21世纪

高等学校精品规划教材

电气工程专业英语

主编 陆地

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内 容 提 要

本书是21世纪高等学校精品规划教材，是为电气工程专业方向而编写的专业英语教学用书，内容主要涉及电机与电器、电力系统及其自动化、高电压与绝缘技术、电力电子与电力传动、电工理论与新技术。全书共分八章，包括电路理论基础，电子电路，电机，电力系统，电力系统设备与保护，控制系统与电力电子，绝缘、防雷与接地，其他。每章节附有词汇和注释，以配合教学的需要。

本书是高等学校电气工程及其自动化专业本科生专业英语的基本教材，亦可作为其他电类专业的教材，还可作为有关工程技术人员的阅读参考书。

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前言

本书是21世纪高等学校精品规划教材，是为电气工程及其自动化专业方向而编写的专业英语教学用书。专业英语是在大学基础英语学习完成以后开设的，目的是使学生进一步巩固和提高英语水平，培养学生阅读相关专业资料的能力，使学生了解学科前沿。书中内容比较新颖，文体规范，难度适中。内容主要涉及电机与电器、电力系统及其自动化、高电压与绝缘技术、电力电子与电力传动、电工理论与新技术，力求反映电气工程及其自动化专业的主要方向。全书共分八章，包括电路理论基础，电子电路，电机，电力系统，电力系统设备与保护，控制系统与电力电子，绝缘、防雷与接地，其他。每章节附有词汇和注释，以配合教学的需要。

参加本书编写的单位和人员有：西安建筑科技大学陆地、于瑛、许岩，西安交通大学刘姝玮，长安大学陆路，清华大学许路，西安电子科技大学姚若玉，陕西教育学院黄希敏等。其中前言、第一章、第三～第五章、第八章第一～第六节由陆地编写；第二章由刘姝玮编写；第六章第一～第五节由于瑛编写；第六章第六～第九节由许岩编写；第七章第一～第三节由陆路编写；第七章第四～第六节由许路编写；第八章第七～第八节由姚若玉编写；第八章第九～第十节由黄希敏编写。本书由陆地担任主编，负责全书的统稿、定稿工作；由于瑛、刘姝玮担任副主编，负责全书的校对工作。

本书由长安大学段晨东、西安建筑科技大学杨延龙主审并提出了宝贵的意见和建议，谨在此表示衷心的感谢！

本书在编写过程中，得到了西安建筑科技大学本科生李玉、何自敏、王涛、邵雪瑾、刘欢欢、孙金萍、张涛、梁江、王蕊、尚文强、杨乐；硕士研究生朱磊、刘晨、李翔、王建信、魏培等的大力支持和帮助，在此表示谢意。

在本书的编写、出版过程中，得到了中国水利水电出版社的大力支持和热心帮助，在此表示衷心感谢。

限于本人业务水平，书中错漏和不妥之处在所难免，敬请广大读者批评指正，本人不胜感激！

编　者

2010年6月20日

Contents

Chapter 1 Circuit Theory Fundamentals

Section 1 Current and Voltage

Two variables $u(t)$ and $i(t)$ are the most basic concepts in an electric circuit, and they characterize the various relationships in an electric circuit.

1. Charge and Current

The concept of electric charge is the underlying principle for explaining all electrical phenomena. Also, the most basic quantity in an electric circuit is the electric charge. Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C) .

We know from elementary physics that all matter is made of fundamental building blocks known as atoms and that each atom consists of electrons, protons, and neutrons. We also know that the charge e on an electron is negative and equal in magnitude to 1.60210×10^{-19} C, while a proton carries a positive charge of the same magnitude as the electron. The presence of equal numbers of protons and electrons leaves an atom neutrally charged.

We consider the flow of electric charges. A unique feature of electric charge or electricity is the fact that it is mobile, that is, it can be transferred from one place to another, where it can be converted to another form of energy.

