ELECTROTECHNICH LAB.

PART 4

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Contents

SERIES CIRCUITS IN AC

17.1 INTRODUCTION

Practically, resistor, inductor and capacitor never found singly on AC circuits because these three components are not easy to produce purely. Especially, system that include an inductor also include a resistor because of the resistance of the conductor wires of the inductor. Because of this, inductors should be taken as **inductor+resistor** in mathematical operations. Resistors are produced nearly in pure form but inductors and capacitors are not.

The resistance of an AC circuit (that is made up through connecting more than one component (**resistor, inductor, capacitor**) serially or parallelly) to the source is called "**impedance**". It is symbolized by "**Z**" and its unit is "**Ohm**" just like the resistance.

In some situations, the opposite of the resistance (**the ease of which electrons may flow**) is used at making mathematical operations in AC circuits. This effect is classified as "**conductance**", "**admittance**" and "**susceptance**". The unit of these three is "**mho**", the opposite reading of the unit of resistance "**Ohm**"

Conductance: is a measure of how easily electricity flows along a certain path through an electrical element if the circuit includes only resistor. Its formula;

$$G = \frac{1}{R}$$

In Formula;

G=Conductance (**mho**)
R=Resistance (**Ohm**)

Admittance: is a measure of how easily electricity flows along a certain path through an electrical element if the circuit includes resistor-inductor or capacitor. Its formula;

$$Y = \frac{1}{Z}$$

In Formula;

Y=Admittance (**mho**)
Z=Impedance (**Ohm**)

Susceptance: is the value obtained through dividing the square of circuit impedance by inductor's or capacitor's resistance to the electric current in AC circuit. Its formula;

$$B = \frac{X}{Z^2}$$

In Formula;

B=Susceptance (**mho**)
X=Reactance (**Ohm**)
Z=Impedance (**Ohm**)

There are three types of circuits that can be formed by connecting resistance, inductor and capacitor serially or parallelly.

1-RL (**Resistor** and **Inductor**) circuits
2-RC (**Resistor** and **Capacitor**) circuits
3-RLC (**Resistor**, **Inductor** and **Capacitor**) circuits

Initially the series and then the parallel connection of these three types will be examined.

As we know, vector and phasor diagram should be learnt better for the solution of AC circuits. One of the variables is taken as reference at start. The reference should be the one that is the same on every component.

In serially connected circuits, the reference is "**current**" because the same current passes through all the components.

In parallelly connected circuits, the reference is "**voltage**" because there is the same voltage on the terminals of all the components.

In the solution, first the reference variable should be positioned, then the position of the other variables should be determined depending on the position of reference variable.

17.2 EXAMINATION OF RL SERIES CIRCUIT IN AC

It is the circuit formed by series connection of resistor and inductor. Practically we can see this circuit as transformer or electric engine. There is only inductor in the structures of these devices. The resistance that we referred in series circuit is the Ohmic resistance of the inductor. In order to explain the topic better, resistor is taken as a second component along with inductor.

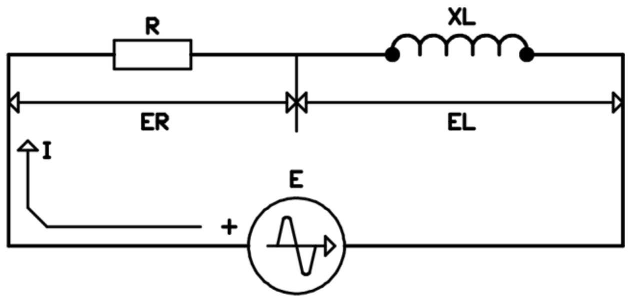

Figure 16.1

In figure 16.1, the same current passes through the resistor and inductor of series circuit. Resistor presents opposition to the current as much as its value and the inductor presents opposition as much as it inductive reactance. Circuit voltage is the Vectorial sum of voltages on resistor and inductor.

