with the load.

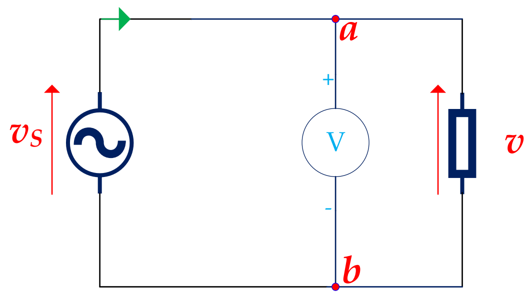


Fig. 2 Voltmeter connection in parallel with load

c. Current Measurement

An electric current is a flow of charged particles such as electrons or ions moving through an electrical conductor or space. This quantity is expressed **in units of ampere (called 'amp' or 'A')** and measured using a device called an **ammeter**. This device should be **connected in series** with the load.

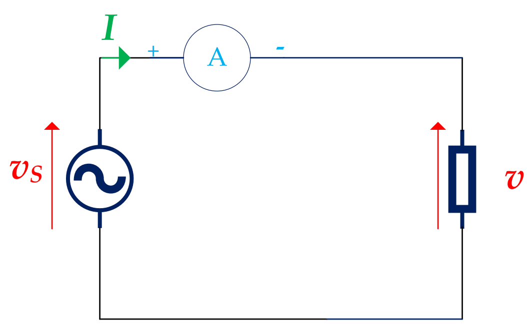


Fig. 3 Ammeter connection in series with load

d. Electric Power Measurement

In ac sinusoidal single-phase system, we are always interested to measure average power consumed by the load. Electric power in single-phase can be measured using a voltmeter and an ammeter and also can be measured using one wattmeter **(in watts 'W')**. This device reads the average value of the product of voltage and current.

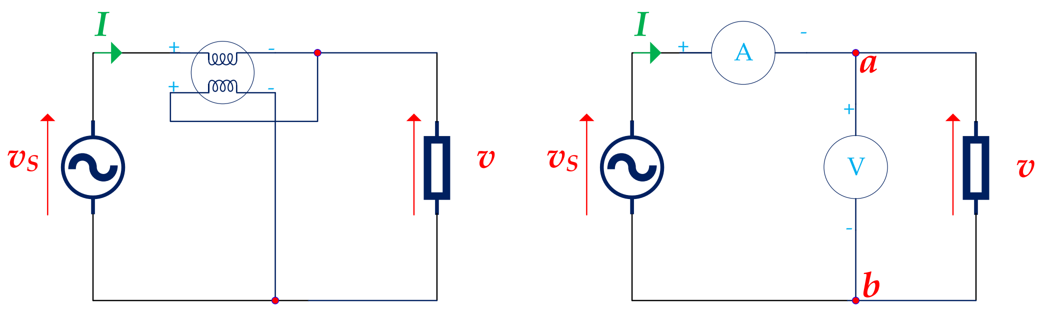


Fig. 3 Power measurement with wattmeter and ammeter-voltmeter

Active Power

This power is also called **real power**, expressed in units of **(watts 'W')**. Its relationship is written as:

$$P = V_{RMS}I_{RMS}\cos\varphi$$

Reactive Power

If the load is inductive or capacitive (reactive), we say there is reactive power flows in the circuit and it is expressed as

$$Q = V_{RMS}I_{RMS}\sin\varphi$$

Apparent Power

Apparent power is the product of the RMS values of voltage and current

$$S = V_{RMS}I_{RMS}$$

The complex apparent power is defined as the product of the RMS voltage and the conjugate of current, it can be written as:

$$\underline{S} = \underline{V}.\underline{I}^*$$

It is demonstrated that this power is:

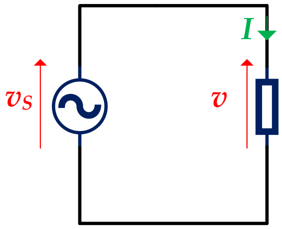
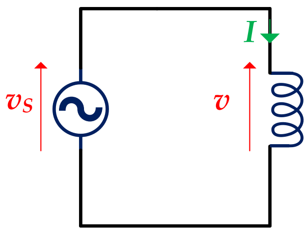
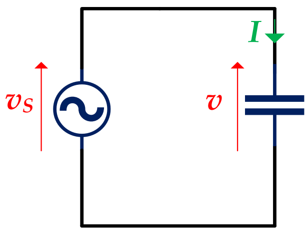
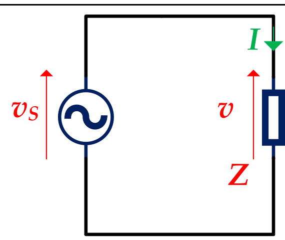
$$\underline{S} = P + jQ$$

Therefore, the magnitude is given by

$$S = \sqrt{P^2 + Q^2}$$

Power Factor

$$\cos\varphi = \frac{P}{S}$$

Load-Type	Apparent power	Active power	Reactive power
	$\underline{S} = RI_{RMS}^2 = \frac{V_{RMS}^2}{R}$	$P = S = \frac{V_{RMS}^2}{R}$	0
	$\underline{S} = jL\omega I_{RMS}^2 = j\frac{V_{RMS}^2}{L\omega}$	0	$Q = \frac{V_{RMS}^2}{L\omega}$
	$\underline{S} = -\frac{j}{C\omega} I_{RMS}^2 = -jC\omega V_{RMS}^2$	0	$Q = -C\omega V_{RMS}^2$
	$\underline{S} = (R + jX)I_{RMS}^2$	$P = \frac{V_{RMS}^2}{R}$	$Q = \frac{V_{RMS}^2}{X}$

4. Experimental Procedure

Implement this series RLC circuit shown in Fig.4; the value of each component of the setup is given:

Circuit parameters	
RMS voltage supply V_s	$30V$
Resistor R	100Ω
Iron-core inductor L	$60mH$
Internal Resistor r	1.2Ω
Capacitor C	$16\mu F$

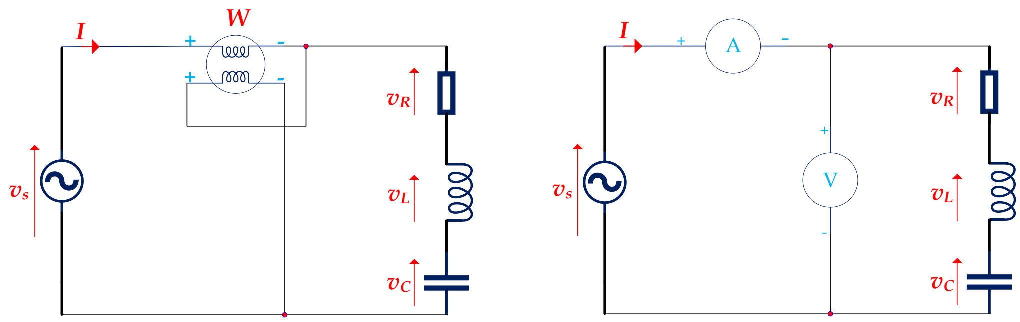


Fig. 4 Circuit diagrams for experiments

Case 1:

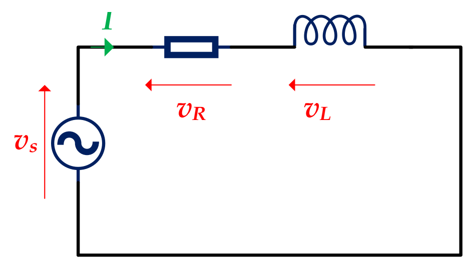


Fig. 5 Series RL circuit **(R=50ohms, L=60mH)**

	V_{sRMS}	V_{RRMS}	V_{LRMS}	I	P	Q	S	PF
Formula	$\frac{V_{max}}{\sqrt{2}}$	RI	$L\omega I$	$\frac{v_{sRMS}}{\sqrt{R^2+(L\omega)^2}}$	RI^2	$\frac{V_L^2}{L\omega}$	$\sqrt{P^2+Q^2}$	$\frac{P}{S}$
Calc								
Measure								

Case 2:

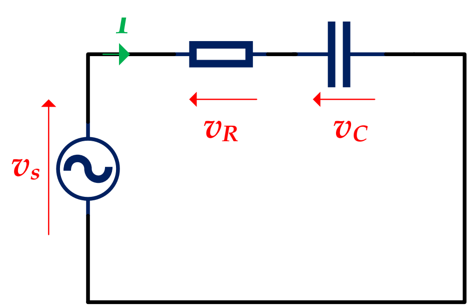


Fig. 5 Series RC circuit **(R=100ohms, C=16uF)**

	V_{sRMS}	V_{RRMS}	V_{CRMS}	I	P	Q	S	PF
Formula				$\frac{v_{sRMS}}{\sqrt{R^2+(\frac{1}{C\omega})^2}}$				
Calc								
Measure								

Case 3:

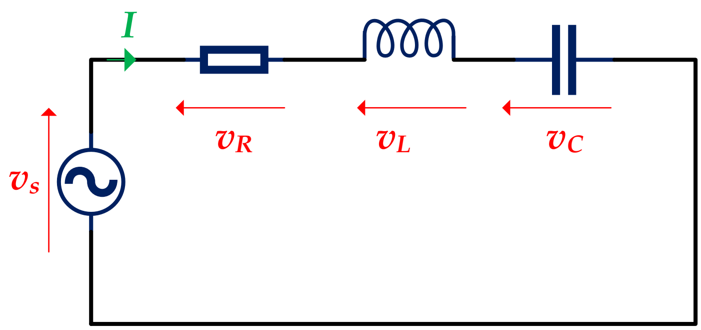


Fig. 5 Series RL circuit **(R=100ohms, L=60mH, C=16uF)**

	V_{RRMS}	V_{LRMS}	V_{CRMS}	I	P	Q	S	PF
Formula				$\frac{V_{sRMS}}{\sqrt{R^2+(L\omega-\frac{1}{C\omega})^2}}$				
Calc								
Measure								

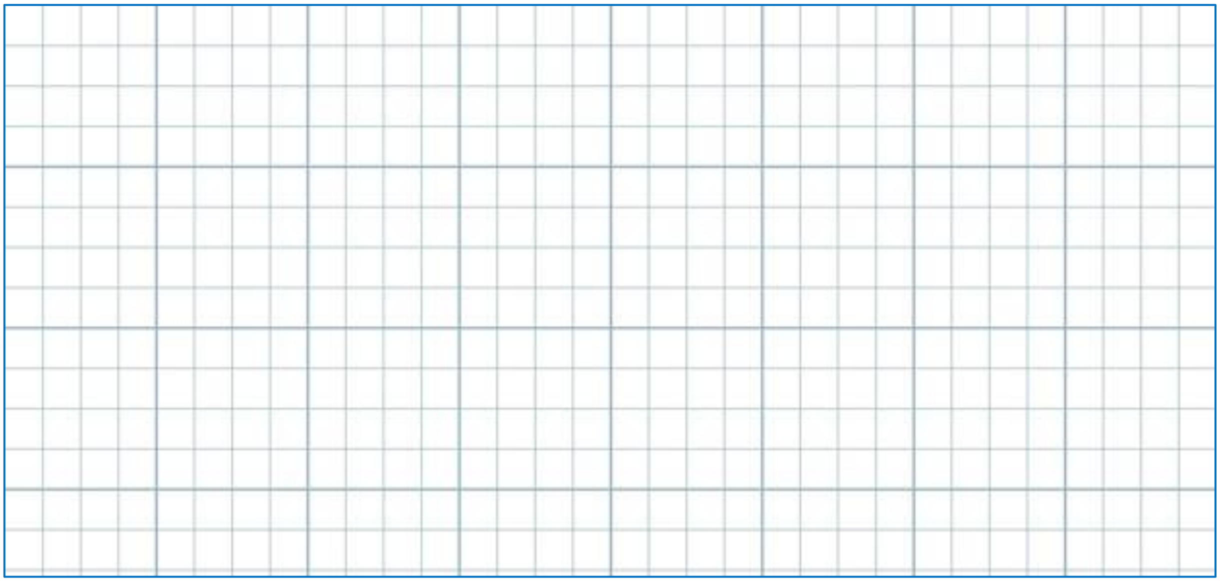
For each table of the three:

1. Complete the table
2. Draw the voltage triangle and power triangle

Case 1:

Case 2:

Case 3:



3. Calculate cos φ using both voltage and power triangles, then compare between them

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4. Why the calculated reactive power is not exactly equal to the measured Q

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5. Conclusion

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Lab 02

Measurement of Voltage, Current, and Power in Three-Phase System

Prepared by Dr. Saad Bella

Experiment progression:

This report prepared by:

Full name		Remarks	Group
01			
02			
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Measurement of Voltage, Current and Power in Three-Phase System

1- Three-phase system

Direct balanced three-phase voltage system

Three-phase system generally employs four wires including the neutral return wire and generally for consummation it is considered balanced three-phase system.

