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**LABORATORY
EXPERIMENT
NO. 3**

**REAL POWER AND REACTIVE
POWER**



OBJECT

1. To interpret the meaning of positive, negative, real and reactive power.
2. To observe the flow of real and reactive power in three-phase circuits.

DISCUSSION

In direct current circuits the real power (in watts) supplied to a load is always equal to the product of the voltage and the current. In alternating current circuits, however, this product is usually greater than the real (or active) power which the load consumes. For this reason, wattmeters are used to measure the real power (in watts).

In three-phase, three-wire AC circuits two wattmeters are needed to measure the real power while three-phase, four-wire circuits require three. These meters may be combined into a single wattmeter of special construction, which greatly simplifies the problem of adding the readings of two or three wattmeters to obtain the total three-phase power. A typical three-phase wattmeter (*Fig. 3-1*) has three input terminals (1, 2, 3) and three output terminals (4, 5, 6).

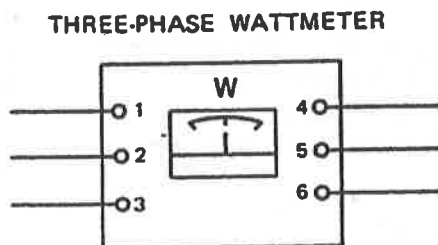


Fig. 3-1

If the wattmeter is connected into a three-phase line, as shown in *Fig. 3-1*, it will show the total real power flowing in the line. If the power flows in the direction of the input terminals to the output terminals (left to right in *Fig. 3-1*) the meter pointer will be deflected to the right and the reading will be positive.

However, if power flow is from right to left, that is, from the output terminals to the input terminals, the meter pointer will be deflected to the left and the reading will be negative.

Real power, therefore, is positive or negative according to its direction of flow. The direction of power flow can easily be found when the "input" terminals have been identified.

Reactive power is the power associated with the charge and discharge of condensers and the increase and decrease of the magnetic fields of inductors when they are part of an alternating current circuit. Because the energy (joules) in a coil merely builds up and decays as the magnetic field increases and decreases in response to the alternating current which it carries, it follows that there is no flow of real power in a coil. On the other hand, a current flows through the coil and a voltage appears across it, so a casual observer is apt to believe that power of some kind is involved. The product of the voltage and current in a coil is called the reactive power, and it is expressed in var or in kilovar (kvar). Reactive power is needed to produce an alternating magnetic field.

In the same way, the alternating electric field in a capacitor also requires reactive power. Owing to the overwhelming prevalence of electromagnetic devices (as opposed to electrostatic devices), we consider that reactive power, whenever it appears, is the kind of power which has the ability to produce a magnetic field.

Reactive power, just like real power, can be measured with appropriate meters called varmeters. In three-phase circuits, the two or three varmeters which would ordinarily be needed can be combined into a single instrument to give one reading of the total reactive power flow in the circuit. Such a meter, shown in *Fig. 3-2*, possesses three input terminals (1, 2, 3) and three output terminals (4, 5, 6).

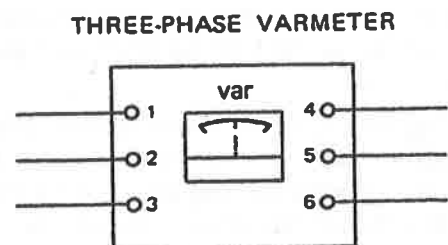


Fig. 3-2

When reactive power flows from the input to the output terminals, the meter will give a positive reading. Conversely, if the flow of reactive power is from the output terminals to the input terminals, a negative reading will result, which can only be rendered visible by means of a suitable reversing switch. For example, if a three-phase source and a three-phase coil are connected as

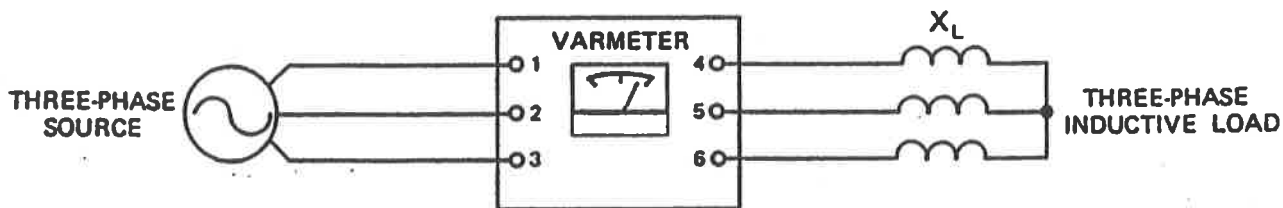


Fig. 3-3

shown in Fig. 3-3, the flow of reactive power is obviously from left to right, and the varmeter will give a positive reading. Just as with a wattmeter, the direction of reactive power flow can readily be found when the input terminals of the varmeter are identified.