When a conducting wire is connected to a battery (a source of electromotive force), the charges are compelled to move. Positive charges move in one direction while negative charges move in the opposite direction. This motion of charges creates electric current. It is conventional to take the current flow as the movement of positive charges, that is, opposite to the flow of negative charges, as Fig. 1 - 1 illustrates. This convention was introduced by Benjamin Franklin (1706 - 1790), the American scientist and inventor. Although we now know that current in metallic conductors is due to negatively charged electrons, we will follow the universally accepted convention that current is the net flow of positive charges. Thus, electric current is the time rate of charge, measured in amperes (A) . Mathematically, the relationship among

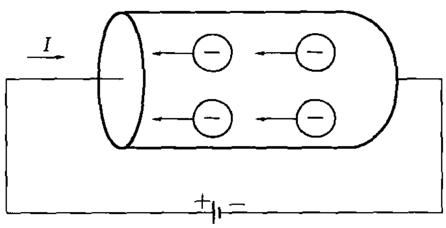

Fig. 1 - 1 Electric current due to flow of electronic charge in a conductor

current i, charge q, and time t is

$$i=\frac{dq}{dt} \tag{1-1}$$

The charge transferred between time t_0 and t is obtained by integrating both sides of Eq. (1-1). We obtain

$$q=\int_{t_0}^{t} i dt \tag{1-2}$$

The way we define current as i in Eq. (1-1) suggests that current need not be a constant-valued function. Charge can vary with time in several ways that may be represented by different kinds of mathematical functions.

2. Voltage, Energy and Power

To move the electron in a conductor in a particular direction requires some work or energy transfer. This work is performed by an external electromotive force (emf), typically represented by the battery in Fig. 1-1. This emf is also known as voltage or potential difference. The voltage u_{ab} between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b. Mathematically

$$u_{ab}=\frac{dw}{dq} \tag{1-3}$$

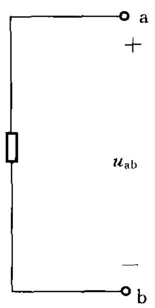

Fig. 1-2 Polarity of voltage u_{ab}

Where w is energy in joules (J) and q is charge in coulombs (C). The voltage u_{ab} is measured in volts (V), named in honor of the Italian physicist Alessandro Antonio Volta (1745-1827), who invented the first voltaic battery. Thus, voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

Fig. 1-2 shows the voltage across an element (represented by a rectangular block) connected to points a and b. The plus (+) and minus (−) signs are used to define reference direction or voltage polarity. The u_{ab} can be interpreted in two ways: ①point a is at a potential of u_{ab} volts higher than point b, ②the potential at point a with respect to point b is u_{ab}. It follows logically that in general

$$u_{ab}=-u_{ba} \tag{1-4}$$

Although current and voltage are the two basic variables in an electric circuit, they are not sufficient by themselves. For practical purpose, we need to know power and energy. To relate power and energy to voltage and current, we recall from physics that power is the time rate of expending or absorbing energy, measured in watts (W). We write this relationship as

$$p=\frac{dw}{dt} \tag{1-5}$$

Where p is power in watts (W), w is energy in joules (J), and t is time in seconds (s).

From Eq. (1-1), Eq. (1-3) and Eq. (1-5), it follows that

$$p=ui \tag{1-6}$$

Because u and i are general functions of time, the power p in Eq. (1-6) is a time-varying quantity and is called the instantaneous power. The power absorbed or supplied by an element is the product of the voltage across the element and the current through it. If the power has a plus sign, power is being delivered to or absorbed by the element. If, on the other hand, the power has a minus sign, power is being supplied by the element. But how do we know when the power has a negative or a positive sign?

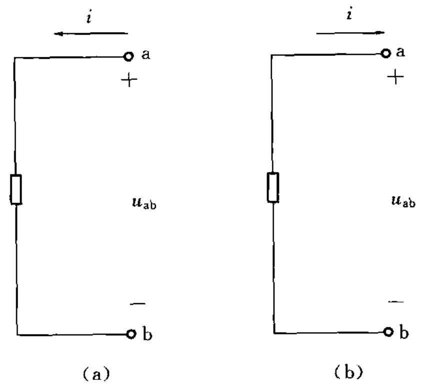

Fig. 1-3 Reference polarities for power using the passive sign convention
(a) absorbing power ($p=ui$); (b) supplying power ($p=-ui$)

Current direction and voltage polarity play a major role in determining the sign of power. It is therefore important that we pay attention to the relationship between current i and voltage u in Fig. 1-3 (a). The voltage polarity and current i direction must conform with those shown in Fig. 1-3 (a) in order for the power to have a positive sign. This is known as the passive sign convention. By the passive sign convention, current enters through the positive polarity of the voltage. In this case, $p=ui$ or $ui>0$ implies that the element is absorbing power. However, if $p=-ui$ or $ui<0$, as in Fig. 1-3 (b), the element is releasing or supplying power.

