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كلية التكنولوجيا
Faculty of Technology
قسم الهندسة الكهربائية و قسم الإلكترونيك
Department of Electrical Engineering and Department of Electronics
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University year: 2024/2025 السنة الجامعية: 2024 /2025

2nd year Electrical Engineering and Electronics السنة الثانية هندسة كهربائية و إلكترونيك

Applied Work in Fundamentals of Electrotechnics 1 أعمال تطبيقية في الكهروتقني الأساسية 1

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PW n°04 : The single phase transformer

Duration : 1^h30.

Date of the experiment: ………. /……../………….. ..

Report prepared by:

Last Name	**First Name**	**Group**	**S/Group**	**Final Note**
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Instructions :

- **Internal laboratory regulations must be observed.**
- **You must wear a lab coat.**
- **Attendance is compulsory and will be monitored. Any unjustified absence or failure to hand in a report will result in a mark of 0/20.**
- **Have your assemblies checked before connecting the voltage source.**
- **It is strictly forbidden to move equipment from one station to another. In the event of a breakdown or faulty equipment, contact the teacher.**
- **The report must be written by a maximum of four students.**
- **The report must be handed in at the beginning of the next session.**
- **The report must include the following sections:**
  - **TP cover page.**
  - **The date of the practical session.**
  - **Last Name and first name of the main writer.**
  - **Last Names and first names of the WP participants.**
  - **Preparation and work in manuscript**

Person in charge of practical work: Dr ROUABHI.R

I- Aim of the experiment:

The aim of this experiment is to present a general method for determining the parameters of the equivalent diagram of a single-phase transformer.

I- Equipment used:

- Single-phase voltage sources (AC/DC).
- Electrical loads (rheostats).
- Measuring instruments (voltmeters, ammeters, multimeters, power meters).
- Single-phase transformers.

II- Theoretical reminder:

1) General information

The transformer is a reversible static converter of electrical energy. It transfers, in alternating current, electrical power from a source to a load, by adapting the voltage (or current) values to the receiver.

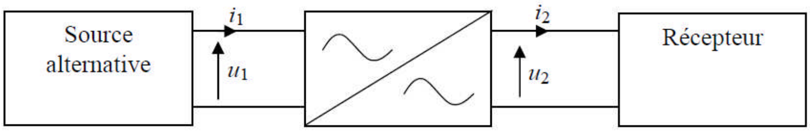

Figure1-Real single-phase transformer

In general, the function of a transformer is to change the RMS value of a voltage without changing its shape (sinusoidal) or frequency. U1 and U2 are the effective values of the voltages U1 and U2 respectively. If U2 >U1: the transformer is a step-up transformer, and if U2 <U1: the transformer is a step-down transformer.

2) Real single-phase transformer

The transformer consists essentially of:

-**A magnetic circuit:** Its function is to channel the magnetic flux.

-**Windings:** On the cores of the magnetic circuit there are several windings (electrically isolated from each other), one of which is connected to the source of alternating current: this is the primary winding, which adopts the receiving convention. The other winding (or the others) is the seat of an induced e.m.f. It can flow into a receiver: this is the secondary winding, and the generator convention is adopted.

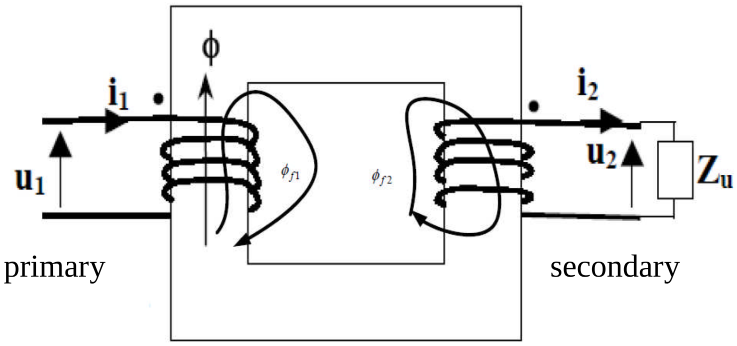

Figure 2–Operating principle of a single-phase transformer.

3) Equivalent diagram

If we designate respectively by:

r_1(Ω): resistance of the primary winding, **r_2(Ω)**: resistance of the secondary winding.

l_1(H): Primary winding inductance, **l_2(H)**: Secondary winding inductance.

Rf(Ω): Magnetic circuit resistance. **Xm (Ω)**: Magnetic circuit reactance.

The equivalent diagram of the real transformer is shown in Figure 3.