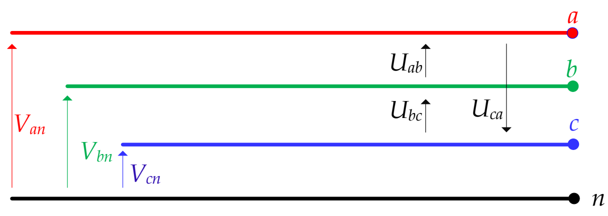


Fig. 1 Three-phase voltage

This system can deliver three-phase voltages V_{an}, V_{bn}, and V_{cn} called line to neutral voltages or (in this case we call them also phase voltages). The expression of delivered voltages can be given as

$$\begin{cases} v(t)_{an} = V_{an}\sin(\omega t) \\ v(t)_{bn} = V_{bn}\sin\left(\omega t - \frac{2\pi}{3}\right) \\ v(t)_{cn} = V_{cn}\sin\left(\omega t - \frac{4\pi}{3}\right) \end{cases}$$

Fig. 2 shows the waveforms of phase voltages

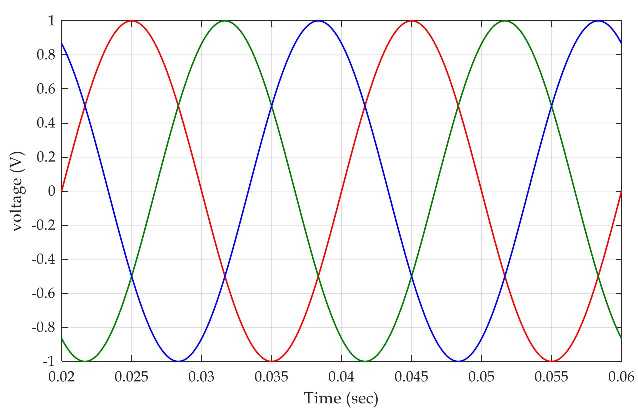


Fig. 2 Three-phase voltage waveforms

Because the system is considered balanced,

- The magnitudes of phase voltages V_{an}, V_{bn}, and V_{cn} are constant and expressed as $V_{an} = V_{bn} = V_{cn}$
- The sum of voltages is zero $v_{an} + v_{bn} + v_{cn} = 0$. Noticing that voltages can be written in instantaneous, vectorial form and can be expressed in complex numbers.

Vectorial representation of a balanced three-phase voltages

Fig. 3 represents vector diagram of phase voltages with their magnitude and phase angle change. It is remarked that the sum of voltages is zero.

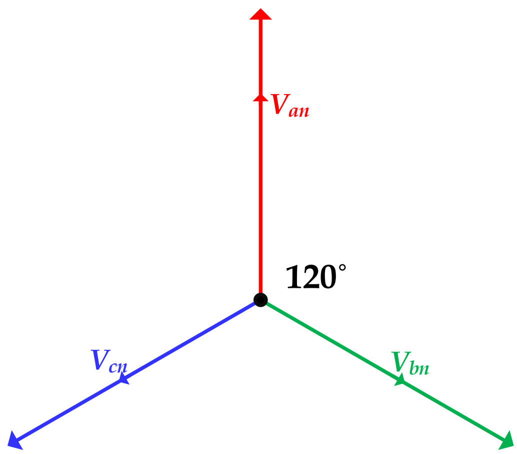


Fig. 3 Three-phase voltage vectors

Ways of connection in three-phase system

Mainly, there is two ways to connect voltage sources (alternator or transformer windings) or loads in balanced three-phase system: **Star** (**Y**) and **Delta** (**Δ**) (this star is also called **Wye connection**).

Star (**Y**) **Configuration:**

This connection is so sued in industry and they also call it **Wye connection**. Fig. 4 shows the configuration where V_{an}, V_{bn}, and V_{cn} are phase voltages, and U_{ab}, U_{bc}, and U_{ca} are line voltages.

Phase voltage: refers to the voltage measured across any one source winding or one load impedance in a balanced three-phase system. We have in our case three elements of quantity V_{an}, V_{bn}, and V_{cn}. So $V_{an} = V_{bn} = V_{cn} = V_{phase}$

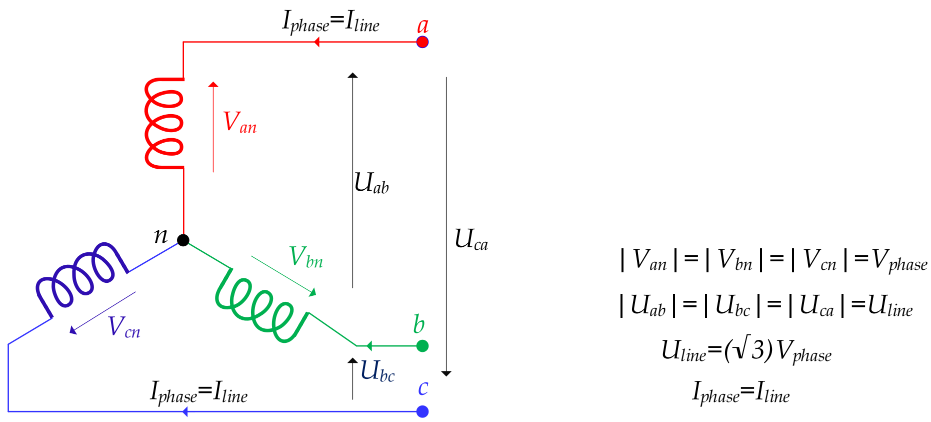


Fig. 4 Wye-connected source or load

Line voltage: refers to the voltage between any two phases in a balanced three-phase system. We have in our case three elements of quantity V_{an}, V_{bn}, and V_{cn}. So $U_{ab} = U_{bc} = U_{ca} = U_{line}$.

So:

$$\begin{cases} V_{an} = V_{bn} = V_{cn} = V_{phase} \\ U_{ab} = U_{bc} = U_{ca} = U_{line} \end{cases}$$

The general relationship between the line voltage and the phase voltage can be written as:

$$\begin{cases} \underline{U_{ab}} = \underline{V_{an}} - \underline{V_{bn}} \\ \underline{U_{bc}} = \underline{V_{bn}} - \underline{V_{cn}} \\ \underline{U_{ca}} = \underline{V_{cn}} - \underline{V_{an}} \end{cases}$$

Because the load is balanced, we have:

$$U_{ab} = U_{bc} = U_{ca} = U_{line} = \sqrt{3}V_{phase}$$

phasor diagram of Star-connected three-phase system

Fig. 5 shows the phasor diagram with line and phase voltages in the system.

The relationship between the phase voltage and the line voltage

It is obvious from the triangle depicted in Fig. 6 that

$$\cos 30 = \frac{U_{bc}}{2V_{bn}} = \frac{U_{bc}}{2V_{cn}} = \frac{U_{line}}{2V_{phase}} = \frac{\sqrt{3}}{2}$$

$$=> U_{line} = \sqrt{3}V_{phase}$$

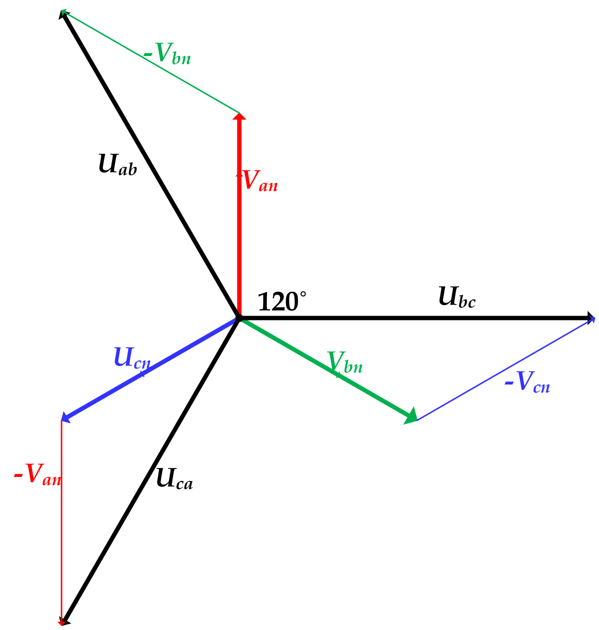


Fig. 5 Phasor diagram of three-phase voltages

So that the line voltage U_{line} is equal to phase voltage V_{phase} times $\sqrt{3}$.

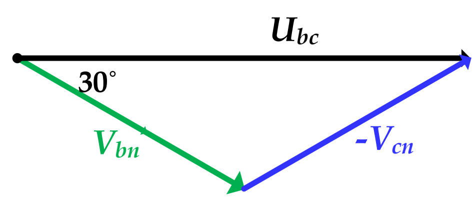
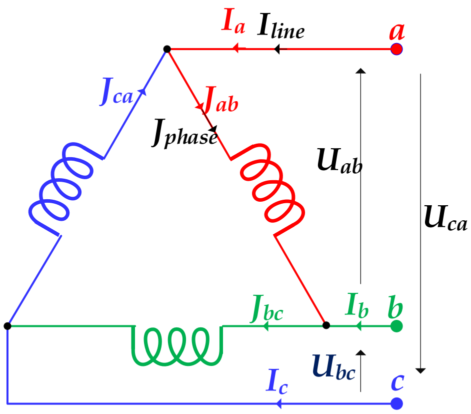


Fig. 6 Line and phase voltages

Delta (Δ) Configuration

This three-phase connection is illustrated on Fig. 7; in this connected-system, the line voltage is equal to the phase voltage because line conductors are connected directly to three-phase sources/windings, and the line current is equal to phase current times $\sqrt{3}$. As it shown in Fig.7



$|V_{ab}| = |V_{bc}| = |V_{ca}| = V_{line} = V_{phase}$

$|I_{ab}| = |I_{bc}| = |I_{ca}| = I_{phase}$

$|I_a| = |I_b| = |I_c| = I_{line}$

$I_{line} = (\sqrt{3}) I_{phase}$

Fig. 7 Delta (Δ) -connected source or load

Supposing that each winding has its impedance Z, so there Z_{ab}, Z_{bc}, Z_{ca} and:

$\underline{J_{ab}} = \frac{\underline{U_{ab}}}{\underline{Z_{ab}}}$, φ_{ab} is the phase difference between V_{ab} and J_{ab}

$\underline{J_{bc}} = \frac{\underline{U_{bc}}}{\underline{Z_{bc}}}$, φ_{bc} is the phase difference between V_{bc} and J_{bc}

$\underline{J_{ca}} = \frac{\underline{U_{ca}}}{\underline{Z_{ca}}}$, φ_{ca} is the phase difference between V_{ca} and J_{ca}

Because the load is balanced, we have:

$\varphi_{ab} = \varphi_{bc} = \varphi_{ca}$ and $J_{ab} = J_{bc} = J_{ca}$

The set of three-phase currents are written as follows:

$$\begin{cases} j_{ab} = J_{ab} \sin(\omega t - \varphi) \\ j_{bc} = J_{bc} \sin\left(\omega t - \frac{2\pi}{3} - \varphi\right) \\ j_{ca} = J_{ca} \sin\left(\omega t - \frac{4\pi}{3} - \varphi\right) \end{cases}$$

So important points:

Phase current: refers to the current measured through any one source winding or one load impedance in a balanced three-phase system. We have in our case three elements of quantity J_{ab}, J_{bc}, and J_{ca}. So $J_{ab} = J_{bc} = J_{ca} = J_{phase}$.