The voltage on the resistor is in the same phase with circuit current. The voltage on the inductor is 90^0 ahead from the circuit current. In order to draw the phasor diagram of such a circuit, first the current as reference variable should be taken to the positive field of the horizontal axis. Then the other variables will be positioned depending on the reference.

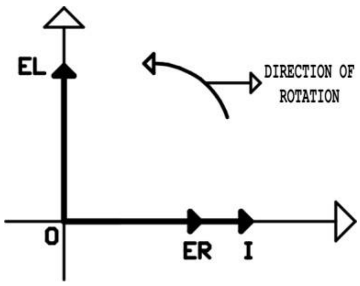

Figure 16.2

After drawing the phasor diagram, circuit voltage is calculated by the help of Pythagorean Theorem.

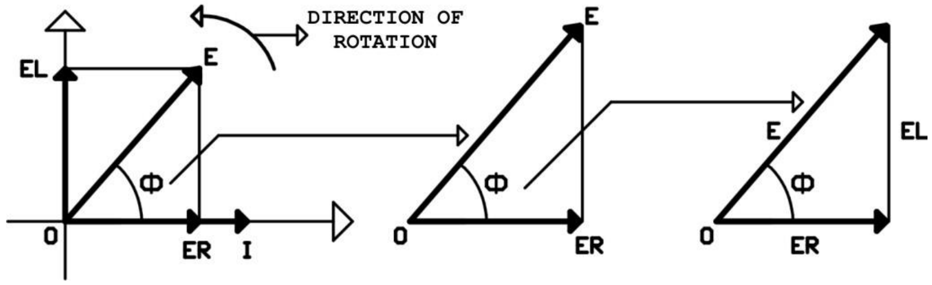

Figure 16.3

$$E^2 = ER^2 + EL^2$$

$$E = \sqrt{ER^2 + EL^2}$$

Circuit phase angle is calculated by using law of cosines.

$$Cos\phi = \frac{ER}{E}$$

After finding the cosine of the angle, the value of the angle can be found in the trigonometric scale.

Note: mathematical operations are explained in Chapter 8.

The demanded values are respectively circuit impedance, circuit phase angle, circuit current, voltages on the components and the power dissipated by the circuit. Mathematical solution is achieved by deriving a new right angle from the phasor diagram.

$$E^2 = ER^2 + EL^2$$

To rewrite the equation in order to make it suitable for resistance and reactance;

$$(I.Z)^2 = (I.R)^2 + (I.XL)^2$$
$$I^2.Z^2 = I^2.R^2 + I^2.XL^2$$

Divide the two sides of the equation by I^2;

$$Z^2 = R^2 + XL^2$$
$$Z = \sqrt{R^2 + XL^2}\ .$$

If the new equation is shown in a right triangle it will be as in the following:

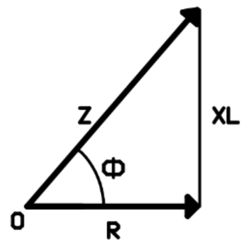

Figure 16.4

The triangle in figure 16.4 is called "**impedance diagram**" or "**impedance triangle**"

Circuit power coefficient;

$$Cos\phi = \frac{R}{Z}$$

Circuit current;

$$I = \frac{E}{Z}$$

Voltages on the Components;

$$ER = I.R \quad , \quad EL = I.XL$$

Active power dissipated by circuit;

$$P = E.I.Cos\phi$$

NOTE: If there is an inductor in serially connected AC circuits, internal resistance of the inductor presents opposition to current just as a real resistance. For this reason, internal resistance of the inductor is added to the real resistance in the experiments of series AC circuits that include inductor.