Three-phase alternating circuits may involve many types of circuits and devices, but the flow of active and reactive power can always be determined by introducing wattmeters and varmeters. The example of Fig. 3-4 will illustrate how some typical readings can be interpreted. An impedance Z forms part of a larger circuit (not shown), and wattmeters W_1 , W_2 and varmeters var_1 , var_2 are connected on either side. The input terminals are assumed to be on the left-hand side of each instrument. The meters give the following readings:

$$W_1 = +70W \quad var_1 = -60var$$

$$W_2 = -40W \quad var_2 = -80var$$

How are we to interpret these results? First, we must recognize that real power and reactive power flow quite independently of each other. The one does not affect the other. Consequently, we must never add or subtract real power and reactive power.

Consider first the active power. Because W_1 is positive, real power is flowing to the right. Because W_2 is negative, real power is flowing to the left. It follows, therefore, that the impedance Z must be absorbing $70 + 40 = 110$ watts.

Next, let us look at the reactive power; 80 var are flowing to the left, towards the impedance

Z , while 60 var are flowing to the left, away from it. It follows that Z is absorbing $(80 - 60) = 20$ var, and this power creates a magnetic field.

This example shows that when wattmeters and varmeters are connected on either side of an electrical circuit or device, we can determine the real and the reactive power which it produces or absorbs.

INSTRUMENTS AND COMPONENTS

Power Supply Module (120/208V 3 ϕ)	EMS 8821
Resistance Module	EMS 8311
Inductance Module	EMS 8321
Capacitance Module	EMS 8331
AC Metering Module (2.5/2.5/2.5A)	EMS 8425
AC Metering Module (250V)	EMS 8426
Three-Phase Watt-Varmeter Module (300W - 300var)	EMS 8446
Connection Leads	EMS 9128
Wound Rotor Induction Motor Module	EMS 8231
or	
Squirrel Cage Induction Motor Module (optional)	EMS 8221

EXPERIMENTS

Caution: High voltages are present in this Laboratory Experiment! Do not make any connections with the power on!

The following experiments involve a three-phase source, three voltmeters, three ammeters, one three-phase watt-varmeter and a balanced

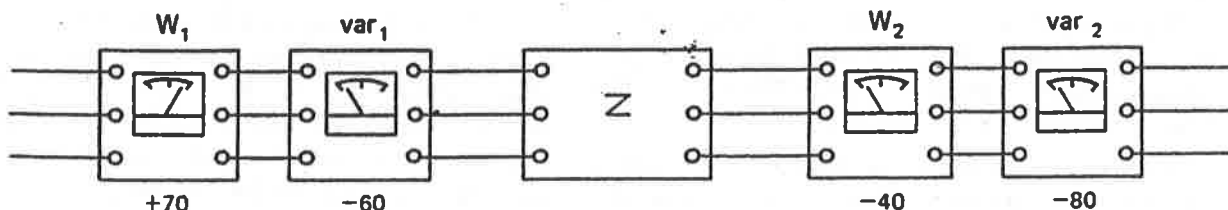


Fig. 3-4

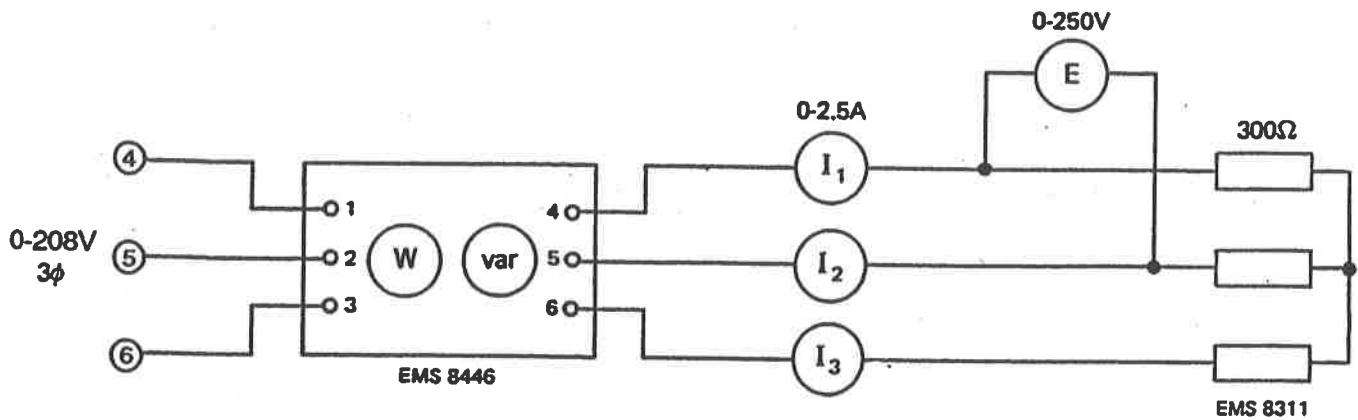


Fig. 3-5

three-phase wye connected load. The source is taken from terminals 4, 5, 6 of the power supply, and adjusted to provide a voltage of about 208 volts.

