EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

1. Basic laws in electrical engineering, voltage sources

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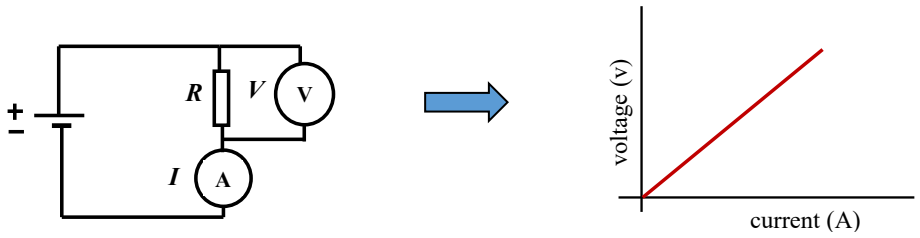
Doc. Ing. Stanislav Kocman, Ph.D.
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1.1 Ohm´s and Kirchhoff´s laws and their applications

1.1.1 Ohm´s law

This law discovered by Georg Simon Ohm defines a relationship between the voltage and the current flowing through a metallic conductor with electrical resistance. The current is directly proportional to the voltage, which is connected to the conductor. The electrical resistance at constant temperature is the constant of proportionality between the voltage and the current (G. Rizzoni: Fundamentals of electrical engineering). The equations are defined as:

$$V = R \cdot I \ \ (\mathrm{V};\Omega,\mathrm{A}) \qquad I = \frac{V}{R} \ \ (\mathrm{A};\mathrm{V},\Omega) \qquad R = \frac{V}{I} \ \ (\Omega;\mathrm{V},\mathrm{A})$$



The resistance of materials commonly used in electrical engineering, e.g. copper for electrical wires, is dependent on the temperature (G. Rizzoni: Fundamentals of electrical engineering) according the formula:

$$R_\vartheta = R_{\vartheta 0} \cdot \left[1 + \alpha \cdot (\vartheta - \vartheta_0)\right] (\Omega;\Omega,\mathrm{K}^{-1},\mathrm{K})$$

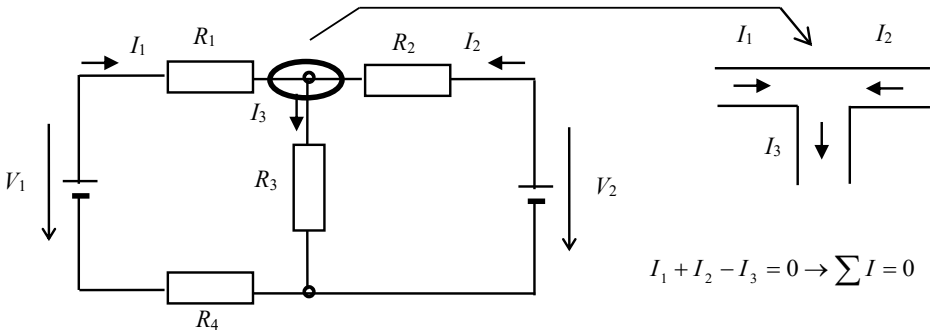
In the case of a long wire of the length l and the constant cross-sectional area S with resistivity ρ (e.g. winding of electrical machines) the resistance is formulated as (G. Rizzoni: Fundamentals of electrical engineering):

$$R = \rho \cdot \frac{l}{S} \ \ (\Omega;\Omega \cdot \mathrm{m},\mathrm{m},\mathrm{m}^2)$$

1.1.2 Kirchhoff´s laws (discovered by Gustav Robert Kirchhoff)

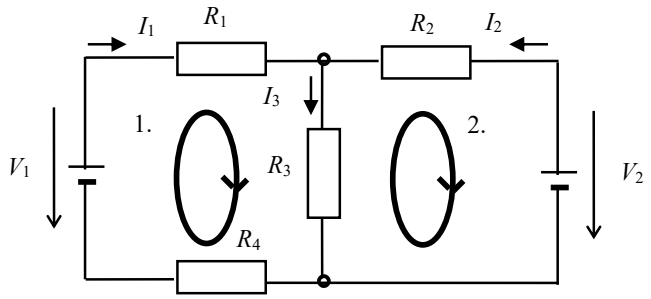
Kirchhoff´s current law

This law provides that the algebraic sum of the currents flowing into a node is equal to the sum of the currents flowing from the node, or the sum of the currents at the node is equal to zero, respectively (G. Rizzoni: Fundamentals of electrical engineering).



