

# Experiment 5: Measure the Equivalent Parameters in the AC Circuit

## 1. Purpose

- Learn the usage of frequently used AC instrument equipment (AC voltmeter, AC ammeter, power meter).
- Know the basic operational methods for AC circuits in the experiment.
- Master the methods to measure the parameters in AC circuits, and understand the concepts of impedance, impedance angle, phase difference, and so on.

## 2. Principal and Illustration

### A. Measure the impedance by using three-meter methods

The impedance in the AC circuit with sine excitation can be represented by  $Z = |Z|\angle\varphi = R + jX$ . By measuring the voltage  $U$ , the current  $I$  and the power  $P$ , using AC voltmeter, AC ampere meter and power meter, respectively, the equivalent parameters of the impedance can be estimated by

$$|Z| = \frac{U}{I}$$

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

$$R = \frac{P}{I^2} = |Z|\cos\varphi$$

$$X = \pm\sqrt{|Z|^2 - R^2} = \pm\sqrt{\left(\frac{U}{I}\right)^2 - \left(\frac{P}{I^2}\right)^2} = \pm|Z|\sin\varphi$$

$$\varphi = \pm\arccos\frac{P}{UI}$$

where “+” applies to inductive situation and “-” applies to capacitive situation.

If an inductor is measured, we have

$$X = \omega L = 2\pi f L \quad \text{or} \quad L = \frac{X}{\omega}$$

If a capacitor is measured, we have

$$X = -\frac{1}{\omega C} = -\frac{1}{2\pi f C} \quad \text{or} \quad C = -\frac{1}{\omega X}$$

**B. The discriminated methods of impedance property**

The measured impedance can be either capacitive or inductive. If the measured values of  $U$ ,  $I$  and  $P$  or the calculated parameters cannot be used to determine the property of the impedance, we then can use the following methods to determine it.

- (1) Capacitor in parallel. Connect a capacitor with suitable capacitance to the measured element in parallel. If the ammeter reading in series increases, the measured element is capacitive. Otherwise, if the ammeter reading decreases, the measured element is inductive.

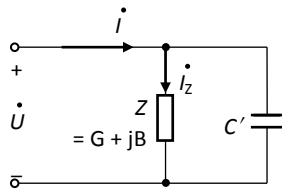
As shown in Figure 3-7-1,  $Z$  is the measured element.  $G$  and  $B$  are the equivalent conductance and equivalent susceptance of  $Z$ .  $C'$  is the test capacitor connected in parallel.  $B'$  is the susceptance of the capacitor  $C'$ .

On the condition that the effective value  $U$  of two-terminal voltage doesn't change, do analysis in the following two situations:

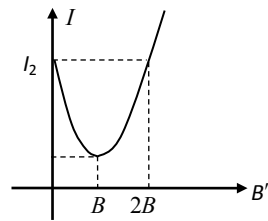
- a) Suppose  $B + B' = B''$ , if  $B'$  and  $B''$  increase, the current also increases, then  $Z$  is a capacitive element.
- b) Suppose  $B + B' = B''$ , if  $B'$  increase and  $B''$  first decreases and then increases, the current  $I$  also first decreases then increases, as shown in figure 3-7-2, then  $Z$  is an inductive element.

From the above analysis, when  $Z$  is a capacitive element, we don't need to have special requirement of the capacitance of  $C'$ . However, when  $Z$  is an inductive element, the circuit can be considered to be inductive only when  $B' < |2B|$ . If  $B' > |2B|$ , the current increases monotonously, which is the same as when the circuit is capacitive, and thus we cannot say it is inductive. Therefore,  $B' < |2B|$  is the reliable condition to determine the property of a circuit, and the condition of judge is

$$C' < |2B / \omega|$$



**Figure 3-7-1** Capacitor in parallel to determine the property of the impedance



**Figure 3-7-2** The relationship between current  $I$  and the susceptance  $B'$ .

- (2) Capacitor in series. Connect a capacitor with suitable capacitance to the measured component in series. If the voltage across the measured impedance decreases, the

circuit is capacitive. Otherwise, if it increases, the circuit is inductive. The condition of judge is

$$\frac{1}{\omega C'} < 2X$$

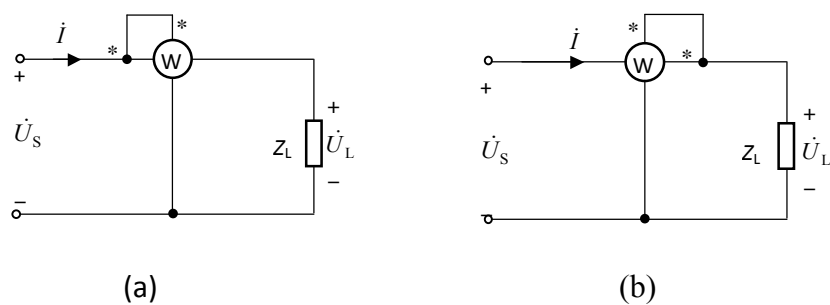
Where  $X$  is the value of reactance of the measured impedance, and  $C$  is the value of capacitance of the capacitor in series, you can prove it by yourself.