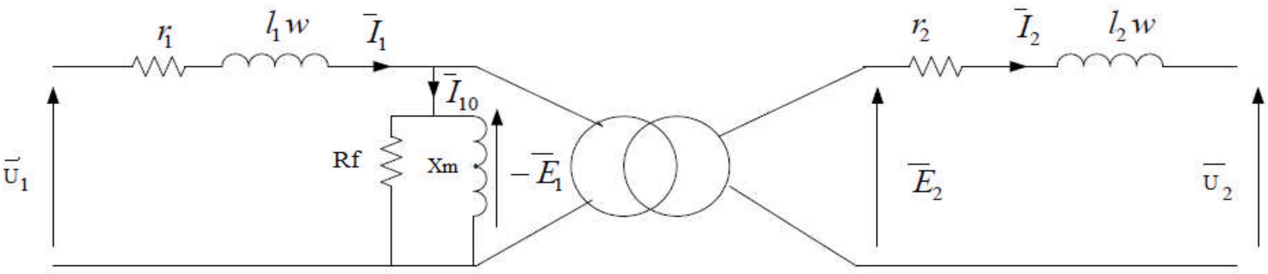

Figure 3 - Equivalent diagram of a real transformer

4) Equivalent diagram under the Kapp hypothesis

The **Kapp** hypothesis consists of neglecting the current **I_{10}** in front of the current **I_1**

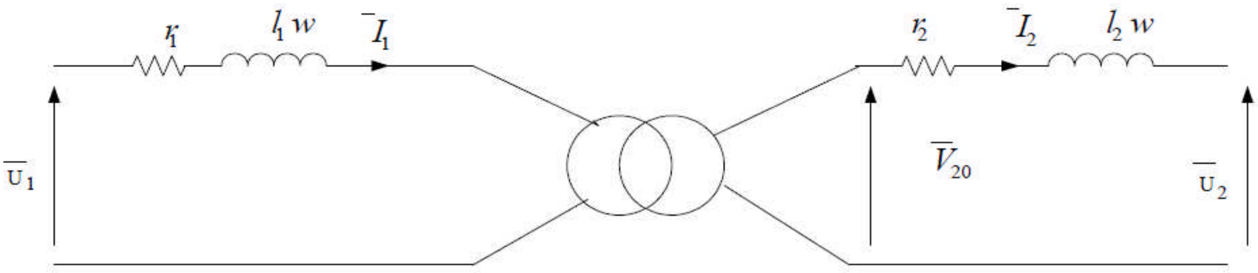

Figure 4 - Equivalent diagram under the Kapp hypothesis

5) Equivalent returned to secondary circuit diagram

The impedance **Z1= r1+jlw** can be transferred from the primary to the secondary by multiplying it by m2. This gives the following diagram:

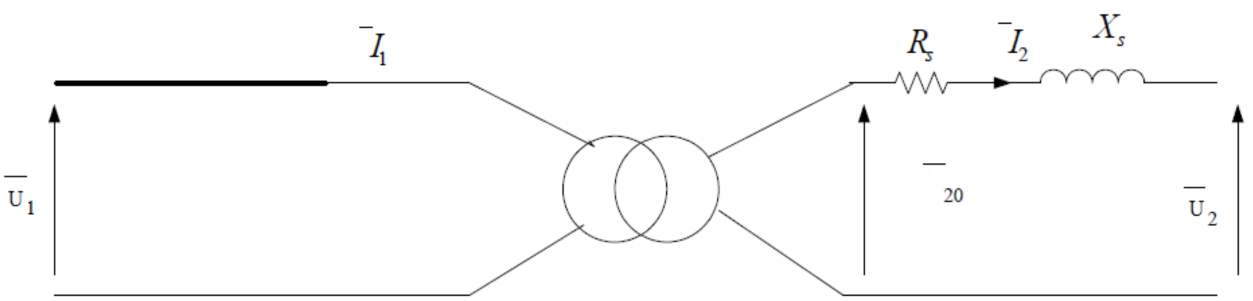

Figure 5 - Equivalent diagram returned to secondary

Where :

$Rs = r_1 + m^2.r_2$: the resistance of the transformer returned to the secondary.

$Xs = X1 + m^2.X_2$: the magnetic leakage reactance returned to the secondary.