Line current: refers to the current between any two phases in a balanced three-phase system. We have in our case three elements of quantity I_a, I_b, and I_c. So $I_a = I_b = I_c = I_{line}$.

So:

$$\begin{cases} J_{ab} = J_{bc} = J_{ca} = J_{phase} \\ I_a = I_b = I_c = I_{line} \end{cases}$$

The general relationship between the line current and the phase current can be written as:

$$\begin{cases} \underline{J_{ab}} = \underline{I_a} - \underline{I_b} \\ \underline{J_{bc}} = \underline{I_b} - \underline{I_c} \\ \underline{J_{ca}} = \underline{I_c} - \underline{I_a} \end{cases}$$

Because the load is balanced, we have:

$$I_a = I_b = I_c = I_{line} = \sqrt{3} J_{phase}$$

We can represent vectorially line and phase currents following the same analogy in the previous section.

Power measurements

Single Wattmeter Method

This method is used only when three-phase system are in **Wye configuration**. To measure three-phase power in a balanced three-phase system whether load or source, we can measure the active power of a single-phase and multiply it by three so the total becomes:

$$P = 3P_1 = 3V_{phase} I_{phase} \cos\varphi$$

Where

$$P_1 = V_{phase} I_{phase} \cos\varphi$$

We have also:

$$Q = 3V_{phase} I_{phase} \sin\varphi$$

$$S = \sqrt{P^2 + Q^2} = 3V_{phase} I_{phase}$$

This works unless the loads is unbalanced whether in Wye or delta configuration, it works only with balanced system.

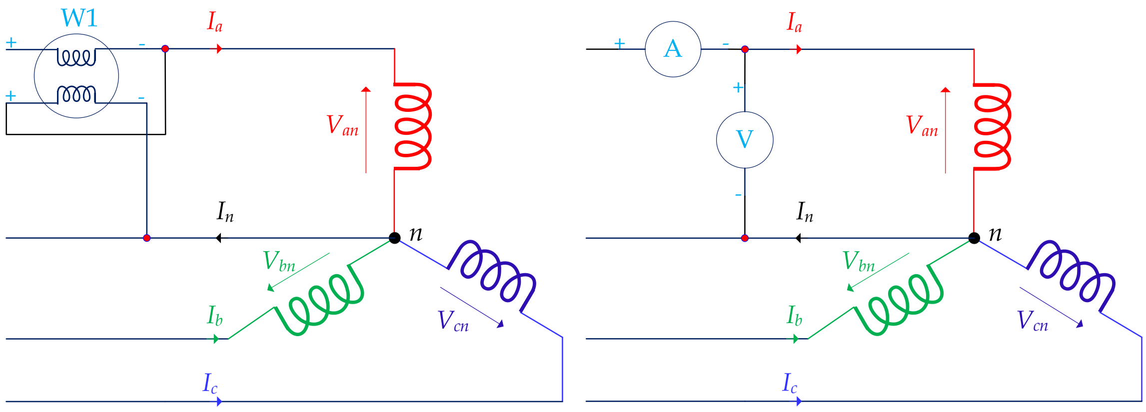


Fig. 8 Single-wattmeter method

Two wattmeter method

This is used in both delta and Wye connection. Assuming Wye connected three-phase system, in this method the neutral is not available so the voltage coil of each wattmeter is connected between two phases.

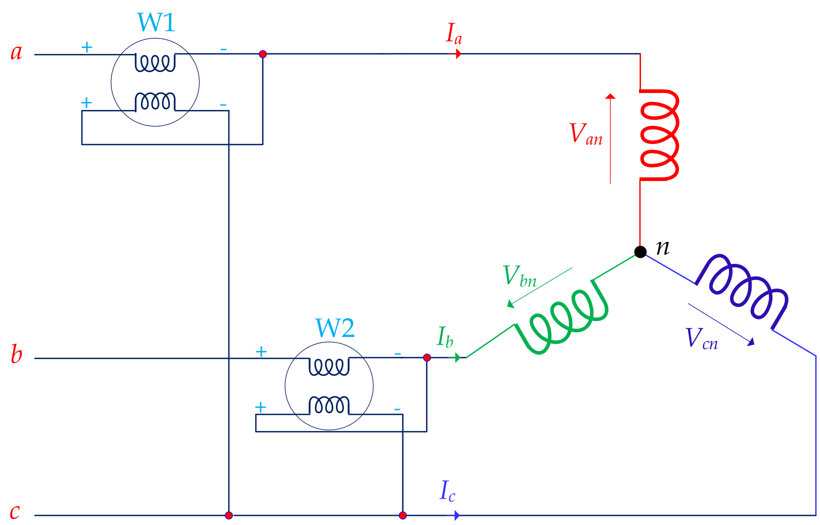


Fig. 9 Two wattmeter method

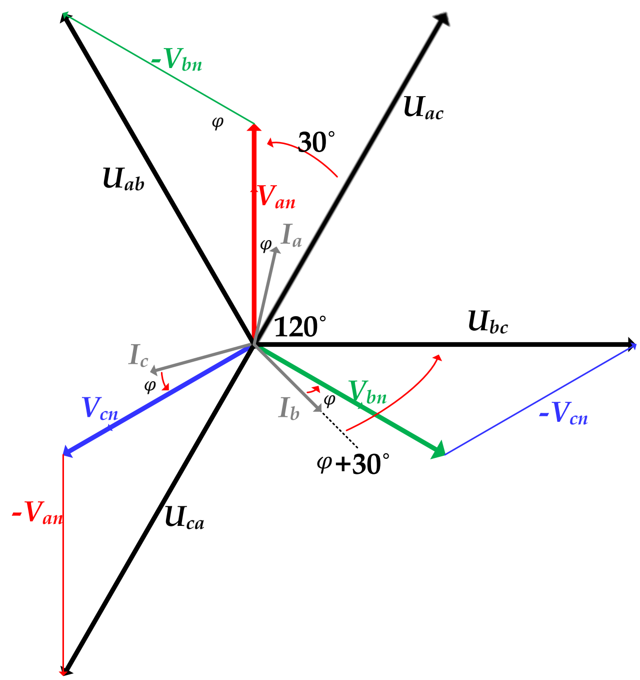


Fig. 10 Voltages and currents phasor diagram

Suppose that this system is inductive load, from Fig. 10 we have:

1. The current **lags** its respective phase voltage by φ
2. The line voltage U_{ac} **lags** phase voltage V_{an} by 30, so the phase difference between the line voltage and the phase current is $30 - \varphi$, see the phasor diagram in Fig. 10
3. The line voltage U_{bc} **leads** phase voltage V_{bn} by 30, so the phase difference between the line voltages and the phase currents is $30 + \varphi$, see the phasor diagram in Fig.10
4. Because the system is balanced, all line voltages are considered identical in their magnitudes as line currents.

So based on these points:

Power measured by wattmeter1:

The power is the result of the dot product of V_{ac} and I_a so

$$W_1 = U_{ac} I_a \cos(30 - \varphi) = U_{line} I_{line} \cos(30 - \varphi)$$

Power measured by wattmeter2:

The power is the result the dot product of $V_{bc}$and I_b so

$$W_2 = U_{bc} I_b \cos(30 + \varphi) = U_{line} I_{line} \cos(30 + \varphi)$$

And the active power consumed by the load is

$$P = W_1 + W_2 = U_{line} I_{line} [\cos(30 - \varphi) - \cos(30 + \varphi)]$$

$$P = 2U_{line} I_{line} \cos(30)\cos(\varphi)$$

$$P = \sqrt{3} U_{line} I_{line} \cos(\varphi)$$

Reactive power

$$Q = \sqrt{3}(W_1 - W_2)$$

Apparent power

$$\underline{S} = P + jQ$$

$$S = \sqrt{(P^2 + Q^2)}$$

Three wattmeter method

This method, in which three wattmeter disposals are necessary, is to perform an accurate measurement of active power. Also, this is used when the unbalanced system is employed. In this case, the neutral is connected so each wattmeter is used to one phase power and we have:

Active power

$$P = W_1 + W_2 + W_3$$

Reactive power

$$Q = Q_1 + Q_2 + Q_3$$

Apparent power

$$S = \sqrt{(P^2 + Q^2)}$$

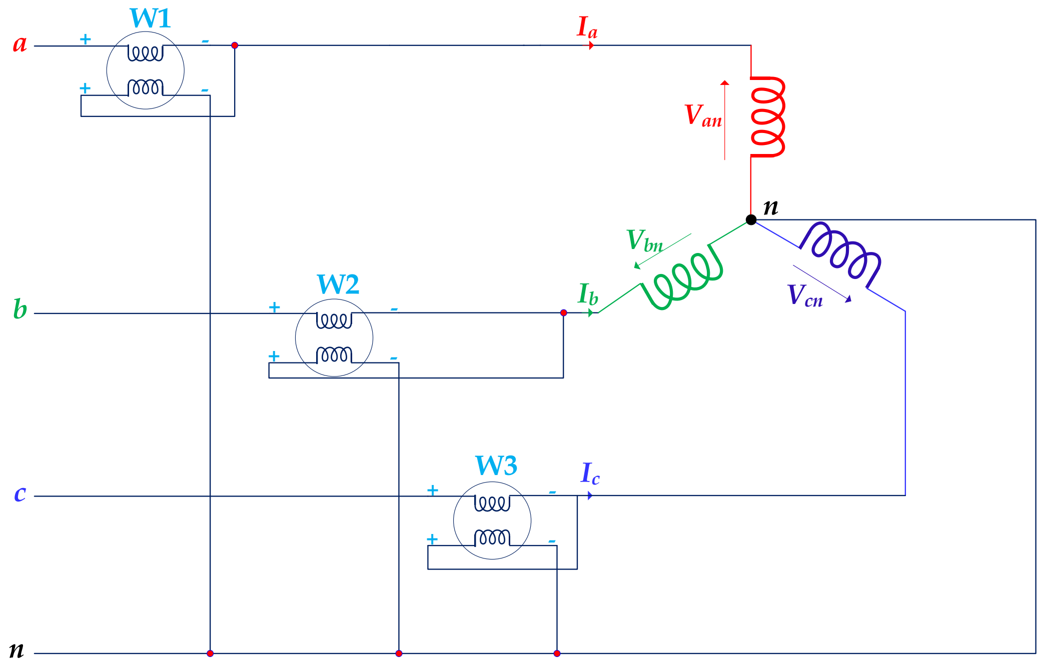


Fig. 11 Three wattmeter method

2- Experiments

2.1 Single Wattmeter Method

In this case, the load is balanced and purely resistive **R** = ⋯⋯⋯ Ω; it is supplied by means of a balanced three-phase voltage of **RMS 50V**.