17.3 EXAMINATION OF RC SERIES CIRCUIT IN AC

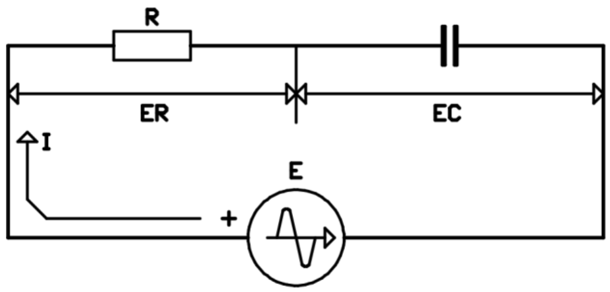

Figure 16.7

In figure 16.7, the AC circuit formed by the series connection of resistor and capacitor is shown. As we know, the same current passes through all the components in serially connected circuits. Resistor presents opposition to the circuit current as much as its value. Capacitor presents opposition as much as its capacitive reactance. Circuit voltage is the Vectorial sum of the voltages on the terminals of capacitor and resistor. The voltage on the resistor is in the same phase with circuit current. The voltage on the capacitor is 90^0 ahead from the circuit current. In order to draw the phasor diagram of such a circuit, first the current as reference variable should be taken to the positive field of the horizontal axis. Then the other variables will be positioned depending on the reference.

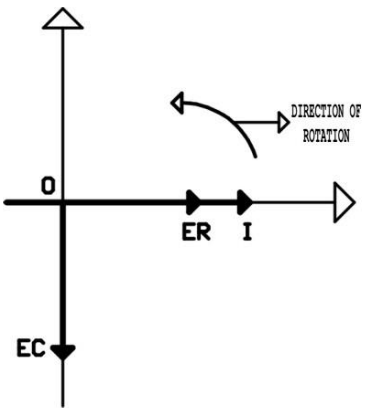

Figure 16.8

After drawing the phasor diagram, circuit voltage is calculated by the help of Pythagorean Theorem.

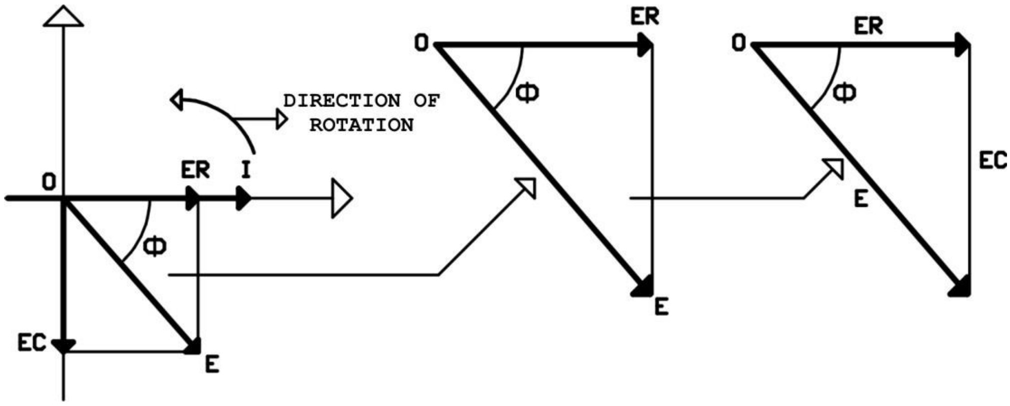

Figure 16.9

$$E^2 = ER^2 + EC^2$$
$$E = \sqrt{ER^2 + EC^2}$$

Circuit phase angle is calculated by using law of cosines.

$$Cos\phi = \frac{ER}{E}$$

After finding the cosine of the angle, the value of the angle can be found in the trigonometric scale.

Practically, the known values in AC circuits are circuit voltage, frequency of working, resistor value and capacitor value. The demanded values are respectively circuit impedance, circuit phase angle, circuit current, voltages on the components and the power dissipated by the circuit. Mathematical solution is achieved by deriving a new right angle from the phasor diagram.

$$E^2 = ER^2 + EC^2$$

To rewrite the equation in order to make it suitable for resistance and reactance;

$$E^2 = ER^2 + EC^2$$
$$(I.Z)^2 = (I.R)^2 + (I.XC)^2$$
$$I^2.Z^2 = I^2.R^2 + I^2.XC^2$$

Divide the two sides of the equation by I^2;

$$Z^2 = R^2 + XC^2$$
$$Z^2 = \sqrt{R^2 + XC^2}\ .$$

If the new equation is shown in a right triangle it will be as in the following impedance triangle:

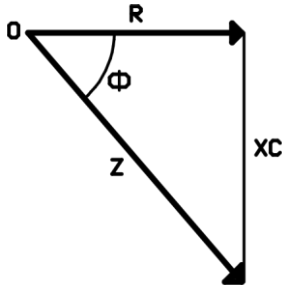

Figure 16.10

Circuit power coefficient;

$$Cos\phi = \frac{R}{Z}$$

Circuit current;

$$I = \frac{E}{Z}.$$

Voltages on the components;

$$ER = I.R \qquad , \qquad EC = I.XC$$

Active power dissipated by circuit;

$$P = E.I.Cos\phi.$$

17.4 EXAMINATION OF RLC SERIES CIRCUIT IN AC

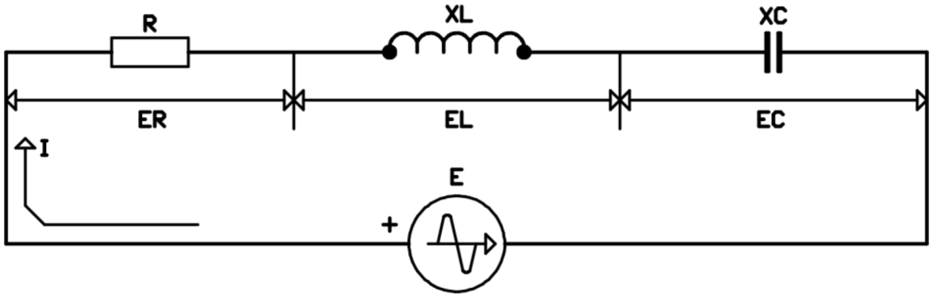

Figure 16.13

In figure 16.7, the AC circuit formed by the series connection of resistor, inductor and capacitor is shown. As we know, the same current passes through all the components in serially connected circuits. Resistor presents opposition to the circuit current as much as its value, Inductor presents opposition to the circuit as much as inductive reactance, Capacitor presents opposition as much as its capacitive reactance. Circuit Voltage is shared vector ally by the circuit components.

The voltage on the resistor is in the same phase with circuit current. The voltage on the capacitor is 90^0 behind the circuit current whereas the voltage on the inductor is 90^0 ahead from the circuit current. So there is a phase difference of 180^0 between Voltage on capacitor (**EC**) and voltage on inductor (**EL**). In order to draw the phasor diagram of such a circuit, first the current as reference variable should be taken to the positive field of the horizontal axis. Then the other variables will be positioned depending on the reference.

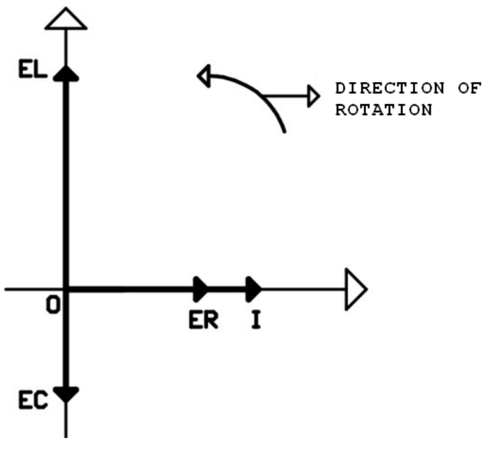

Figure 16.14

It is clearly seen in figure 16.14 that there is a phase difference of 180^0 between (**EL**) and (**EC**). The resultant of two forces with a 180^0 phase difference has a magnitude as much as the difference between these two forces and its direction will be the direction of the greater force. If we explain this process in phasor diagram, the resultant force can be seen in two different situations.