In fact, the law of conservation of energy must be obeyed in any electric circuit. For this reason, the algebraic sum of power in a circuit, at any instant of time, must be zero

$$\sum p=0 \tag{1-7}$$

This again confirms the fact that the total power supplied to the circuit must balance the total power absorbed. From Eq. (1-7), the energy absorbed or supplied by an element from time t_0 to time t is

$$w=\int_{t_0}^{t} p\mathrm{d}t \tag{1-8}$$

New Words and Expressions

current	*n.* 电流
voltage	*n.* 电压
variable	*n.* 变量
charge	*n.* 电荷；*v.* 充电，带电
coulomb	*n.* 库仑（电荷的单位）

circuit	*n.* 电路
underlying	*adj.* 基本的，根本的；潜在的；在下（面）的，下层的
electron	*n.* 电子
magnitude	*n.* 大小，尺寸，数量，数值
electromotive	*adj.* 电动的
ampere	*n.* 安，安培（电流的单位）
integrate	*v.* 积分，求积分
work	*n.* 功
rectangular	*adj.* 矩形的，直角的，正交的
joule	*n.* 焦耳（能量、热量、功的单位）
volt	*n.* 伏特（电压、电位、电势的单位）
convention	*n.* 习惯，惯例，常规
polarity	*n.* 极性
power	*n.* 功率、效率；动力，电力，能力，电源；乘方，幂
watt	*n.* 瓦特（功率的单位）
time-varying	*adj.* 时变的
passive	*adj.* 无源的，消极的，被动的；*n.* 无源
algebraic	*adj.* 代数的
instant	*n.* 瞬间，瞬时，即刻，时，时刻
positive charge	正电荷
negative charge	负电荷
electromotive force	电动势
potential difference	电位差
voltaic battery	伏达电池
reference direction	参考方向
instantaneous power	瞬时功率

Notes

[1] Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs.
电荷是构成物质的原子的电气属性，其单位为库仑。

[2] The presence of equal numbers of protons and electrons leaves an atom neutrally charged.
质子和电子数量相同时的原子呈现电中性。

[3] The voltage u_{ab} between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b.
电路中 a、b 两点间电压 u_{ab} 等于从 a 到 b 移动单位电荷所需的能量（或所需做的功）。

Section 2 Circuit Elements

An electric circuit is simply an interconnection of the elements. There are two types of elements found in electric circuits: passive elements and active elements. An active element is capable of generating energy while a passive element is not. Examples of passive elements are resistors, capacitors and inductors. The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them.

1. Independent Sources

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.

An independent voltage source is a two-terminal element, such as a battery or generator, which maintains a specified voltage between its terminals. The voltage is completely independent of the current through the element. The symbol for a voltage source having u volts across its terminals is shown in Fig. 1 - 4 (a). The polarity is as shown, indicating that terminal a is u volts above terminal b. Thus if $u>0$, terminal a is at a higher potential than terminal b. The opposite is true, of course, if $u<0$.

In Fig. 1 - 4 (a), the voltage u may be time-varying, or it may be constant, in which case we would probably label it U. Another symbol that is often used for a constant voltage source, such as a battery with U volts across its terminals, is shown in Fig. 1 - 4 (b). In the case of constant sources we shall use Fig. 1 - 4 (a) and Fig. 1 - 4 (b) interchangeably.

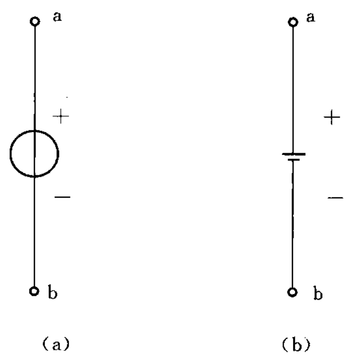

Fig. 1 - 4 Symbols for independent voltage sources
(a) used for constant or time-varying voltage;
(b) used for constant voltage (DC)

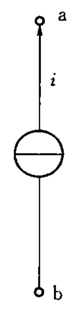

Fig. 1 - 5 Symbols for independent current sources

We might observe at this point that the polarity marks on Fig. 1 - 4 (b) are redundant since the polarity could be defined by the positions of the longer and shorter lines.

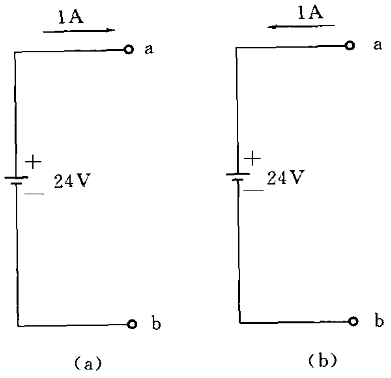

Fig. 1 - 6 Symbols for independent sources
(a) a source delivering power;
(b) a source absorbing power

An independent current source is a two-terminal element through which a specified current flows. The current is completely independent of the voltage across the element. The symbol for an independent current source is shown in Fig. 1 - 5, where i is the specified current. The direction of the current is indicated by the arrow.