6) Determine the elements of the equivalent diagram:

Three tests are carried out:

✓ **No-load test (Open circuit test)**

This test consists of applying the rated voltage to the primary winding and measuring the no-load voltage at the secondary, the current and the no-load power absorbed by the primary, as shown in the following diagram:

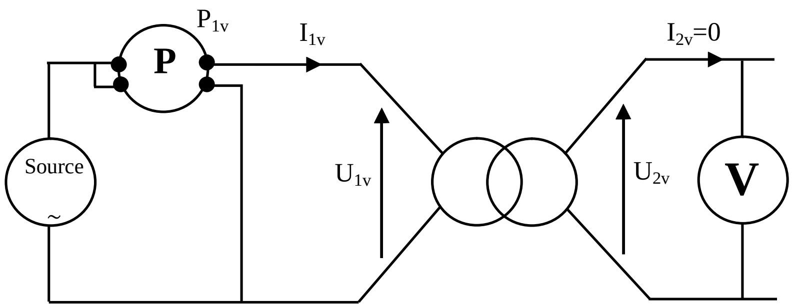

Figure 6 - No-load test

In this case, we can practically determine:

- The transformation ratio $m = \frac{U_{2v}}{U_{1v}}$
- The magnetic circuit resistance $R_f = \frac{U_{1v}^2}{P_f} \approx \frac{U_{1v}^2}{P_{1v}}$.
- The magnetising reactance $X_m = \frac{U_{1v}^2}{Q_f} \approx \frac{U_{1v}^2}{Q_{1v}}$.
- Joule losses are negligible compared with iron losses $P_F \approx P_{1v}$

✓ **Short-circuit test with reduced primary voltage**

A reduced voltage $U_{1cc} \ll U_{1n}$ (rated voltage) is applied to the primary, and $U_{1cc}$is gradually increased from 0 until $I_{2cc} = I_{2n}$.

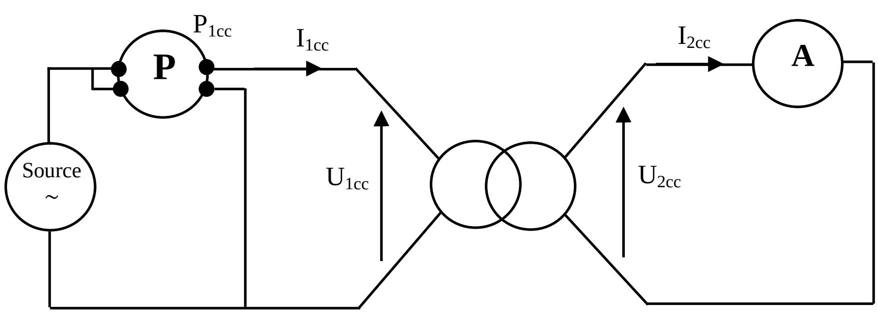

Figure 7- Short-circuit test

Since $U_{1cc} \ll U_{1n} \Rightarrow$ the iron losses during the short-circuit test are negligible and therefore:

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

The equivalent diagram brought back to the secondary (short-circuited) is as follows:

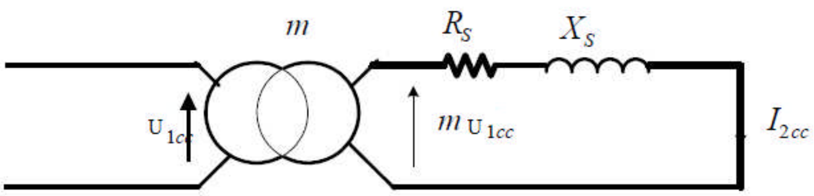

Figure 8- equivalent diagram for short-circuit test

$$Z_s = m\frac{U_{1cc}}{I_{2cc}} \quad \text{and} \quad X_s = \sqrt{{Z_s}^2 - {R_s}^2}$$

Iron losses are negligible compared to joule losses, therefore $P_J \approx P_{1cc}$.

- ✓ **Load test**

  A nominal voltage is applied to the primary.

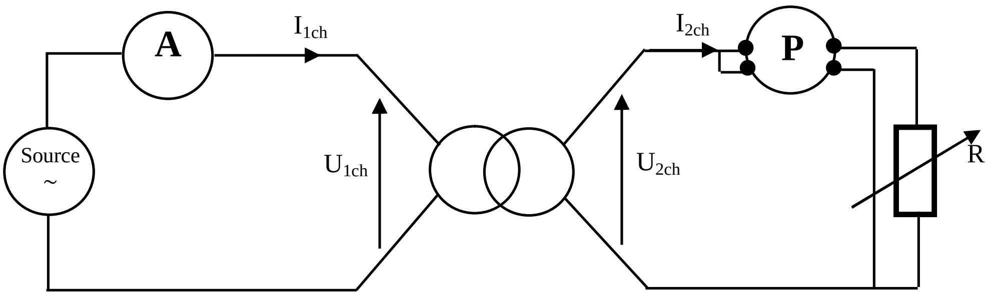

Figure 9 - Load test

Finally, we can calculate the efficiency of the transformer $\eta(\%) = \frac{P_2}{P_1}.100 = \frac{P_2}{P_2+P_f+P_j}.100.$

II- Practical study:

1. Transformer characteristics

On the transformer, note the following characteristics:
Nominal voltage at the primary U_{1n} = …………………
Nominal voltage at the secondary U_{2n} = …………………
Apparent power S_n = ……………..……

2. Nominal currents

Assuming $S_1 = S_2 = S_n$, determine the rated primary and secondary currents, I_{1n} and I_{2n}..