Kirchhoff´s voltage law

This law provides that the algebraic sum of the voltages of sources is equal to the sum of the appliance voltages around a closed circuit, or the sum of the voltages around the closed circuit is equal to zero, respectively (G. Rizzoni: Fundamentals of electrical engineering).



Left circuit 1:

Right circuit 2:

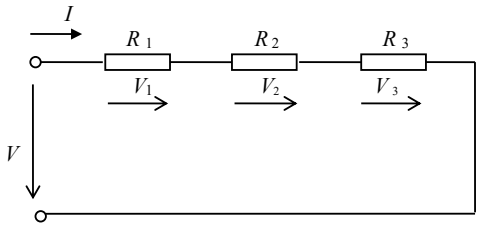
$$1.: -V_1 + R_1 \cdot I_1 + R_3 \cdot I_3 + R_4 \cdot I_1 = 0$$

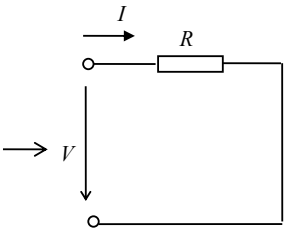
$$2.: V_2 - R_3 \cdot I_3 - R_2 \cdot I_2 = 0$$

$$\sum V = 0$$

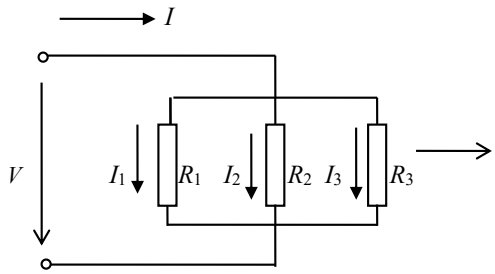
1.1.3 Application

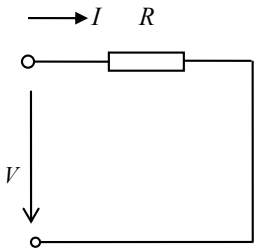
The usage of these basic laws is e.g. for solutions in electrical circuits.





$$V = V_1 + V_2 + V_3 =$$
$$= R_1 I + R_2 I + R_3 I$$
$$= I \cdot (R_1 + R_2 + R_3)$$
$$\rightarrow \sum_{x=1}^{n} R_x = R$$





$$I = I_1 + I_2 + I_3 =$$
$$= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} =$$
$$= V \cdot \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)$$
$$\rightarrow \sum_{x=1}^{n} \frac{1}{R_x} = \frac{1}{R}$$

1.2 Elementary electrical circuit, characteristics of its components

The basic elements of an electrical circuit are a source of the electric energy (commonly a voltage source), appliance (load) and a conductive connection the source to the appliances (electrical wires, power line). These components make the elementary electrical circuit. The real electrical circuits contain more elements, such as electrical devices for switching and protecting power line and loads, sensors, regulators, convertors, etc. (A. L. Sheldrake: Handbook of electrical engineering).

The voltage source provides the potential difference across its terminals i.e. electrical voltage, and supplies electrical power into the electrical circuit (electrical load). The power line transmits the electrical energy generated by the source with low losses as possible and in a declared quality. It should grant such requirements as good electrical conductivity, mechanical ruggedness or economic aspect. The appliance consumes the electrical power and converts it to another form of power (e.g. heat, light, mechanical…).