1- Make the connection as shown in fig

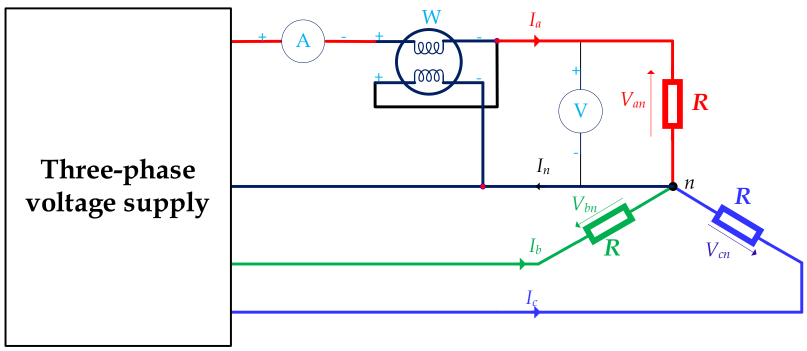


Fig. 12 single wattmeter method

2- Complete the table

	V_{an}	I_a	$V_{an}I_a$	P_1	Q_1	S_1	$PF1$
Formula			$V_{an}I_a$	$V_{an}I_a \cos\varphi$			$\cos\varphi = \frac{P}{S}$
Calc							
Measure							

3- Calculate the total power consumed by the three-phase load and *PF*:

$P_T = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$

$Q_T = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$

$S_T = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$

$PF = \frac{P_T}{S_T} = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\ \cdots\cdots\cdots\cdots$

2.2 Two Wattmeter Method

In this case the system of three-phase voltage is considered balanced with no connected neutral. Considering that the load is balanced and inductive $\mathbf{R} = \cdots\cdots\cdots\cdots\Omega$, $\mathbf{L} = \cdots\cdots\cdots\cdots$ mH Do:

1- Rig up the circuit diagram as shown in fig

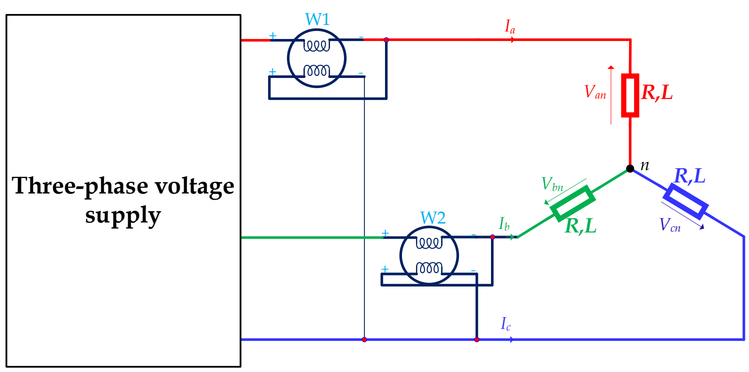


Fig. 13 Two wattmeter method

2- Complete the table

	P_1	P_2	Q_1	Q_2	S_1	S_2	PF
Formula							$\cos\varphi = \frac{P_T}{S_T}$
Calc							
Measure							

3- Calculate the total power consumed by the three-phase load and *PF*:

$P_T = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$

$Q_T = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$

$S_T = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$

$$PF = \frac{P_T}{S_T} = \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \cdots\cdots\cdots\cdots$$

4- Measure the line voltage U

…………………………………………………………………………………………………...

5- Measure the phase voltage V

…………………………………………………………………………………………………...

6- Calculate the ratio $\frac{U}{V}$ then give its signification

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

2.3 Three Wattmeter Method

To verify this method, we consider a three-phase voltage system. The load is considered unbalanced capacitive $\mathbf{C}_a = \cdots\cdots\cdots\cdots$ µF, $\mathbf{C}_b = \cdots\cdots\cdots\cdots$ µF, $\mathbf{C}_c = \cdots\cdots\cdots\cdots$ µF.

1- Rig up the circuit diagram as shown in Fig. 14.

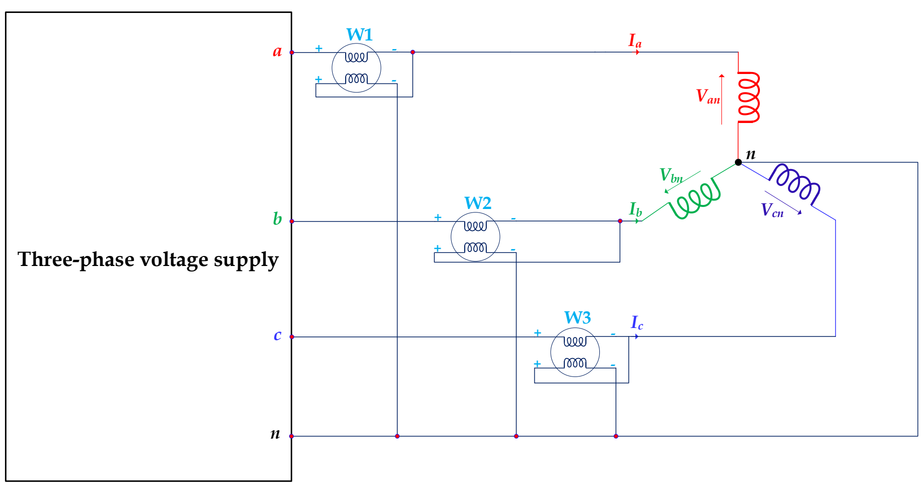


Fig. 14 Three wattmeter method

2- Complete the table

	P_1	Q_1	S_1	P_2	Q_2	S_2
Formula						

Calc						
Measure						

	P_3	Q_3	S_3	P_T	Q_T	S_T
Formula						
Calc						
Measure						

3- Calculate the power factor ***PF*** for each phase then for the entire system:

$$PF1 = \frac{P_1}{S_1} = \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$PF2 = \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$PF3 = \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$PF = \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

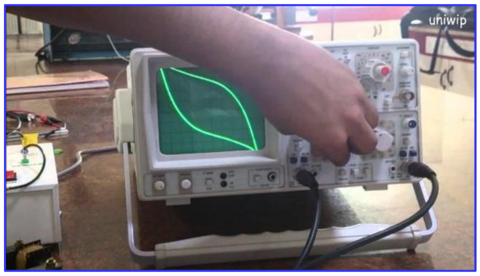
4- For the question 3, give a summary:

……………………………………………………………………………………………………...

……………………………………………………………………………………………………...

Lab 03

Hysteresis Cycle



Prepared by Dr. Saad Bella

Experiment progression:

This report prepared by:

Full name		Remarks	Group
01			
02			
03			
04			
05			
06			
07			
08			

1. Objectives

- **To study** and understand the principle of magnetic hysteresis and its consequences in ferromagnetic materials.
- **To learn how to** establish the **B(H) curve** from experimental data using an experimental setup with **CASSY Lab**.

2. Required Equipment

- AC voltage suppl.
- Measurement instrument (to measure voltage and current by sensor-cassy 2).
- A PC equipped with CASSY Lab software.

3. Background

3.1 Magnetic Circuits: A magnetic circuit is a closed path in which the magnetic flux lines circulate. In transformers and electrical machines, as electric current passes through the circuit, it creates magnetic flux that flows in the ferromagnetic materials like iron provoking magnetic field in it.

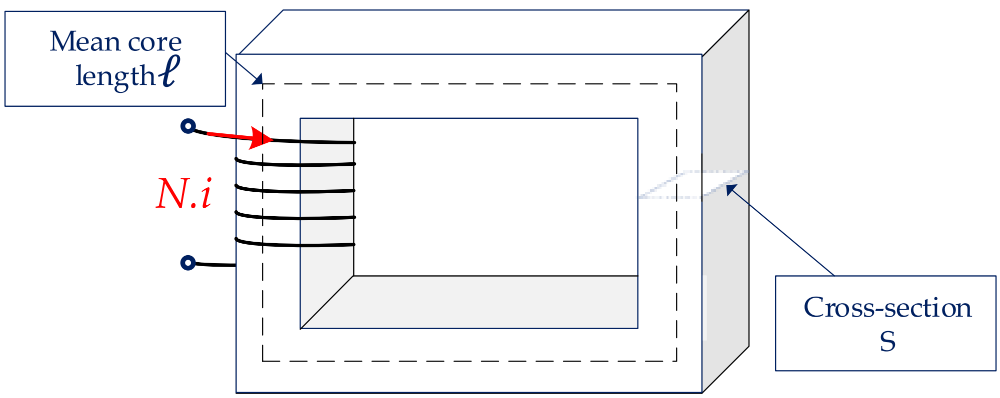


Fig. 1 Magnetic circuit

3.2 Electric Current – *The Source of Magnetization*

If **an electric current *i*** passes through the coil with N turns that is wound around the magnetic circuit, it creates a **magneto-motive force F_m** that leads to provoke magnetic flux through the core.

$$F_m = N.i$$

3.3 Magnetic Field Strength – *The Magnetizing Force*

Also called magnetizing intensity or magnetic intensity, it is a measure of the strength of the external magnetic field that is applied to a material to magnetize it.

$$H = \frac{B}{\mu}$$

3.4 Magnetic Flux — *The Total Magnetic Flow*

Magnetic **flux** can be defined as the total quantity of magnetic field lines that passes within the cross-section of the magnetic core.

$$\Phi = \int_S B.dS$$

If B is uniform and perpendicular to the surface S:

$$\Phi = B.S$$

Its unit is Weber (Wb) where 1 Wb = 1 Tesla × 1 m^2.

In the closed circuit:

$$\Phi = \mu_0 \mu_r HS$$

3.5 Magnetic Flux Density — *The Intensity of Magnetic Induction*

The magnetic induction or magnetic flux density is the **amount of flux per unit area** — it tells you how much flux passes through a unit area of the material's cross-section:

$$B = \frac{\Phi}{S}$$

$$\mathrm{B} = \mu H$$

$$\mu = \mu_0 \mu_r$$

- $\mu_0 = 4\pi \times 10^{-7}$ H/m: it is the permeability of free space.
- **The unit of B is Tesla (T)** = 1 Wb/m^2.
- μ_r: it is the relative permeability of the material.

3.6 Ampere's Law

Ampère's Circuital Law: it states that the **magnetic field** generated by an electric current is proportional to the size of that electric current. Hence, the relation between current and magnetic field is given as follows:

$$\oint_{\Gamma} H.dl = i$$

For a coil with **N** turns of wire

$$\oint_{\Gamma} H.dl = N.i$$

After integrating it

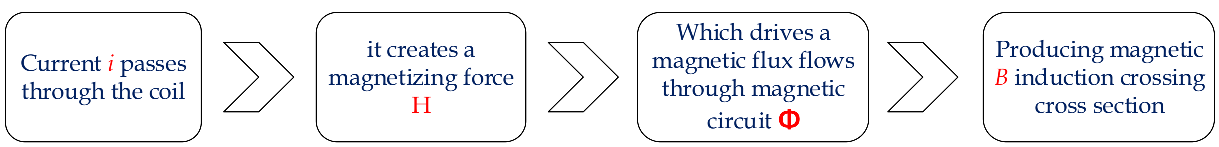
$$H = \frac{N}{\ell}.i \ [A/m]$$

3.7 Faraday's Law

According to its principle, a change in **magnetic flux** rate (because there is a change in the entered current) will induce a **voltage** across the terminals of the coil. In the following equation gives the relationship between the voltage and magnetic flux ratio:

$$e(t) = -N\frac{d\Phi}{dt}$$

3.8 Physical Sequence Inside the Core



3.9 Hysteresis Phenomenon

When a ferromagnetic material is placed in a magnetic field of strength H (generated by a current in a coil, for example), it becomes magnetized.

If H varies (because of alternating current), the magnetic flux density B *lags behind* the magnetic field strength H. This lagging phenomenon is called **hysteresis,** it is a complete cycle of magnetization and demagnetization, the resulting curve is a closed loop in another word a hysteresis loop.

