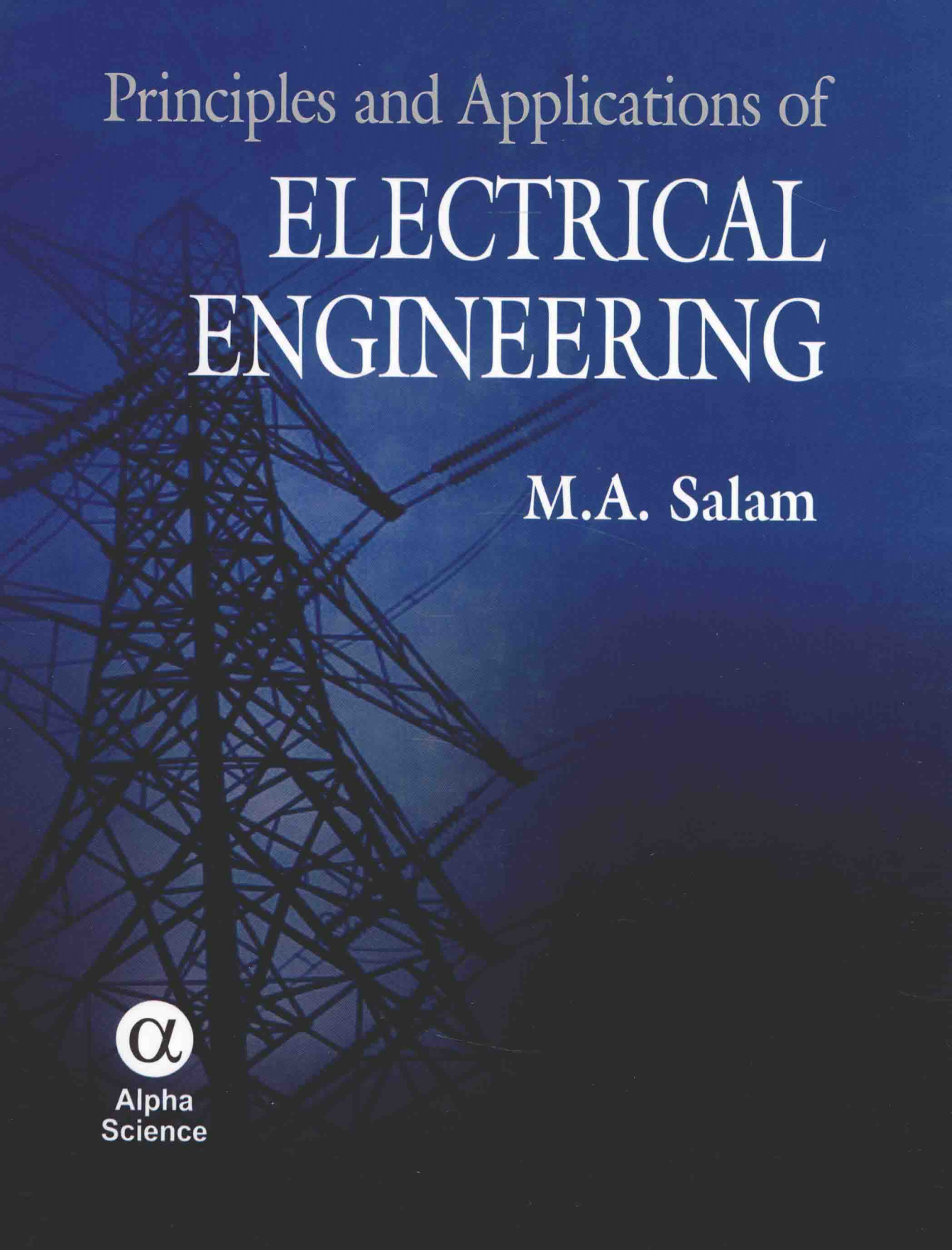
Principles and Applications of ELECTRICAL ENGINEERING

M.A. Salam



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Preface

Preface to the First Edition

Engineering is the art of applying scientific and mathematical knowledge to practical fields such as designing systems, structures, machines, devices and processes. Generally, electrical engineering covers generation, transmission and distribution of electrical power. Nowadays, the field of electrical engineering is widespread and includes new specialized areas such as digital systems, satellite communications, signal processing, robotics, bionics, mechatronics, signal processing, computer, control, artificial intelligence and networks. Most universities have decided to have one combined electrical course for Mechanical, Chemical, Petroleum, Civil and Architecture engineering departments. In addition, the Accreditation Board for Engineering and Technology (ABET) encourages to put one course related to electrical engineering in the non-electrical engineering curriculum that can identify broader engineering education, contemporary, ethical and social issues.

Principles and Applications of Electrical Engineering is one of the core courses for undergraduate students of Mechanical, Mechatronics, Chemical, Petroleum, Civil and Architecture engineering. This book is suitable for readers who prefer a self-study approach to master the fundamentals of electrical engineering. Based on the years of experience in teaching undergraduate and graduate courses, the author has tried to develop the contents of this book in a systematic way and easy-to-understand. This book offers opportunities to develop a sound knowledge in the following areas:

- Basic definitions and simple dc circuits
- Basics of ac circuits
- Three-phase circuits
- Diode circuits
- Bipolar junction transistors
- TRIAC, DIAC and SCR
- Operational Amplifier
- Digital logic circuits
- Basics of magnetic circuits
- Transformers
- DC machines
- AC machines
- Power generation, transmission and tariff

Features

Several textbooks already exist in this area, but this book is written to provide an alternative with the following key features.

