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# Introduction to electric installations and technology

Juan Pérez Cruz | Manuel Pineda Sánchez
Rubén Puche Panadero | Ángel Sapena Bañó

EDITORIAL
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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# Prologue

This work was created with the idea to assist and review of certain matters of Electrical Engineering and Electricity. It is intended as a help to students who have to take courses on electrical technology, and as an introduction to the basic applications of single-phase and three-phase circuits.

It is especially aimed to two types of readers: students who access the Electrical Technology course, taught in the Master's Degree in Industrial Engineering, coming from Bachelor Degrees where they have seen very few concepts of electricity. And secondly for those technicians who are new to the field of electrical installations.

This text consists of five units. The first one is about the review of the association of passive elements; this unit is very basic, yet essential to understand how you should solve the problems with the various electrical circuits presented in the course. The second unit is about the introduction of single-phase circuits that serve as the basis for understanding the later three-phase circuits, which are introduced in unit three. The fourth and fifth units are about the approach to the different forms of electrical energy distribution, in both single-phase (unit 4) and three-phase networks (unit 5). All approaches are based on alternating current distributions. There is also an annex where some exercises in previous units are solved.

In order to be as clarifying as possible, we have developed a large number of examples. They always refer to the closest environment, many figures have been used, and the most important concepts have been repeated many times.

A bibliography has been included with two types of texts; the most basic type (*) complementary to this text and others that are an extension and application (**) of what is studied in this text.

Finally, we want to thank the colleagues of the Teaching Unit to which we belong and especially Mr José Roger for the support and help given in the preparation of this text.

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# Unit 1
# Association of Passive Elements

## 1.1. Association of passive elements. Resistances

There are two ways to connect the resistances:

a) Series connection:

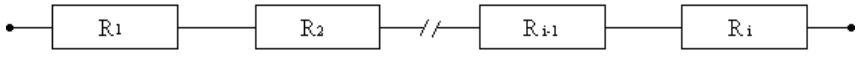


**Figure 1.1**

The resulting value of the resistance assembly is the sum of them all.

$$R_T = R_1 + R_2 + \cdots + R_i$$

Example 1.1.- In the circuit in Figure 1.2 , composed of 3 resistances, whose values are $R_1 = 10\ \Omega$, $R_2 = 15\ \Omega$ and $R_3 = 27\ \Omega$. Calculate the equivalent resistance:

$$R_T = R_1 + R_2 + R_3 = 10 + 15 + 27 = 52\ \Omega$$

$$\boxed{R_T = 52\ \Omega}$$

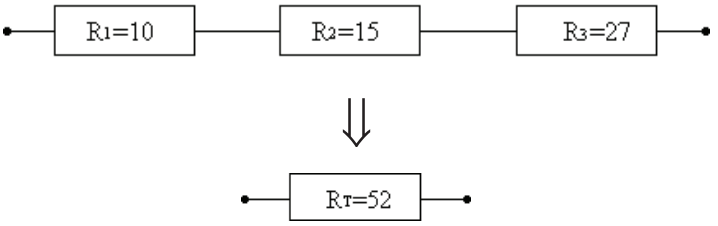


**Figure 1.2**

b) Parallel connection:

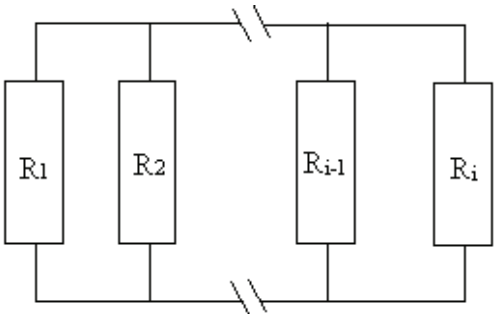


**Figure 1.3**

The resulting value of the resistance assembly is:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_i}$$

Example 1.2.- In the circuit in Figure 1.4, where there are three parallel resistances whose values are R1 = 10 Ω, R2 = 15 Ω and R3 = 27 Ω. Calculate the equivalent resistance:

$$\frac{1}{R_T} = \frac{1}{10} + \frac{1}{15} + \frac{1}{27} = \frac{15 \cdot 27}{10 \cdot 15 \cdot 27} + \frac{10 \cdot 27}{10 \cdot 15 \cdot 27} + \frac{10 \cdot 15}{10 \cdot 15 \cdot 27} = \frac{405 + 270 + 150}{4050}$$

$$\boxed{R_T = 4{,}91\ \Omega}$$

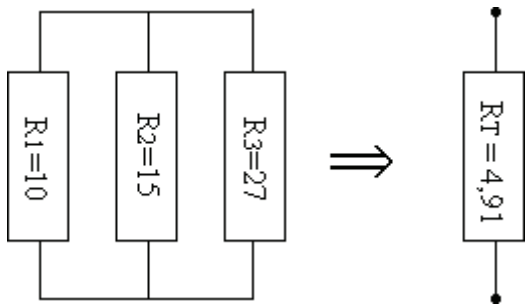


**Figure 1.4**

a. In the particular case of 2 resistances in parallel we get the following equation:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 \times R_2} \Rightarrow R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