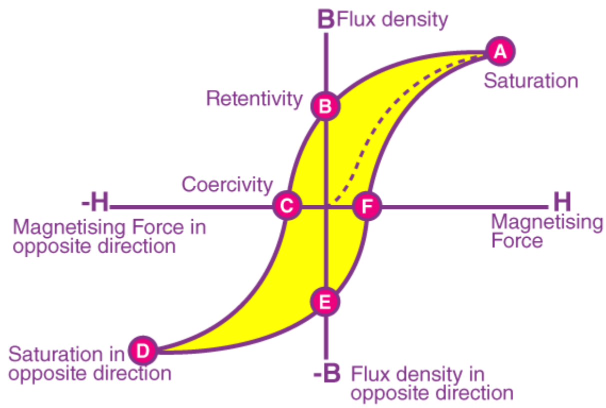


Fig. 2 hysteresis loop

Key Parameters of the Hysteresis Loop:

- ***Remanence (Br):*** The residual magnetic induction remaining in the material when the external magnetic field (H) is reduced to zero. The amount of magnetic flux density that remains is called remanence or retentivity.
- ***Coercive Force (Hc):*** The reversed magnetic field intensity required to reduce the magnetic induction (B) in the material to zero (to for magnetization back to zero).

3.10 Hysteresis Loss: The area of the hysteresis loop represents the energy dissipated as heat per unit volume during one complete magnetization cycle. This energy loss ($Energy$) is given by the integral:

The area of the loop corresponds to the **energy loss per unit volume per cycle**:

$$Energy = \oint HdB \;\; [J.m^{-3}.cycle^{-1}]$$

In uniform circuit like which we work on, the energy loss becomes:

$$Energy = H.B \;\;\; [J.m^{-3}.cycle^{-1}]$$

Its unit is in $J.m^{-3}$ per cycle, and the hysteresis power loss per cycle is given by:

$$P_h = \frac{Energy}{T}$$

i.e.:

$$P_h = Energy.f \quad [J.m^{-3}.cycle^{-1}].\left[\frac{cycle}{s}\right]$$

Hence, the equation of power loss per unit volume is given as:

$$P_h = Energy.f \quad [W.m^{-3}]$$

Finally, Energy lost in the core:

$$P_{Total} = P_h.V_{core} \quad [W]$$

4. Magnetic Induction Measurement

Fig. 3 shows the circuit diagram of the setup used to determine B-H curve, it consists of a transformer –*with* N_1 *turns for the primary and* N_2 *turns for the secondary*- powered with alternating voltage source v_s with frequency of 50Hz.

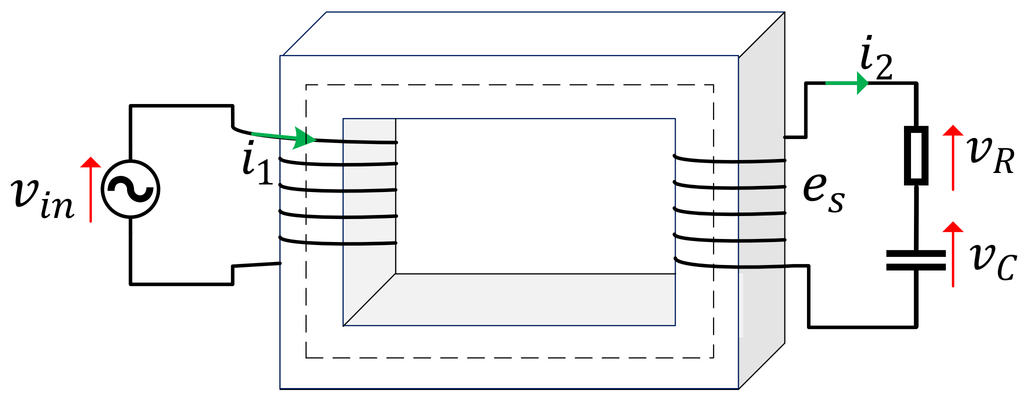


Fig. 3 Magnetic circuit

4.1 Ampere's Law (*Measuring H)*

In primary side, primary coil current i_1 is proportional to the magnetic field strength H.

$$H = \frac{N_1}{\ell}.i$$

Hence, by measuring i_1 we get values for *x-axis* of B-H curve.

4.2 Faraday's Law (*Measuring B)*

The **secondary winding** with N_2 turns experiences an induced emf proportional to the time derivative of the flux:

In the secondary winding (N_2 turns) with $\Phi = S.B$:

$$e_s(t) = -N_2 \frac{d\Phi}{dt} = -SN_2 \frac{d\mathrm{B}}{dt} = v_C + v_R$$

The voltage across the capacitor, v_C, is proportional to the integral of the current flowing into it. Under the specific condition that the resistor R is much larger than the capacitor's impedance ($e_s \approx v_R$), we can relate v_C directly to the integral of e_s. This leads to the final relationship:

$$v_C(t) \approx \frac{1}{RC} \int e_s(t)dt \propto B(t)$$

Hence:

$$v_C = \frac{-N_2}{RC} \int (\frac{d\Phi}{dt})\, dt = \frac{-N_2 S.B}{RC}$$

By rearranging the equation, we get the B:

$$B = -\frac{RC}{N_2 S}.v_C$$

Therefore, this can be used to get values for *y-axis* of B-H curve. By plotting the curve $v_C(i_1)$ is the same as displaying the curve B-H.

4.3 Loss Calculation

The **area enclosed by the loop** represents the energy dissipated as heat (per unit volume) during one complete cycle of magnetization.

5. Experiment Procedure

This experiment uses an E-I transformer core with N_1 turns of primary coil and N_2 for the secondary coil. The parameters for the lab experiment are given in the table below:

Parameter	*Value*
N_1/N_2	300/140 turns
Magnetic path length ℓ	35.2 cm
Cross-section S	9 cm²
Series resistor R	1 $k\Omega$
Series capacitor C	$16\mu F$
AC source v_{in}	30V

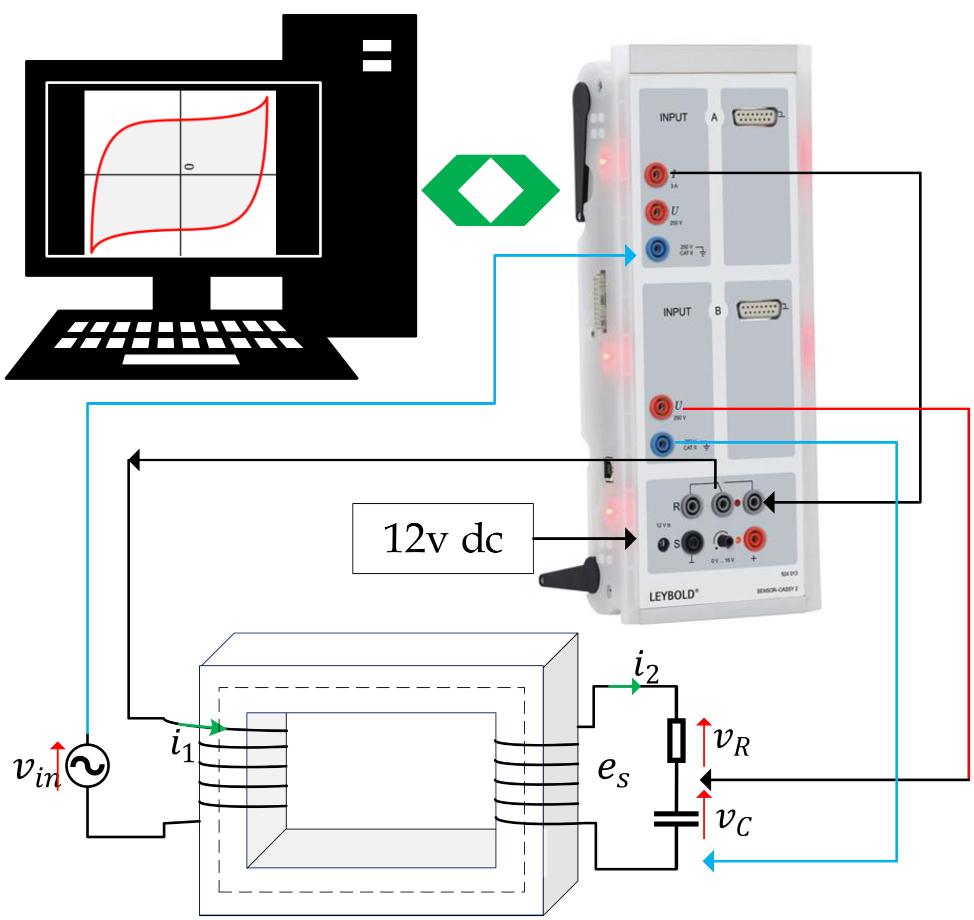


Fig. 4 Setup for this Lab

1- **Assemble** the circuit shown in Fig. 4, use sensor-CASSY to measure the current i_1 for *x-axis* and voltage v_c for *y-axis.*

2- Record and **complete** the table, then **plot** signals $v_C(t)$, $i_1(t)$.

$\boldsymbol{t(ms)}$	0	2	4	6	8	10	12	14	16	18	20
$\boldsymbol{v_C(mV)}$											
$\boldsymbol{B(T)}$											
$\boldsymbol{i_1(mA)}$											
$\boldsymbol{H(A.m^{-1})}$											

3- **Plot** $B(t)$ and $H(t)$

4- Use these two signals to **plot** $B(H)$ where (**draw it on graph paper)**

$$\begin{cases} v_C(t) \to B(t) \\ i_1(t) \to H(t) \end{cases}$$

5- Give an interpretation of the hysteresis loop linking it with magnetization and demagnetization cycle.

6- Calculate the area drawn on the graph paper then deduce the energy loss per unit volume per cycle.

7- Calculate the power loss per unit volume knowing the frequency of source 50Hz.

8- Give the coordinate (*H*,*B*) of each of { Saturation, remanence, and coercivity}.

Lab 04

Single-Phase Transformer

Prepared by Dr. Saad Bella

Experiment progression:

This report prepared by:

Full name		Remarks	Group
01			
02			
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6. Objectives

- To **study** equivalent diagram of a single-phase transformer,
- To **determine** the parameters of this equivalent circuit diagram.

7. Required Equipment

- AC and DC power supply
- Single-phase transformer
- Variable electrical load (Rheostat)
- Measurement equipment (voltmeters, ammeters, multimeters, power meters).

8. Background

A **transformer** is an electrical device that transfers energy between circuits using electromagnetic induction, primarily to *increase* or *decrease* voltage levels to ensure efficient power distribution, without changing the frequency.

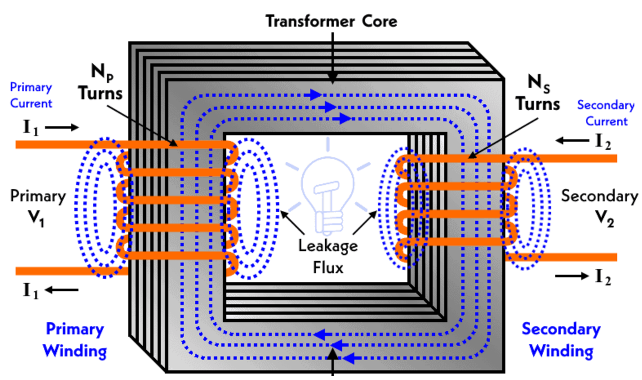


Fig. schematic diagram of a transformer

It consists of two coils (**primary** and **secondary**) around a magnetic core; the alternating current in the primary creates a magnetic field, inducing a voltage in the secondary, the ratio of the coils determining the change in voltage, making them essential for everything from electrical grids to home electronics.