- 3-1) Using a load of three 300Ω resistances connected in wye as shown in Fig. 3-5, measure E , I , W , var and record your results in Table 3-1.
- 3-2) Replace the resistive load by three inductances having a reactance of 300 ohms , connected in wye. Record your results in Table 3-1.

Note: The leads coming from the source must be connected to terminals 1, 2, 3 of the watt/varmeter in the order of their phase sequence. If the phase sequence of the power supply is 1-2-3, the varmeter will give the correct reading when terminals 1, 2, 3 of the power supply are connected to terminals 1, 2, 3 of the instrument.

In this experiment the varmeter reading should be positive. If it is negative, the phase sequence is incorrect and two leads of the source should be interchanged.

- 3-3) Repeat Experiment 3-2, using three capacitances having a reactance of 300 ohms , connected in wye. Record your results in Table 3-1.
- 3-4) Repeat Experiment 3-3, but add three resistances of 300 ohms (wye connected) in parallel with the capacitive load. Record your results in Table 3-1. Is the real power affected when the capacitive load is switched in and out?
Is the reactive power affected when the resistive load is switched in and out?
- 3-5) Repeat Experiment 3-1, but place the inductive load of Experiment 3-2 in parallel with the resistive load. Record your results in Table 3-1.

Why is the real power slightly affected when the inductive load is switched in and out?

.....
Is the reactive power affected when the resistive load is switched in and out?

- 3-6) Repeat Experiment 3-1, but use an inductive load of 300 ohms in parallel with a capacitive load of 300 ohms , all connected in wye. Record your results in Table 3-1. Do you agree that, to all intents and purposes, the capacitance is supplying most of the reactive power required by the inductance?

Would you agree that the capacitance can be considered to be a source of reactive power?

3-7) is intentionally skipped.

- 3-8) Knowing that the apparent power in volt-amperes (VA) is given by the expression

$$VA = \sqrt{W^2 + var^2}$$

Calculate the apparent power VA in Table 3-1.

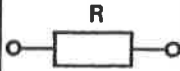

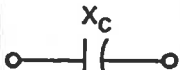
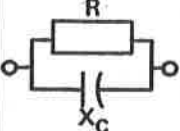
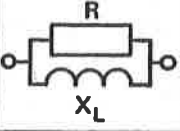
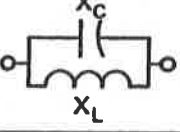
EXPERIMENT NO.	LOAD	E (V)	I (A)	W	var	VA	$E I \sqrt{3}$
3-1							
3-2							
3-3							
3-4							
3-5							
3-6							

Table 3-1

□ 3-9) Knowing that the apparent power of a balanced three-phase circuit is given by the equation $VA = EI\sqrt{3}$, calculate this power, and compare with the value found in Experiment 3-8.

QUESTIONS AND PROBLEMS

1. An electrical load Z is connected to the terminals of a 120 volt AC source. Show the direction of real and reactive power flow if Z is composed of a) a resistance, b) an inductance c) a capacitance, d) a resistance and inductance, e) a resistance and capacitance, f) a single-phase motor. See Fig. 3-6.

2. Calculate the real and reactive power which is delivered by the single-phase source in the two single-phase circuits shown in Fig. 3-7.

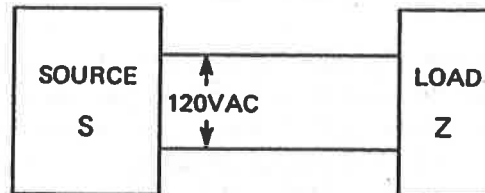
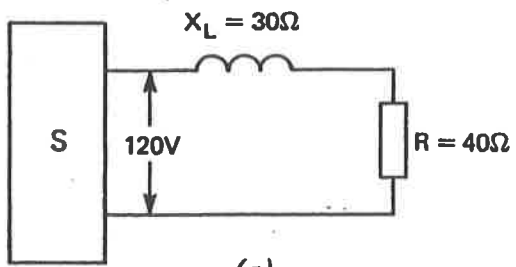
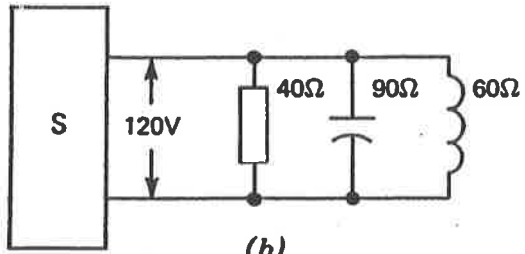


Fig. 3-6



(a)



(b)

Fig. 3-7