Example 1.3.- In the circuit in Figure 1.5, where there are two parallel resistances whose values are $R_1 = 15\ \Omega$ and $R_2 = 27\ \Omega$. Calculate the equivalent resistance:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 \times R_2} \Rightarrow R_T = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{15 \times 27}{15 + 27} = 9{,}64\,\Omega$$

$$\boxed{R_T = 9{,}64\ \Omega}$$

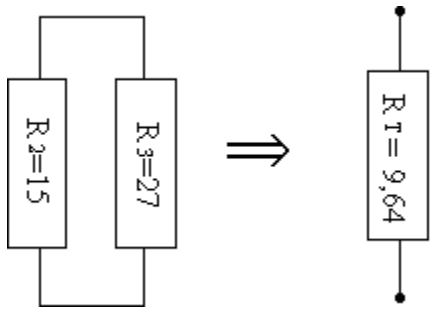


**Figure 1.5**

b. If the two parallel resistances are equal, we get:

$$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}=\frac{R_1+R_2}{R_1\times R_2}\Rightarrow R_T=\frac{R_1\times R_2}{R_1+R_2}=\frac{R^2}{2\times R}=\frac{R}{2}$$

Example 1.4.- In the circuit in Figure 1.6, where the two resistances are equal and whose value is 27 Ω, calculate the equivalent resistance:

$$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}=\frac{R_1+R_2}{R_1\times R_2}\Rightarrow R_T=\frac{R_1\times R_2}{R_1+R_2}=\frac{R^2}{2\times R}=\frac{R}{2}=\frac{27}{2}=13,5\Omega$$

$R_T = 13,5\ \Omega$

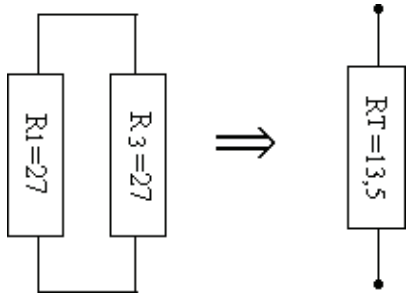


**Figure 1.6**

Note: For the case of association of series connection of resistances, the resulting resistance value is always higher than the highest of them all, while in the case of parallel connection of resistances the value of the resulting resistance is always lower than the lowest value of the group. If there are 2 equal resistances in parallel connection the result value is half of the associated resistance. If there are three equal resistances in parallel connection the resultant value of the resistance is R/3, etc.

c) Series parallel connection of resistances:

It is solved similarly to the previous cases. Initially gathering the resistances in parallel, we obtain a unique value for each group of resistances in parallel, as it has been done in section (b). This way we get a circuit with only resistances in series, which is now solved as it has been done in section (a).

Example 1.5.- In the circuit in Figure 1.7, there are two groups of parallel resistances: one with 2 resistances with values R=20 Ω and R=25 Ω, another parallel circuit with resistances with values R=10 Ω and R=17 Ω, and another resistance in series with value R= 40 Ω. Calculate the equivalent resistance.

$$R_{P1} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{20 \times 25}{20 + 25} = 11{,}11\,\Omega \qquad R_{P2} = \frac{R_3 \times R_4}{R_3 + R_4} = \frac{10 \times 17}{10 + 17} = 6{,}30\,\Omega$$

$$R_T = R_{p1} + R_{p2} + R_5 = 11{,}11\ \Omega + 6{,}30\ \Omega + 40\ \Omega = 57{,}41\ \Omega$$

$$\boxed{R_T = 57{,}41\ \Omega}$$

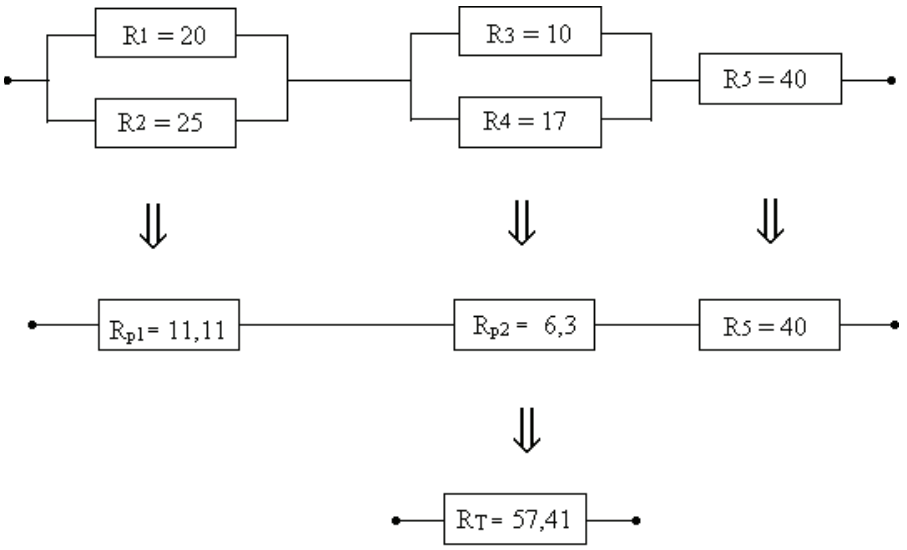


**Figure 1.7**

## 1.2. Association of passive elements. Inductors

In circuits where only inductors appear, the association between them is performed similarly to the case of the resistances. The value of the inductance (L) of an inductor is expressed in henries, although due to the small size of the usual values they usually come expressed in milli-henries (mH):

a) Association of inductors in series. The inductance value of the resulting inductor is the sum of the values of the circuit series inductances.

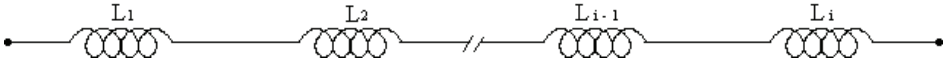


**Figure 1.8**

$$L_T = L_1 + L_2 + \cdots + L_i$$

Example 1.6.- In the circuit in Figure 1.9, where $L_1 = 10$ mH, $L_2 = 15$ mH, and $L_3 = 27$ mH, calculate the equivalent inductor.

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