I_{1n}= ………………………………..….. I_{2n} = ……………………….……….………..

3. Choice of load resistance

Efficiency is calculated from measurements at rated voltages and currents. The load resistor **R** must be chosen so that the transformer operates at rated power.
What is the value of the load resistor **R** connected to the secondary winding to obtain the rated current I_{2n}?
R = …………………….

4. Measuring winding resistances: voltammetric method

To verify the simplifying assumptions of the separate loss method, it will be necessary to know the value of the transformer winding resistances. To measure them accurately, the voltammetric method is used.

1. Carry out the following assembly.

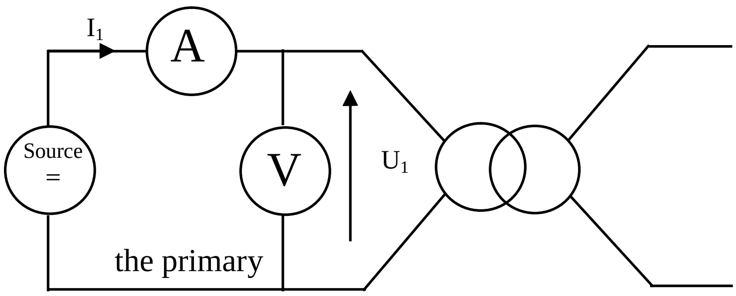

Figure 10

2. Set the power supply to operate at rated current.
3. Read U_1 and I_1. Deduct the resistance of the primary winding r_1.

U_1= ………………… ; I_1= …………………. ; r_1= …………………………

4. Repeat the operation for the transformer secondary.

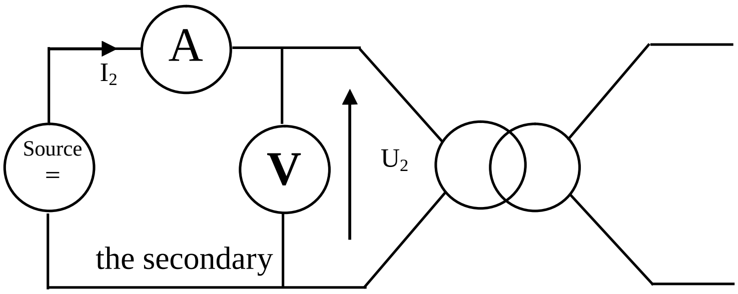

Figure 11

1. Set the power supply to operate at the rated current or, if this is not possible, at the maximum current that the power source can deliver.
2. Read $\mathbf{U_2}$ and $\mathbf{I_2}$. Subtract the resistance of the primary winding r2.

$\mathbf{U_2}$= ………………….. ; $\mathbf{I_2}$= …………………….. ; $\mathbf{r_2}$=……………………….

Note:

The resistance of a copper wire changes with temperature. To obtain the most accurate value, it should be measured when 'hot' by passing the rated current through the wire and when the winding has reached its operating temperature.

5. No-load test:

This test is carried out at nominal voltage. Since the transformer is operating at no load, the current will be low.

1. Set up the diagram below.

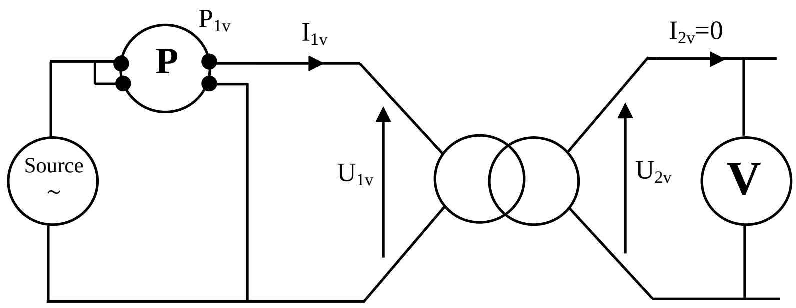

Figure 12

2. Vary the primary voltage from **0 à ….U_{1n}** and plot the curve **U_{2v}=f (I_{1v})**.

U_{1v}(A)	40	80	120	160	220
I_{1v}(A)	.	.	.	.	.
U_{2v}(V)					

Table 1

3. Take measurements of the following quantities:

Greatness	U_{1n}(V)	U_{2v} (V)	I_{1v}(A)	P_{1v}(W(att	Q_{1V} (Var)	Cos (φ_1)
Measurement	.	.	.	.	.	.