9. Equivalent Circuit Diagram

The equivalent circuit diagram of a transformer simplifies its real-world behavior using lumped circuit elements, showing primary/secondary winding resistances (r_1, r_2), leakage reactance (X_1, X_2), core loss resistance (R_f), and magnetizing reactance (X_m) in a parallel branch, allowing engineers to analyze voltage drops, efficiency, and performance, with common forms including the "*exact*" circuit (with shunt R_f-X_m branch) and the "*approximate*" circuit (moving the shunt branch to the input/output terminals)

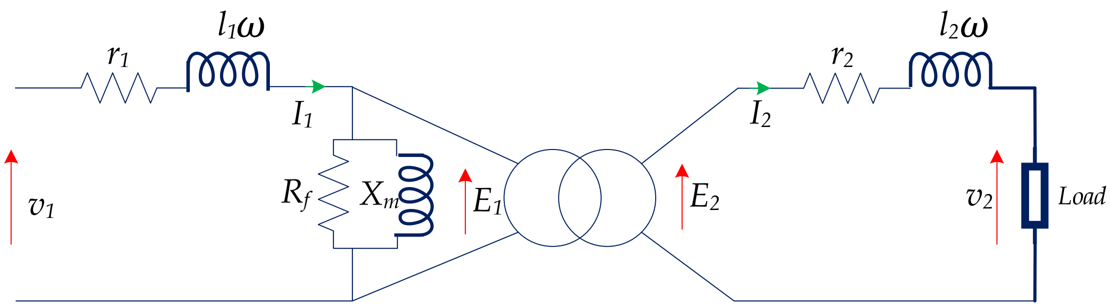


Fig. 1 Equivalent circuit diagram of a real transformer

These points are the key components for the equivalent diagram

- *Primary Winding Resistance (r_1) & Leakage Reactance ($l_1\omega$):* represent the physical resistance and flux leakage of the primary coil, shown as series elements.
- *Primary Winding Resistance (r_2) & Leakage Reactance ($l_2\omega$):* Similar to the primary.
- *Core Loss Resistance (Rf):* A parallel resistor representing energy lost as heat in the core (hysteresis and eddy currents).
- *Magnetizing Reactance (X_m):* A parallel inductor representing the current needed to magnetize the core.

10. Simplified Equivalent Circuit (Approximate)

5.1 Under Kapp Hypothesis

For quick voltage regulation checks, the entire excitation branch *(R_f & X_m):* can be **neglected**, leaving only the series equivalent resistance and reactance.

5.2 Equivalent Circuit Referred to the Secondary Side

The equivalent circuit referred to the secondary side models a transformer by **moving** all primary winding parameters to the secondary side using the square of the **transformation ratio**

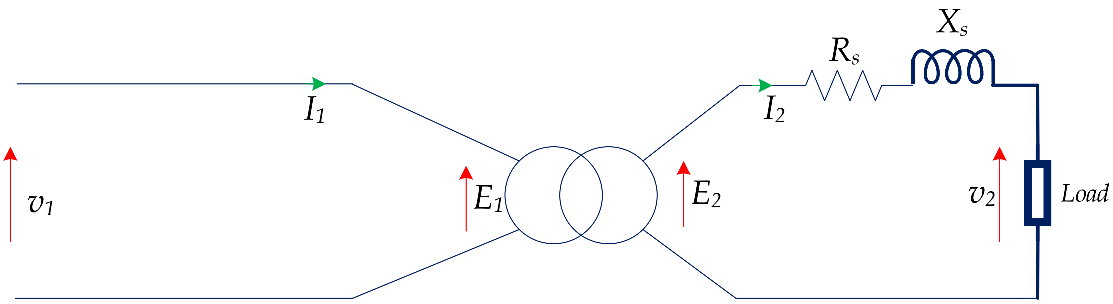


Fig. 2 Equivalent circuit diagram referred to secondary

- Transformer resistance referred to the secondary: $R_s = r_1 + m.r_2$
- Magnetic leakage reactance referred to the secondary: $X_s = X_1 + m.X_2$

11. Determining Parameters via Transformer Tests

6.1 *Open-Circuit Test*

The method is to apply **rated voltage** to the primary side with letting the secondary side open-circuited where its purpose is to measure the **total core loss**. In this case we determine:

- Transformation ratio: $m = \frac{v_{2oc}}{v_{1oc}}$
- Magnetic circuit resistance: $R_f = \frac{v_{1oc}^2}{P_f} \approx \frac{v_{1oc}^2}{P_{1oc}}$
- Magnetic circuit reactance: $X_m = \frac{v_{1oc}^2}{Q_f} \approx \frac{v_{1oc}^2}{Q_{1oc}}$
- Joule losses are negligible compared to the iron loss: $P_f \approx P_{1oc}$

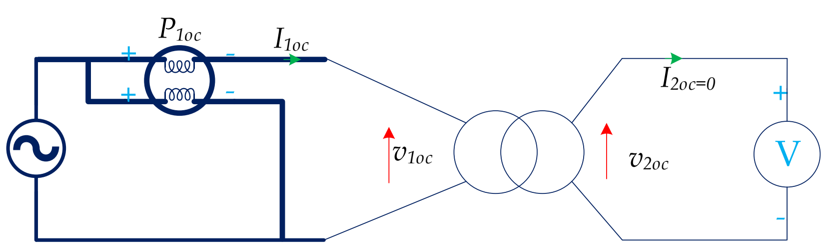


Fig. 3 Open-circuit test

6.2 *Short-Circuit Test*

The method is to apply **reduced voltage** to the primary side $v_{1sc} \ll v_{1n}$ (*reduced than rated voltage*) with short-circuited the secondary until rated current flows ($I_{2sc} = I_{2n}$).

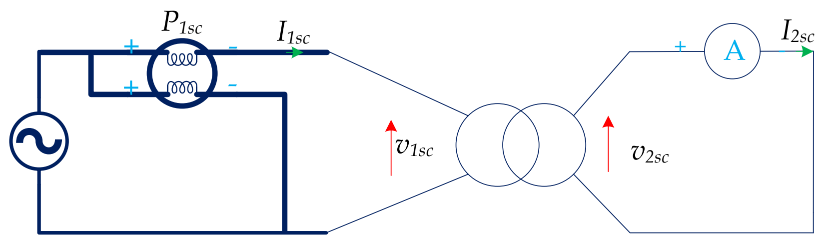


Fig. 4 Short-circuit test

Where the purpose is to measure total winding resistance and leakage reactance (**copper losses**).

$$P_{1sc} = R_s . I_{2sc}^2 \Rightarrow R_s = \frac{P_{1sc}}{I_{2sc}^2}$$

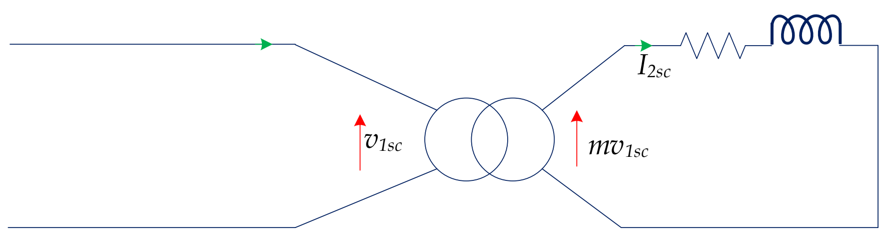


Fig. 6 Short-circuit equivalent diagram

$$Z_s = m\frac{v_{oc1}}{I_{sc2}} \text{ and } X_s = \sqrt{{Z_s}^2 - {R_s}^2}$$

Iron losses are negligible compared to copper losses, hence:

$$P_j \approx P_{sc1}$$

6.3 Load Test

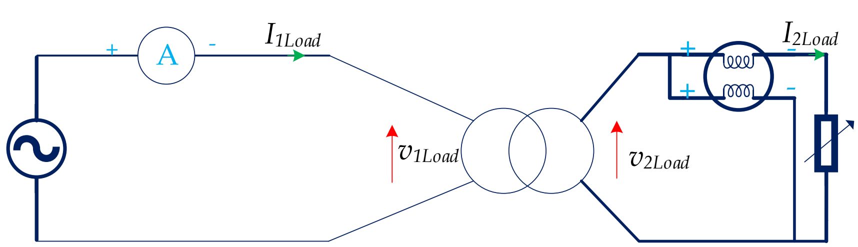


Fig.7 Load test

Transformer efficiency is the ratio of output power to input power, calculated as:

$$\eta(\%) = \frac{P_2}{P_1}.100 = \frac{P_2}{P_2 + P_f + P_j}$$

12. Experimental Procedure

7.1 Determining transformer features

a. *Transformer Nameplate*

Check the transformer nameplate for the voltage and current ratings (assume $S_n = S_1 = S_2$):

Rating voltage at primary:	$v_{1n} = \cdots$
Rating voltage at primary:	$v_{2n} = \cdots$
Apparent power:	$S_n = \cdots$
Rating voltage at primary:	$I_{1n} = \cdots$
Rating voltage at secondary:	$I_{2n} = \cdots$

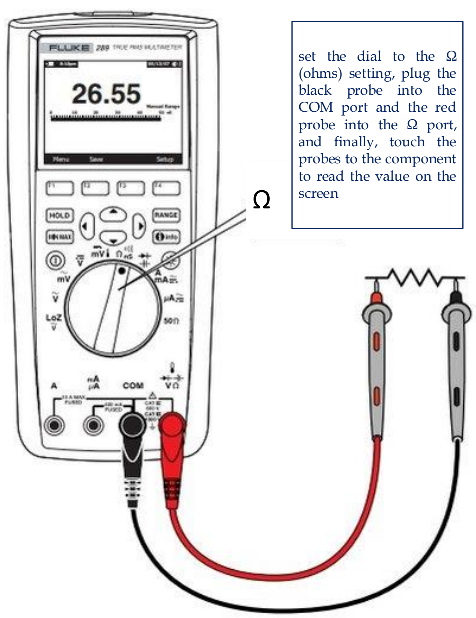
b. *Load Value Choice*

We can use the rated current to extract the lowest value that can a load take at the secondary, where: $R = \frac{v_{2n}}{I_{2n}} = \cdots$

c. *Winding Resistance Measuring*

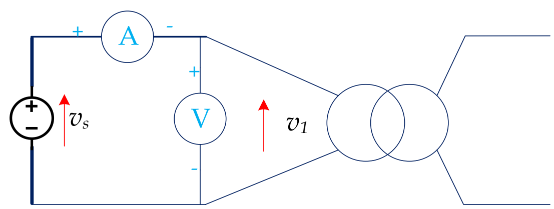
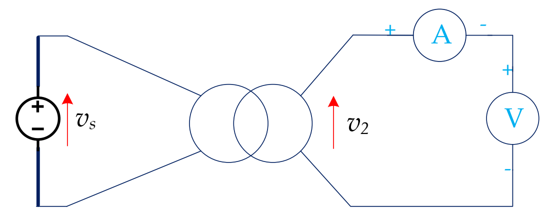
c.2 Direct Method:

We can use **ohmmeter** tool to measure directly the resistance value, use it and write the value of resistance: $r_1 = \cdots$, $r_2 = \cdots$



c.2 Voltammetric Method:

Carryout these circuits and make the current flowing at its rating value. Read the voltage and current using both **voltmeter** and **ammeter** then calculate the resistance of both windings.

primary resistance	*secondary resistance*
	
$v_1 = \cdots \quad , I_1 = \cdots \quad , r_1 = \cdots$	$v_2 = \cdots \quad , I_2 = \cdots \quad , r_2 = \cdots$

7.2 Transformer Tests

a. Open-Circuit Test

The method is to apply **rated voltage** v_{1n} to the primary side with letting the secondary side open-circuited as shown in Fig. 8.