Independent sources are usually meant to deliver power to the external circuit and not to absorb it. Thus if u is the voltage across the source and its current i is directed out of the positive terminal, then the source is delivering power, given by $p=ui$, to the external circuit. Otherwise it is absorbing power. For example, in Fig. 1 - 6 (a) the battery is delivering 24W to the external circuit. In Fig. 1 - 6 (b) the battery is absorbing 24W, as in the case when it is being charged.

2. Dependent Sources

An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.

Dependent sources are usually designated by diamond-shaped symbols, as shown in Fig. 1 - 7. Since the control of the dependent source is achieved by a voltage or current of some other element in the circuit, and the source can be voltage or current, it follows that there are four possible types of dependent sources, namely:

(1) A voltage-controlled voltage source (VCVS).

(2) A current-controlled voltage source (CCVS).

(3) A voltage-controlled current source (VCCS).

(4) A current-controlled current source (CCCS).

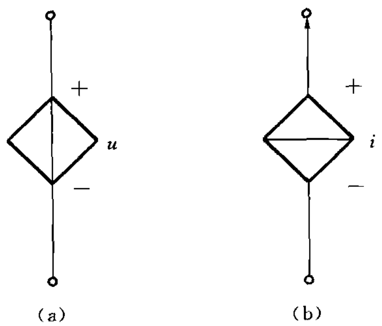

Fig. 1 - 7 Symbols for dependent sources
(a) dependent voltage source;
(b) dependent current source

Dependent sources are useful in modeling elements such as transistors, operational amplifiers and integrated circuits.

It should be noted that an ideal voltage source (dependent or independent) will produce any current required to ensure that the terminal voltage is as stated, whereas an ideal current source will produce the necessary voltage to ensure the stated current flow. Thus an ideal source could in theory supply an infinite amount of energy. It should also be noted that not only do sources supply power to a circuit, but also they can absorb power from a circuit. For a voltage source, we know the voltage but not the current supplied or drawn by it. By the same token, we know the current supplied by a current source but not the voltage across it.

New Words and Expressions

active	*adj*. 有源的，有功的，有效的；活动的，主动的，积极的；活性的，放射的，激励的
resistor	*n*. 电阻，电阻器件
capacitor	*n*. 电容器
inductor	*n*. 电感器
source	*n*. 电源，(光、信号、辐射) 源
generator	*n*. 发电机；(脉冲、信号、气体) 发生器，震荡器，加速器
diamond-shaped	*adj*. 菱形的
transistor	*n*. 晶体管，半导体管
operational	*adj*. 运算的，计算的；操作的，工作的，业务的，运转的
amplifier	*n*. 放大器
token	*n*. 标记，象征，记号；特征，证明
active element	有源元件
ideal independent source	理想独立源
constant voltage source	恒定电压源
independent source	独立源
dependent source	非独立源
controlled source	受控源
voltage-controlled voltage source	电压控制电压源
current-controlled voltage source	电流控制电压源
voltage-controlled current source	电压控制电流源
current-controlled current source	电流控制电流源
integrated circuit	集成电路
by the same token	同理，同样；另外，还有

Notes

[1] In Fig. 1 - 6 (b) the battery is absorbing 24W, as in the case when it is being charged.

图 1 - 6 (b) 中，电池就像充电情况，吸收功率 24W。

[2] It should be noted that an ideal voltage source (dependent or independent) will produce any current required to ensure that the terminal voltage is as stated, whereas

an ideal current source will produce the necessary voltage to ensure the stated current flow.

应该注意：一个理想电压源（独立或受控）可向电路提供任意电流以保证其端电压为规定值，而电流源可向电路提供任意电压以保证其规定电流。

Section 3 Ohm's Law

The circuit element used to model the circuit-resisting behavior of a material is the resistor. The resistor is the simplest passive element.

Georg Simon Ohm (1787 – 1854), a German physicist, is credited with formulating the current-voltage relationship for a resistor based on experiments performed in 1826. This relationship is known as Ohm's Law.

