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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 Electrical Measurement أعمال تطبيقية في القياسات الكهربائية

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PW n° 03: MEASUREMENT OF CAPACITANCES

Duration: $1^{h}30$.

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. Abderrzak Laib

<u>*PW n°03: Capacitance Measurement*</u>

I/ Objective of the Experiment:

Measurement of capacitance using the volt-ampere (V-A) method.

1/ The Volt-Ampere Method:

The volt-ampere method is a fundamental technique for measuring capacitance based on the analysis of the relationship between voltage, current, and capacitive reactance in an AC circuit. This method exploits the fact that in an AC system, a capacitor behaves as a frequency-dependent impedance element, where the current leads the voltage by 90 degrees.

Principle:

For a purely capacitive circuit supplied with an alternating voltage $V(t) = V_m Cos(wt)$ the current i(t) through the capacitor of capacitance C is given by:

$$i(t) = C\frac{dV(t)}{dt} = CwV_m Sin(wt)$$

Since the RMS values of voltage and current are typically measured in practical applications, the capacitive reactance Xc is defined as:

$$X_c = \frac{1}{wC} = \frac{V}{I}$$

where:

- V is the RMS voltage across the capacitor,
- I is the RMS current through the capacitor,

-w=2*pi*f is the angular frequency of the applied AC voltage,

- C is the capacitance to be determined.

Rearranging for capacitance:

$$C = \frac{1}{wX_c} = \frac{I}{wV}$$

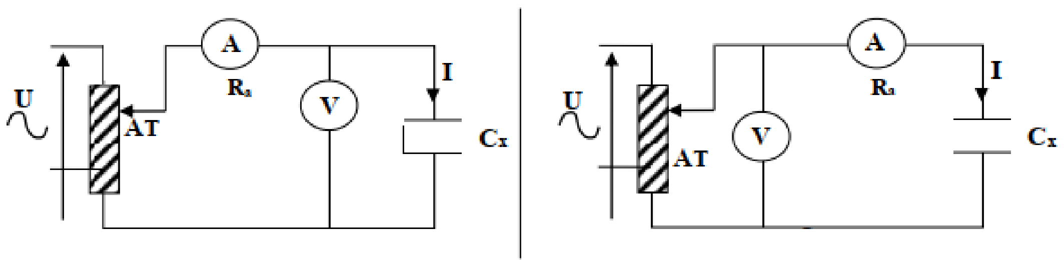

Figure 1: Upstream and Downstream Circuit Configurations

This figure illustrates the electrical setups for measuring capacitance using the volt-ampere method. The upstream configuration (Montage Amont) typically refers to the arrangement where the voltage measurement is taken before the capacitor, while the downstream configuration (Montage Aval) refers to the setup where the voltage is measured after the capacitor. These configurations help analyze the behavior of the capacitor in different circuit placements, ensuring accurate capacitance estimation.

The volt-ampere (V-A) method is used only for measuring capacitance values greater than 0.1 µF

Measurement errors are minimized by using the upstream (Amont) and downstream (Aval) configurations as follows:

- **Upstream**: for capacitance values C<10 µF

- **Downstream** : for capacitance values C ≥10 µF

The impedance Z is expressed as: $Z = R + \frac{1}{JCw}$

Where R is the parasitic resistance introduced by the capacitance C and the connection wires. However, R can be neglected, considering the circuit as purely capacitive, leading to:

$$Z = \frac{1}{JCw} = Xc = \frac{Uc}{I}$$

The exact capacitance values can still be calculated for each configuration by accounting for systematic errors.

In the case of the upstream (Amont) configuration, the voltmeter measures a voltage U given by:

U = Ua + Uc

Thus:

$$C_{mea} = \frac{1}{2\Pi f U} \begin{cases} C_{calc} = \dfrac{1}{2\pi f \sqrt{\frac{U^2}{I^2} + R_a}} & \quad Upstream \\ C_{calc} = \dfrac{\sqrt{I^2 - I_V^2}}{2\Pi f U} & \quad downstream \end{cases}$$

Mathematically demonstrate equations (1) and (2).

III/ Experimentation:

1) Volt-Ampere (V-A) Method:

The downstream (Aval) and upstream (Amont) configurations are implemented as shown in Figure 1.

- **A**: Ammeter, class …

- **V**: Voltmeter, class …

- **AT**: Autotransformer

- Cx: Capacitor box containing the capacitors to be measured

Operating Procedure:

Before starting the experiment, several precautions must be observed:

1. The autotransformer should only be connected with its output set to the minimum value, i.e., zero.

2. The voltmeter and ammeter should be initially set to their maximum range.

3. **Important Note**: During the experiment, the appropriate measurement ranges should be selected. However, any range adjustments must be performed while the circuit is de-energized, meaning the autotransformer must be disconnected.

The autotransformer's cursor should be set to the position corresponding to **70 volts**, as indicated by the voltmeter. This voltage value remains constant throughout all measurements.

Error Calculation:

The total relative error is given by: $\frac{\Delta C_{mes}}{Cmes} \approx \frac{\Delta U_{mes}}{Umes} + \frac{\Delta I_{mes}}{Imes} + \frac{\Delta f_{mes}}{fmes}$

$$\frac{\Delta f_{mes}}{fmes} = 0.5\% \; ; \qquad f=50Hz, \qquad C_{probable} \approx \Delta C_{mes} \mp C_{mes}[F].$$

$\Delta U_{mes} = \frac{Class*Range}{100}$ .Where **Class** and **Range** refer to the specifications of the voltmeter.

$\Delta I_{mes} = \frac{Class*Range}{100}$. Where **Class** and **Range** refer to the specifications of the ammeter.

Measure the current for the three capacitors C1, C2, and C3.

Record the measured and calculated results in the following table:

	C1=4 micro F		C2 =11 micro F	
Adopted Circuit Configuration	**Downstream**	**Upstream**	**Downstream**	**Upstream**
Range for I (R_A)				
Scale for I (S_A)				
Reading for I (Re_A)				
Range for V (R_V)				
Scale for V (S_V)				
Reading for V (Re_V)				
$I_m=(Re_A/S_A)*R_A$				
$U_V=(Re_V/S_V)*R_V$				
Xc				
Ra				
Rv				
C_{mes}[F]				
$\Delta Cmes$ [%]				
C_{calc}[F]				
$\partial C_{mes} = \frac{\Delta Cmes}{C_{mes}}$ [%]				
$C_{probable}$ [F]				

Conclusion