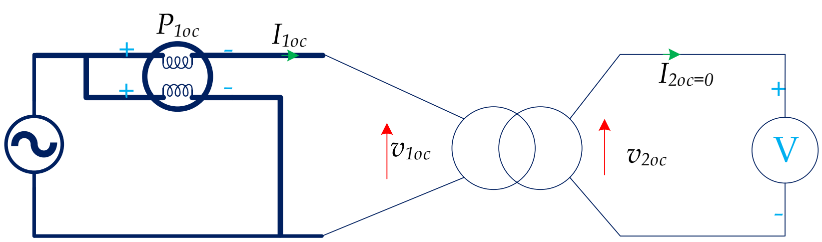


Fig. 8 Open-circuit test

1. Set the circuit as it is shown in Fig. 8.
2. Vary the primary voltage and complete the table

v_{1oc} (V)	40	80	120	160	220
I_{1oc} (A)					
v_{2oc} (V)					
P_{1oc} (watt)					
Q_{1oc} (VAR)					
P.F ($\cos\varphi$)					

3. Plot $v_{2oc} = f(I_{1oc})$
4. Use $v_{1oc} = v_{1n}$ measurement column to complete this table

Formula	Transformation ratio $m = \cdots$	$P.F = \cdots$	Iron loss $P_{fer} = \cdots$
Calculation			

5. Calculate R_m and R_f, what you conclude for this test

b. *Short-Circuit Test*

In this test, we should start by applying **reduced voltage** to the primary side (start with 0V) until rated current flows though the secondary.

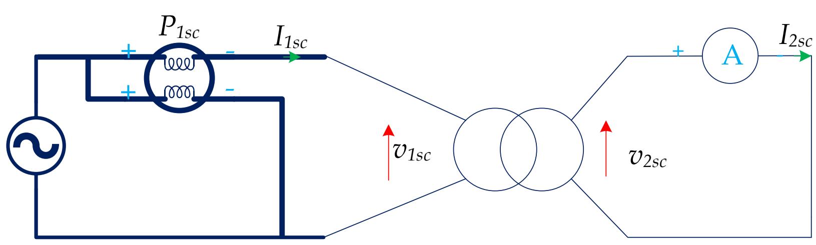


Fig. 9 Short-circuit test

1. Set the circuit as it is shown in Fig. 9.
2. Complete the table with necessary measurements

$v_{1sc}\ (V)$					
$I_{2sc}\ (A)$					
$I_{1sc}\ (A)$					
$P_{1sc}\ (watt)$					

3. Plot $P_{1sc} = f(I_{2sc}^2)$ then calculate R_s graphically.
4. Use the column, where the secondary current is at its rated value, to calculate: P_j, R_s, Z_s, X_s

c. *Load Test*

This is a normal test to calculate transformer **efficiency** while applying the **rated voltage** at primary side $\boldsymbol{v_{1Load} = v_{1n}}$.

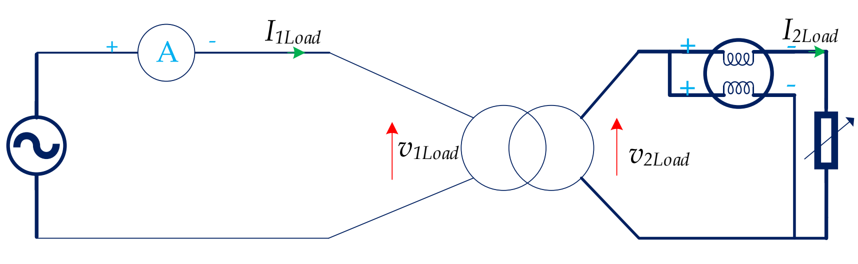


Fig. 10 Load test

1. Complete the table

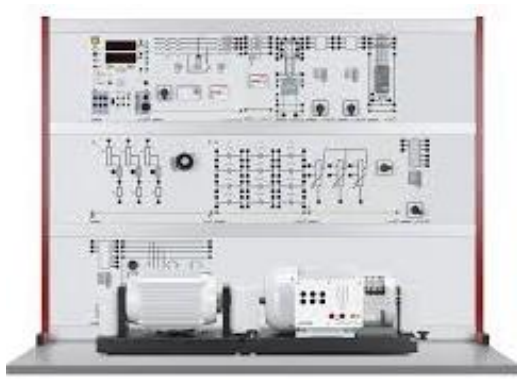
I_{1Load}						
I_{2Load}						
v_{2Load}						
P_{2Load}						
$P_{jLoad} = R_s . I_{2Load}^2$						
$P_{1Load} = P_{2Load} + P_{fer} + P_{jLoad}$						
$\eta(\%) = \left(\frac{P_{2Load}}{P_{1Load}}\right) . 100$						

2. Plot $\eta = f(I_{2Load})$ then give an interpretation to this.
3. Give I_{2Load} at which the efficiency is maximum.

Lab 05

Direct Current Machine

Prepared by Dr. Saad Bella



Experiment progression:

This report prepared by:

	Full name	Remarks	Group
01			
02			
03			
04			
05			
06			
07			
08			

13. Objectives

- To **study** a DC machine as a generator,
- To **study and use** it as a motor.

14. Required Equipment

- DC power supply
- DC machine set-up

15. Background

A **direct current machine** is an electromechanical energy conversion **device** that operates on direct current (DC), acting either as:

- a **motor** to **convert** electrical energy into mechanical energy, or as
- a **generator** to convert mechanical energy into DC electrical energy.

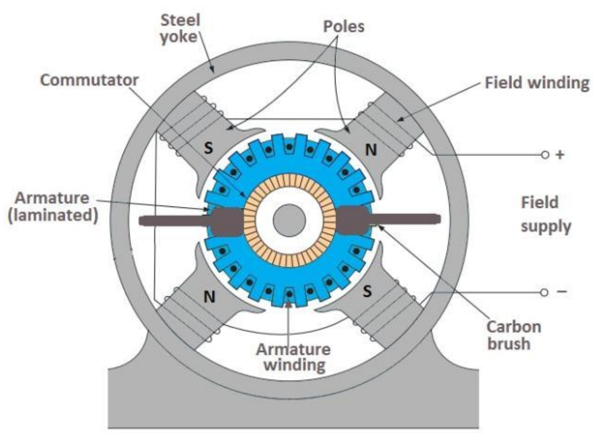


Fig.1 DC Machine Structure

Different parts of DC Motor are:

- **Armature or Rotor:** this is a rotating part that rotates around it on its axis. It is a cylinder of magnetic laminations that are insulated from one another to minimize Eddy Currents. This armature is separated from the field coil which is fixed part by an air gap.
- **Field Coil or Stator:** this is a fixed part, and its winding is the responsible to produce a magnetic field.
- **Yoke, or outer frame:** this is a machine frame name, it is made of cast iron or steel to provides mechanical strength for the whole assembly of the motor.

- **Pole:** It is on which we wounded the field winding to give magnetic flux. The materials used for this are steel laminations in order to reduce the power drop because of the eddy currents.
- **Commutator:** It is a cylindrical structure that is made of copper segments stacked together but insulated from each other. The primary function of a commutator is to supply electrical current to the armature winding, it acts as a mechanical switch to maintain DC direction and helps in producing steady rotating torque.
- **Brushes:** The brushes of a DC motor are made with carbon or graphite blocks that maintain electrical contact between the stationary circuit and the rotating commutator to transfer current while minimizing friction and wear.

16. Reversibility Principle in DC Machines

The term "machine" is used because the device is electrically reversible:

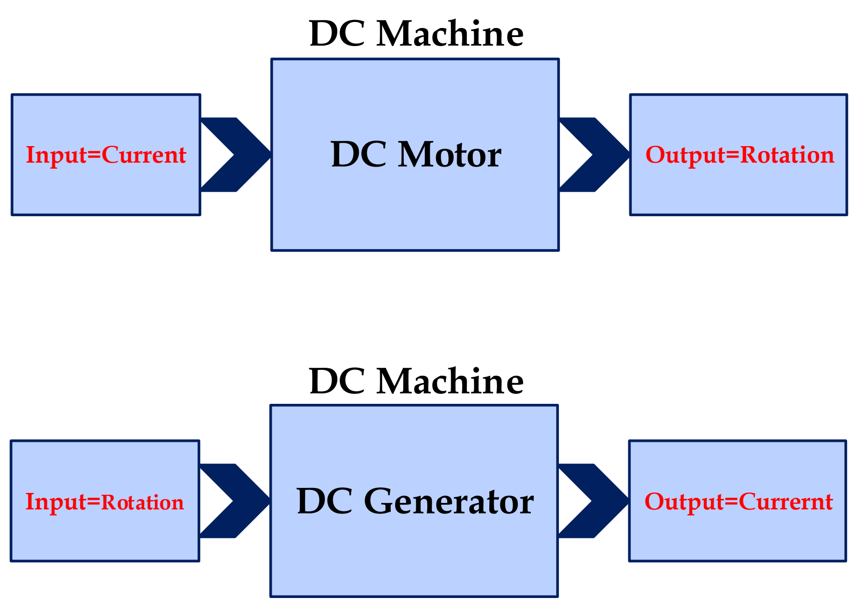


Fig. 2 DC Machine Reversibility

4. 1. Generator Action (Mechanical → Electrical)

When the machine is driven by an external mechanical force (Prime Mover), the Armature conductors cut the magnetic flux produced by the Field Poles.

- *Result*: According to Faraday's Law, an Electromotive Force (EMF) is induced.
- *How*: Fleming's Right-Hand Rule.

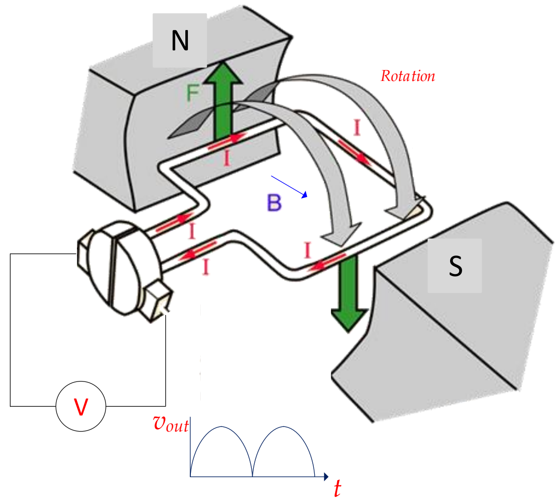


Fig. 3 Working Principle of a DC Generator

4. 2. Motor Action (Electrical → Mechanical)

When the machine is powered with supply voltage, current flows through the Armature conductors while they are inside the magnetic field.

- *Result*: According to Lorentz Force Law, a mechanical force (Torque) is generated, causing the rotor to spin.
- *How:* Fleming’s Left-Hand Rule.

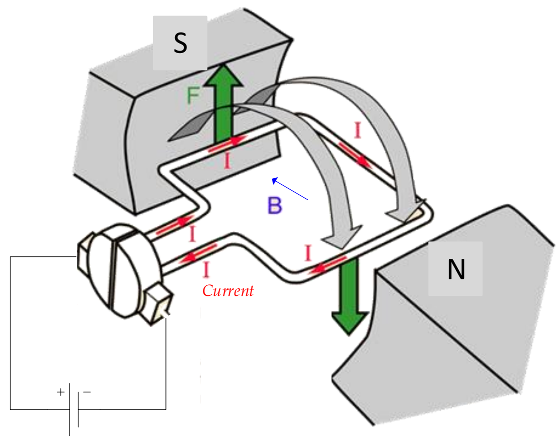


Fig. 4 Working Principle of a DC Motor

The rotation direction of the DC motor is depending to the magnetic field relative direction and the rotor (armature) current. This rotation can be reversed by inverting either:

- The Excitation Current (I_{ex}) or Field Current: Reverses the magnetic flux (Φ).
- The Supply Voltage (U): Reverses the armature current (I).