- (3) Use an oscilloscope to observe the phase relationship between the voltage and current waveforms of the impedance. If the phase of voltage exceed that of current, the circuit is inductive, otherwise it is capacitive.
- (4) Use power factor meter or digital phase meter to measure power factor  $\cos\varphi$  and the phase angle. If the reading leads, the circuit is inductive, otherwise it is capacitive.

### C. Wiring and usage of power meter

Power meter (wattmeter) is a moving coil instrument, whose current coil is connected to the load in series and the voltage coil is connected to the load in parallel.

The correct wiring of power meter: one terminal of the current/voltage coil is marked by “\*”. When wiring power meter, the terminal of current coil marked by “\*” is the terminal that the current flows into and the other terminal is the one that the current flows out. The terminal of voltage coil marked by “\*” can be connected to the terminal of current coil also marked by “\*” and the other terminal should be connected to the other terminal of the load. So the pointer of power meter will have a positive deflection.

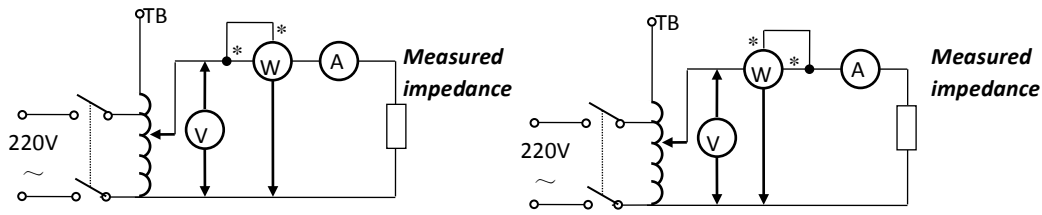


**Figure 3-7-3** Two wiring methods of a power meter

The wiring method of Figure 3-7-3a is called forward wiring method of voltage coil in parallel. The power meter readings include the dissipated power of current coil. It can be used in the situation that the load impedance is much larger than the impedance of the current coil.



**B. Observe and measure the influence of forward and backward wiring methods of power meter voltage coil on the measured equivalent parameters**



(a) Voltage coil forward wiring method      (b) Voltage coil backward wiring method

**Figure 3-7-5** Power meter voltage coil forward and backward wiring methods to measure the equivalent parameters of impedance.

- (1) Connect the elements, as shown in figure 3-7-5a. Use power meter voltage coil forward wiring method to measure the equivalent parameters of 15W incandescent light bulb ( $R$ ), the ballast of 30W fluorescent lamp ( $L$ ) and 4.7 $\mu$ f capacitor ( $C$ ). Record the data into table 3-7-2.
- (2) Connect the elements, as shown in figure 3-7-5b. Use power meter voltage coil backward wiring method to measure the equivalent parameters of 15W incandescent light bulb ( $R$ ), the ballast of 30W fluorescent lamp ( $L$ ) and 4.7 $\mu$ f capacitor ( $C$ ). Record the data into table 3-7-2.

Table 3-7-2 The equivalent parameters of the measured impedance by the two wiring methods of power meter.

Two wiring methods	Measured impedance	Measurement value			Calculation value				
		$U$ (V)	$I$ (A)	$P$ (W)	$ Z $ ( $\Omega$ )	$\cos\phi$	$R$ ( $\Omega$ )	$L$ (mH)	$C$ ( $\mu$ F)
Voltage coil forward wiring	15W incandescent Light bulb $R$								
	Inductance coil $L$								
	Capacitor $C$								
Voltage coil backward wiring	15W incandescent Light bulb $R$								
	Inductance Coil $L$								
	Capacitor $C$								

**4. Questions**

- (1) In the 50Hz AC circuit, suppose we have measured  $P$ ,  $I$ , and  $U$  of an iron-core coil, then, how to calculate its resistance and inductance?
- (2) How to determine the property of impedance by the method of capacitor in series?

Try to analyze the relationship qualitatively between the current  $I$  and the capacitance  $X_C$  of the capacitor in series, and prove that in this experiment,  $C'$  should satisfy

$$\frac{1}{\omega C'} < 2X$$

Where  $X$  is the reactance of the measured reactor.

## **5. Write Your Report**

- (1) Answer the questions above.
- (2) Based on the data you recorded, complete all calculations.
- (3) Based on the data from table 3-7-2, analyze the influence of forward and backward wiring of power meter voltage coil on the measured equivalent parameters of the measured elements.