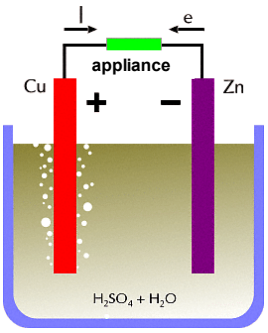
1.3 Classification of voltage sources, principle of operation, application

1.3.1 Classification of voltage sources (https://en.wikipedia.org/wiki/Battery (electricity))

- galvanic cells (non-rechargeable, conversion of chemical energy into electrical one)
- accumulators (rechargeable, conversion of chemical energy into electrical one)
- generators (conversion of mechanical energy into electrical one)
- photovoltaic cells (conversion of solar energy into electrical one)

1.3.2 Principle of operation, application

Volta´s galvanic cell (so-called wet cell) regarded as the first stable source of electrical energy consists primarily from two electrodes (copper and zinc plates) soaked into liquid electrolyte. As the electrolyte the dilute sulphuric acid can be used. In consequence of chemical reactions between the electrodes and electrolyte electrical potential occurs on the electrodes. Their difference is the electromotive force, which is equal to open circuit voltage. This principle is common for other types of galvanic cells and accumulators, which differ by using various kinds of materials for electrodes and electrolyte (https://en.wikipedia.org/wiki/Battery_(electricity)). The electrical generator is rotating machine generating electrical energy from mechanical energy using the principle of electromagnetic induction. DC generator (so-called dynamo) can be used for generating DC voltage, widely used in the past, but replaced by more suitable sources with semiconductor rectifiers during the last decades.



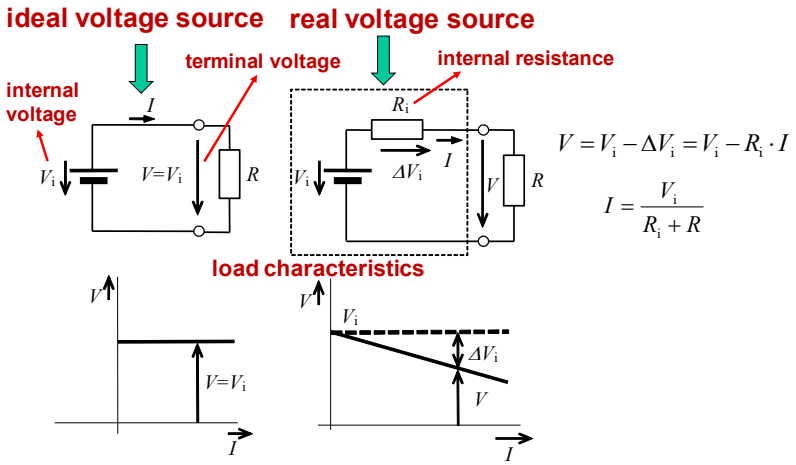
Photovoltaic cell is based on the photovoltaic effect mainly applied in the semiconductor technology when silicon layers are doped by boron and phosphorus and when other additional elements are used (https://en.wikipedia.org/wiki/Solar_cell).

The application of sources: power supply of electrical power lines (generators, solar panels), power supply of mobile installations: cars, boats, planes, cameras etc., consumer electronics, computer techniques, home appliances etc. (also with galvanic cells and accumulators).

1.4 Characteristics and conditions of voltage sources

1.4.1 Characteristics of voltage sources

The important parameter of the voltage source is its internal resistance, which represents the resistance of the used constructive elements of the source and depending on the type of the electrodes and electrolyte materials. The internal resistance of an ideal source is zero, at the practical one always exists even if at the high quality ones is very low. According to its value the sources can be divided into two main categories: “hard” and “weak” (G. Rizzoni: Fundamentals of electrical engineering).



1.4.2 Conditions of voltage source

- load up to the source rating (nominal) operating point
- no-load condition: source terminals disconnected, the source does not supply electrical power into the electrical circuit, internal voltage is equal to the terminal voltage
- short-circuit condition: terminals short-circuited, voltage across the terminals is zero. This condition is very dangerous, very large short-circuit current flows from the source, it can be 3-20 times the rating one causing damage or destruction of power line and devices or loads, a protection is necessary.