17. Fundamental DC Machine Equation

Induced Electromotive Force (E)

The **e.m.f** is directly proportional to the magnetic flux and the angular velocity:

$$E = K.\Phi.\Omega$$

At constant flux (constant field current or permanent magnet), the **e.m.f** is proportional to speed: $\mathrm{E = k.n}$ which leads to $\frac{E}{E'} = \frac{n}{n'}$.

Electromagnetic Torque (T_e) Electrical power (P_e) is converted into mechanical power (P_m). This transition is defined by the electromagnetic power:

$$\boldsymbol{P_e = E.I = T_e.\Omega}$$

I.e.

$$\boldsymbol{T_e = \frac{P_e}{\Omega} = \mathbf{K.\Phi.I}}$$

5.3 Mechanical to Electrical Operation Mode (Generator)

When the armature is driven at a constant speed by an external motor (Prime Mover), it cuts the magnetic flux produced by the field winding.

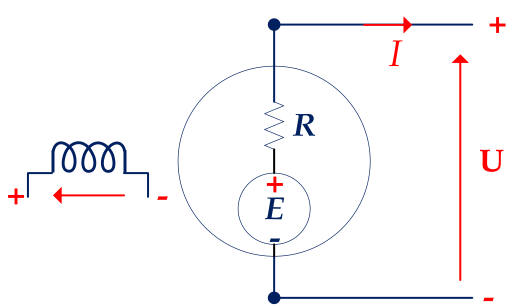


Fig. 5 Generator Circuit

In this case, the terminal voltage (U) is lower than the induced **e.m.f** E due to the internal resistance.

$$\begin{cases} U = E - RI \\ U < E \end{cases}$$

5.4 Electrical to Mechanical Operation Mode (Motor)

When an external DC voltage is applied to the armature, the interaction between the armature current and the magnetic field produces mechanical torque.

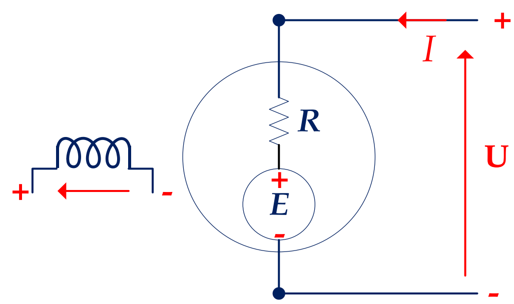


Fig. 6 Motor Circuit

In this case, the applied voltage (U) must overcome the back **e.m.f** (E)

$$\begin{cases} U = E + RI \\ U > E \end{cases}$$

I_{ex} ↗ (increasing current): you start with the excitation current at zero and gradually increase it to its maximum rated value.

I_{ex} ↘ (decreasing current): after reaching the maximum current, you gradually decrease the excitation current back to zero (*not zero, it is slightly higher because the remnant voltage).*

Note: *to not damage dc machine when working with "Always decrease the **excitation current** to its minimum or zero slowly before switching off the power supply, and never open the field circuit while the machine is running."*

18. Experimental Procedure

1. Separately Excited DC Generator (No-Load Test)

In a separately excited DC generator, the field winding is energized by an independent external DC source. During a No-Load test, the generator is driven at a constant rated speed 1500rpm while the field current (*I*) is gradually increased. The primary goal is to observe the relationship between the field current and the generated armature voltage (*E*).

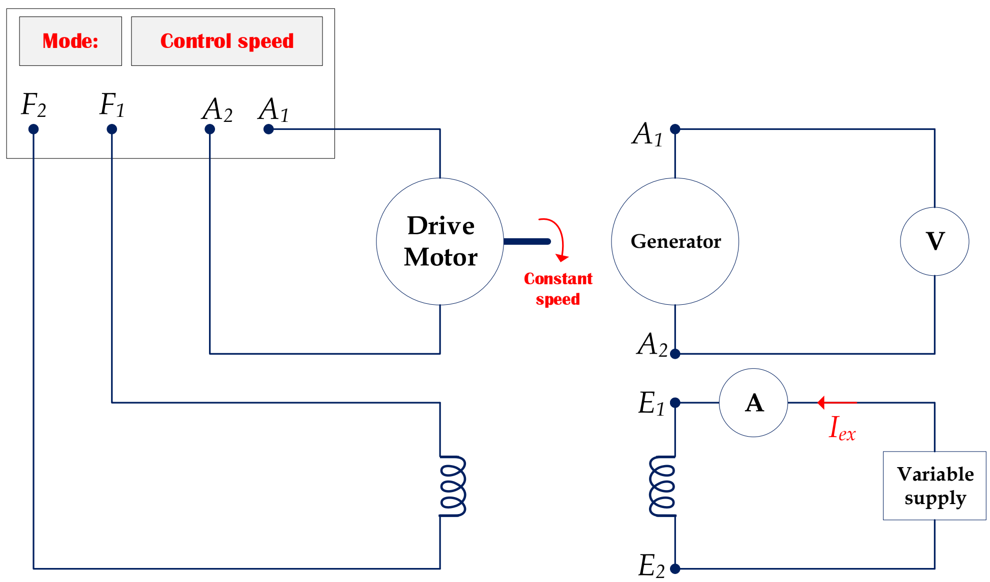


Fig. 7 procedure of generator setup

The rotor is no-load U = E

-The field winding, the excitation circuit, behaves as a resistor and $V_{ex}=(R_h+r_{ex})I_{ex}$

1) Set the circuit shown in figure 7.

2) Complete the following table.

I_{ex} (A)	***0***							
U = *E* *When increasing* I_{ex}								
U = *E* *When decreasing* I_{ex}								

3) Use Fig to plot the curve $E=f(I_{ex})$

4) Interpret the gotten curve

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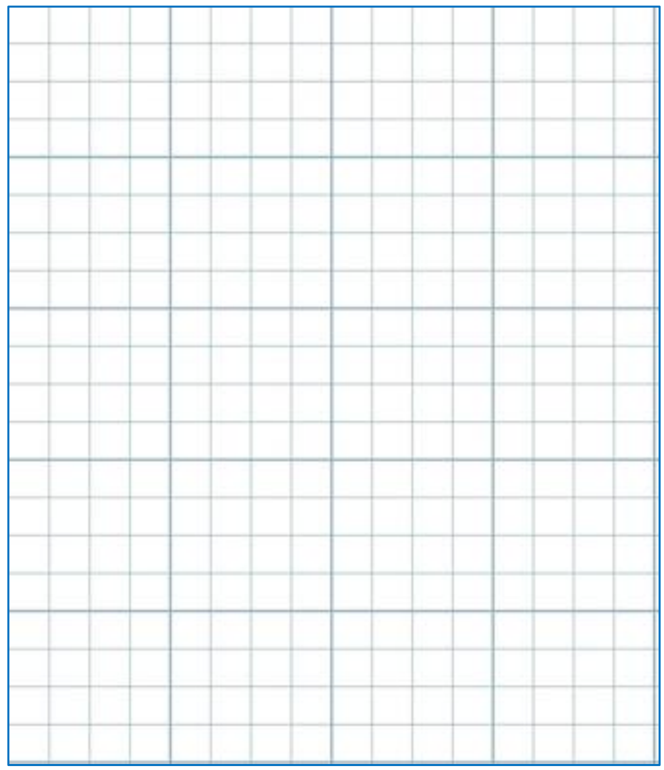

Fig.

5) Give the value of the remnant electromotive force

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2. Separately Excited DC Motor (No-Load Test)

A separately excited DC motor operates by supplying the field and armature circuits from different sources. In a No-Load test, the motor is allowed to run without any mechanical load attached to its shaft. Under these conditions, the armature current remains very low, as it only needs to overcome internal friction and windage losses.

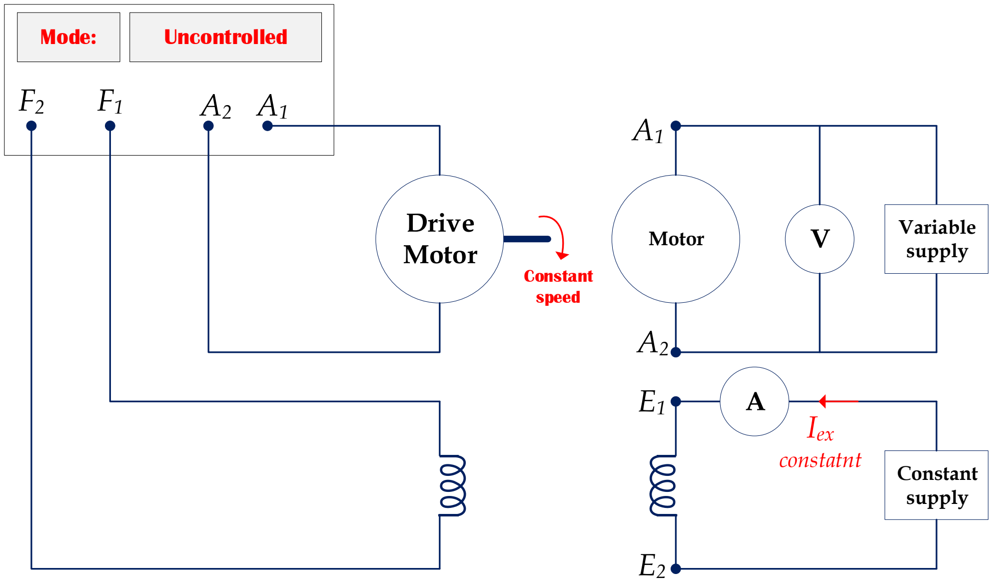

Fig. 8 procedure of motor setup

1) Set-up the circuit then complete the table

U(*V*)	***0***	***10***	***20***	***30***	***40***	***50***	***60***	***70***	***80***
n(rpm)									

2) sketch $n=f(U)$

3) Interpret this then find the expression of the function f

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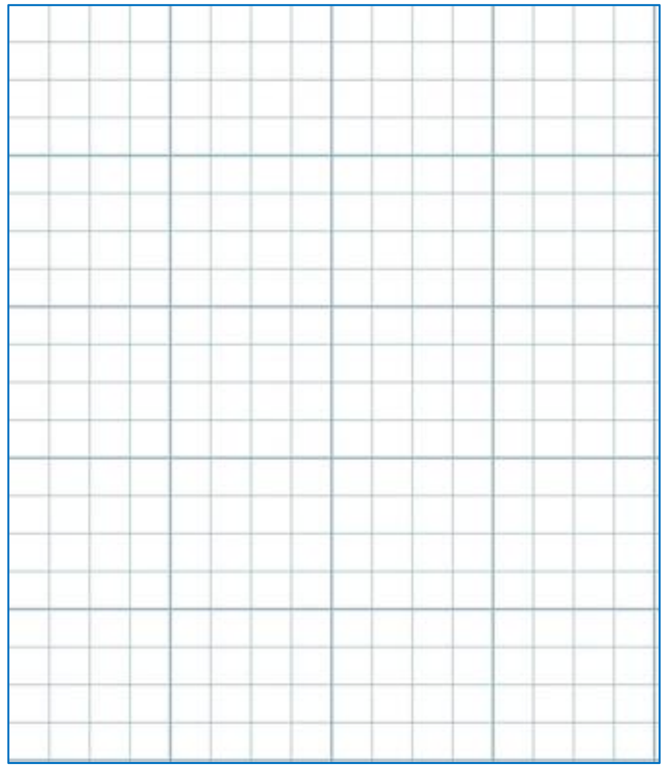

Fig.

4) Conclusion

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