Ohm's Law states that the voltage across a resistor is directly proportional to the current flowing through the resistor. The constant of proportionality is the resistance value of the resistor in ohms. The circuit symbol for the resistor is shown in Fig. 1 – 8. For the current and voltage shown, Ohm's law is

$$u(t)=Ri(t) \tag{1-9}$$

Where $R \geqslant 0$ is the resisance in ohms.

Rearranging Eq. (1 – 9) into the form $R=u(t)/i(t)$, we see that

$$1 \text{ ohm}=1\text{V/A}$$

The symbol used to represent the ohm is the capital Greek omega (Ω).

Since R is constant, Eq. (1 – 9) is the equation of a straight line. For this reason, the resistor is called a linear resistor. A graph of $u(t)$ versus $i(t)$ is shown in Fig. 1 – 9, which is a line passing through the origin with a slope of R. Obviously, a straight line is the only graph possible, in which the ratio of $u(t)$ to $i(t)$ is constant for all $i(t)$.

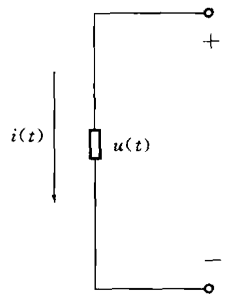

Fig. 1 – 8 Circuit symbol for the resistor

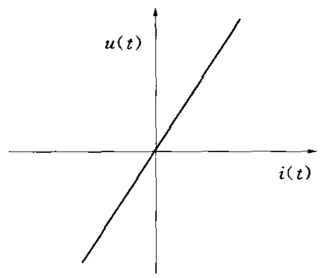

Fig. 1 – 9 Voltage-current characteristic for a linear resistor

Resistors with resistances do not remaining constant for different terminal currents are known as nonlinear resistors. For such a resistor, the resistance is a function of the current flowing in the device. A simple example of a nonlinear resistor is an incandescent lamp. A typical voltage-current characteristic for this device is shown in Fig. 1 - 10, where we see that the graph is no longer a straight line. Since R is not a constant, the analysis of a circuit containing nonlinear resistor is more difficult.

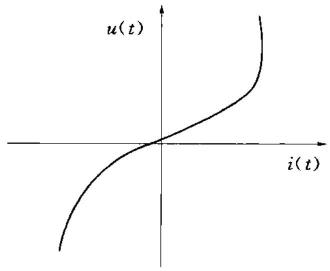

Fig. 1 - 10 Typical voltage-current characteristic for a nonlinear resistor

In reality, all practical resistors are nonlinear because the electrical characteristics of all conductors are affected by environmental factors such as temperature. Many materials, however, closely approximate an ideal linear resistor over a desired operating region. We shall concentrate on these types of elements and simply refer to them as resistors.

Since the value of R can range from zero to infinity, it is important that we consider the two extreme possible values of R. An element with $R=0$ is called a short circuit, as shown in Fig. 1 - 11 (a). For a short circuit

$$u=iR=0 \tag{1-10}$$

showing that the voltage is zero but the current could be anything. In practice, a short circuit is usually a connecting wire assumed to be a perfect conductor. Thus, a short circuit is a circuit element with resistance approaching zero.

Similarly, an element with $R=\infty$ is known as an open circuit, as shown in Fig. 1 - 11 (b). For an open circuit

$$i=\lim_{R\to\infty}\frac{u}{R}=0 \tag{1-11}$$

indicating that the current is zero though the voltage could be anything. Thus, an open circuit is a circuit element with resistance approaching infinity.

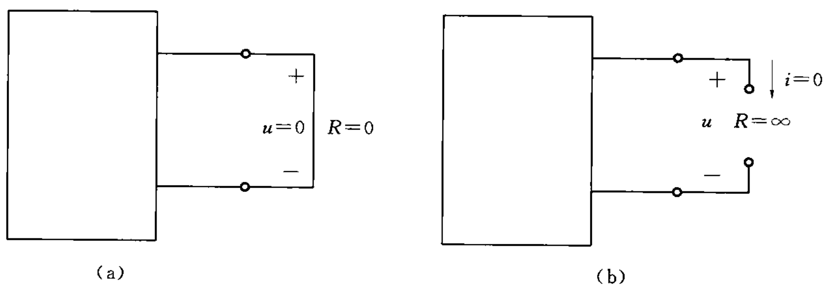

Fig. 1 - 11 short circuit and open circuit

(a) short circuit ($R=0$); (b) open circuit ($R=\infty$)

Another important quantity which is useful in circuit analysis is known as conductance, defined by