Table 2

4. From these measurements, complete the following table:

Formula	the transformation ratio m =	the power factor Cos (φ_1) =	the iron losses P_{Fer} =
Calculation	.	.	.

Table 3

5. Calculate the magnetic resistance **Rm** and the magnetic reactance **Xm**.
6. What can we conclude?

6. Short-circuit test:

For the short-circuit test, it is necessary to work at rated current and therefore at a very low voltage (a few volts).

1. Set up the diagram below.

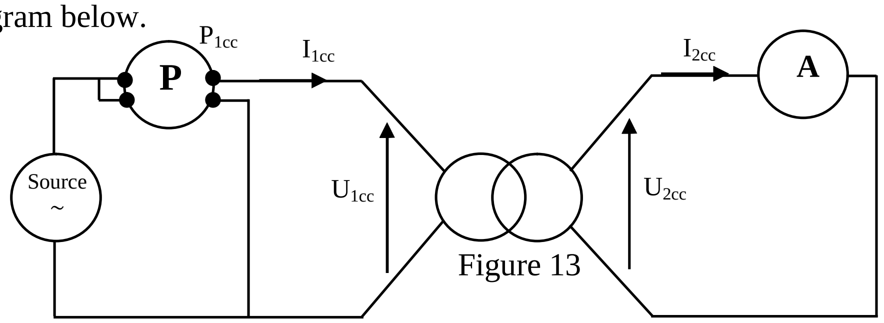

Figure 13

2. Take the necessary measurements to plot the curve: $\mathbf{P_{1CC}= f (I_{2CC}^2)}$.

U_{1cc}(V)	.	.	.	.	.
I_{2cc}(A)	.	.	.	.	.
P_{1cc}(Watt)					

Table 4

3. Calculate the secondary resistance **Rs** (graphically).
4. Measure the following quantities:

Greatness	U_{1cc}(V)	I_{1cc}(V)	I_{2cc}(A)	P_{1cc}(Watt)
Measurement	.	.	.	.

Table 5

5. From these measurements, complete the following table:

Formula	Joule or copper losses Pj=	Resistance reduced to secondary level Rs=	impedance reduced to secondary level Zs=	reactance reduced to secondary level Xs=
Calculation	.	.	.	.

Table 6

6. What can we conclude?

7. Load test:

Make the following assembly : **$U_{1ch}=U_{1n}$**

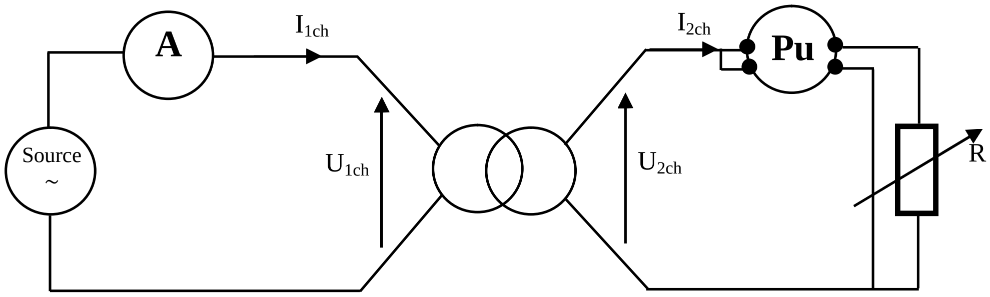

Figure 14

1. For **$0 \leq I_{2ch} \leq I_{2n}$**, record **$I_{1ch}$**, **$U_{2ch}$** ,**$P_{2ch}$** and complete the following table:

I_{1ch} (A)						
I_{2ch} (A)	1	1.5	2	2.5	3	3.2
U_{2ch} (V)						
P_{2ch} (W)						
$Pj_{ch}=Rs.\ I_{2ch}^{2}$						
$P_{1ch}=P_{2ch}+P_{fer}+Pj_{ch}$						
η (%) = (P_{2ch} / P_{1ch})*100						

Table 7

2. Plot and interpret the curve **$\eta=f\ (I_{2ch})$**.
3. Give the value of **I_{2ch}** ch so that **η** is maximum.
4. Draw conclusions.