If EC>EL, direction of the resultant force will be in "**EC**" direction and its magnitude will be "**EC-EL**". In that situation the circuit is capacitive.

If EL >EC, direction of the resultant force will be in "**EL**" direction and its magnitude will be "**EL-EC**". In that situation the circuit is inductive.

It is seen in the phasor diagram that "**EL**" is greater than "**EC**", **EL >EC.** Phasor diagram will be as in figure 16.15

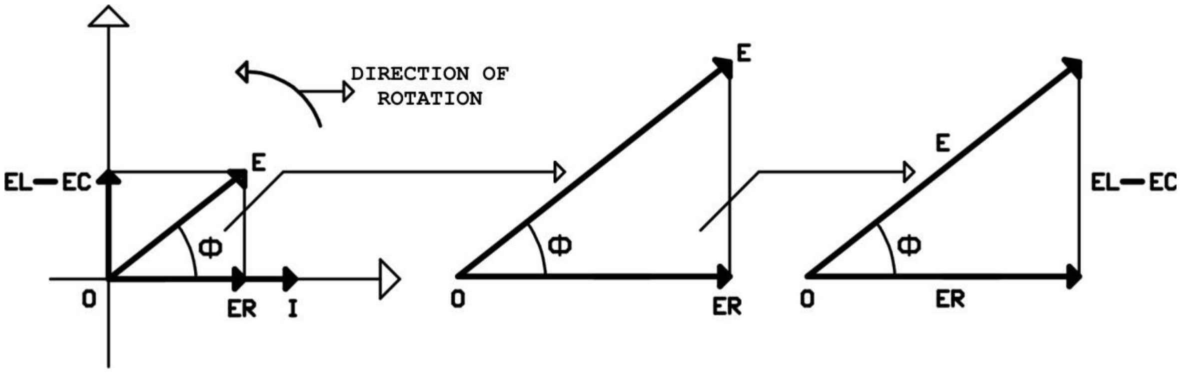

Figure 16.15

After drawing the phasor diagram, circuit voltage is calculated by the help of Pythagorean Theorem.

$$E^2 = ER^2 + (EL - EC)^2$$
$$E = \sqrt{ER^2 + (EL - EC)^2}$$

Circuit phase angle is calculated by using law of cosines.

$$Cos\phi = \frac{ER}{R}$$

After finding the cosine of the angle, the value of the angle can be found in the trigonometric scale.

Practically, the known values in AC circuits are circuit voltage and frequency, resistor value, inductor value and capacitor value. The demanded values are respectively circuit impedance, circuit phase angle, circuit current, voltages on the components and the power dissipated by the circuit. Mathematical solution is achieved by deriving a new right angle from the phasor diagram.

$$E^2 = ER^2 + (EL - EC)^2$$
$$(I.Z)^2 = I^2.R^2 + \left[I(XL - XC)\right]^2$$
$$I^2.Z^2 = I^2.R^2 + I^2.(XL - XC)^2$$

Divide the two sides of the equation by I^2;

$$Z^2 = ER^2 + (XL - XC)^2$$

$$Z = \sqrt{R^2 + (XL - XC)^2}$$

(**XL-XC**) or (**XC-XL**) value is called impedance difference and symbolized by “**XF**”.

Let’s show the equation on impedance triangle:

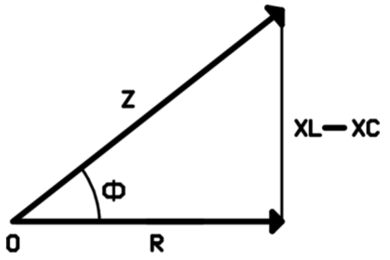

Figure 16.16

Circuit power coefficient;

$$Cos\phi = \frac{R}{Z}$$

Circuit current;

$$I = \frac{E}{Z}$$

Voltages on the components;

$$ER = I.R \quad , \quad EL = I.XL \quad , \quad EC = I.XC$$

Active power dissipated by circuit;

$$P = E.I.Cos\phi$$