- Easy and clear presentation of each article
- Interpretation of basic electrical parameters in terms of mathematical equations
- Emphasis on modern engineering techniques for circuit reduction
- Step-by-step problem solving procedures
- Use PSpice software in circuit simulation
- Inclusion of rectifier circuits, bipolar transistors and digital electronics
- Detailed description of the construction of each machine
- Inclusion of different circuits to explain the working principles of the machines
- Detailed description of the testing of each machine
- Inclusion of worked examples and practice problems
- A large number of exercise problems at the end of each chapter
- Inclusion of answers to practice and exercise problems

Aids for Instructors

Instructors who adopt this book as a text may obtain the solution manual as a supplement copy by contacting the publishers.

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Chapter 1

Basics of Electricity and PSpice

1.1 Introduction

Electrical, electronic, communication, control and computer engineering are the important branches of the applied science. These branches of engineering are solely dependent on the electrical circuit theory and its analysis. Therefore, the Principles and Applications of Electrical Engineering is one of the most fundamental courses for those branches of engineering students. In addition, this book is suitable for the students of Mechanical, Civil, Petroleum, and Chemical Engineering. In practical life, we are getting the music by stereo systems, news and entertainments by TV set or radio, and lights using electric bulbs. These equipment are normally designed by applying the proper knowledge of electrical and electronic engineering branches. Moreover, receiving and sending messages (text, picture etc) through internet are the efforts of communication and computer engineering branches. The basic parameters of circuit analysis like electric charge, current, voltage, resistance, conductance, power and energy will be discussed in this chapter. In addition, basics of PSpice will be discussed.

1.2 Electrical Circuit

An electrical circuit is a closed path, which is formed by the circuit variables and the sources. The circuit variables are resistor, inductor and capacitor. A simple electrical circuit is shown in the Fig. 1.1. An electrical circuit may be series, parallel or a combination of series-parallel.

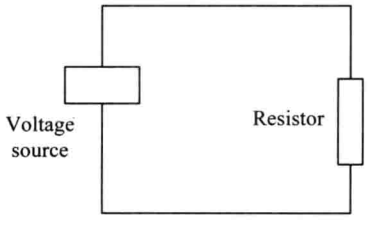

Fig. 1.1 Simple electrical circuit.

1.3 Charge and Current

The nature of the electric current is dependent on the modern electron theory. This theory is explained clearly using the concepts of atoms. Everything around us is made up of atoms. The central part of the atom is called nucleus. The nucleus consists of the protons and the neutrons. Around the nucleus, there are number of electrons normally moving in different orbits that are shown in the Fig. 1.2. The

particles of the nucleus can be distinguished from each other by their masses and charges, which are shown in the Table 1.1. The proton has a positive charge and the neutron has no charge. An atom is electrically neutral.

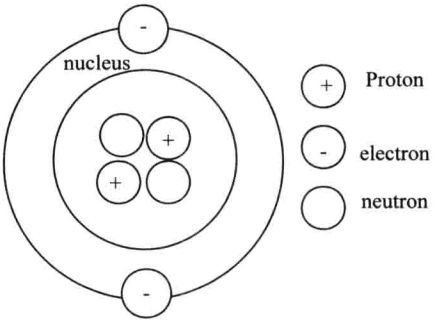

Fig. 1.2 Helium atomic structure.

In some chemical reactions, it can lose or gain a number of electrons. Such gain or loss of electrons produces an electrically charged atom. Therefore, the charge is the electrical property of the matter, which is responsible for flowing electric current through the conductor. The charge is represented by the letter Q or q and coulomb (C) is used as the unit of charge in honour of Charles Augustin de Coulomb (1703-1806). The coulomb is the larger unit of the charge. Whereas the micro-coulomb (μC), nano-coulomb (nC), pico-coulomb (pC) are the smallest units of the charge. The charge of the proton and neutron are $+1.602\times10^{-19}$ C and -1.602×10^{-19} C respectively. The flow of free electrons through a conductor is called the current. The directions of the free electrons and current are shown in the Fig. 1.3.

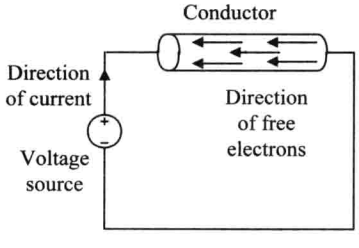

Fig. 1.3 Directions of free electrons and current.

In an alternative way, current is defined as the rate of change of charge. The current is represented by the letter I or i and the unit of the current is ampere (A). Mathematically, the current can be expressed as,

$$i = \frac{dq}{dt} = \frac{dQ}{dt} \tag{1.1}$$

In general, the expression of current is,

$$I = \frac{Q}{t} \tag{1.2}$$

Where,

I is the current in A,

Q is the charge in C,

t is the time in second (s).

If the charge is known then the current can be determined from the equation (1.2). Alternatively, if the current is known then the charge from the equation (1.1) can be determined as,

$$q = \int_{-\infty}^{t} i(t)\,dt = \int_{0}^{t} i(t)\,dt + q(0) \tag{1.3}$$

Where $q(0)$ is the initial charge.

Table 1.1 Mass and charge of atom particles.

Name of particle	Mass (kg)	Charge (C)
Electron	9.11×10^{-31}	-1.602×10^{-19}
Proton	1.67×10^{-27}	$+1.602 \times 10^{-19}$
Neutron	1.67×10^{-27}	0

Example 1.1

A charge of $q = 4t^2 + 3t$ C enters through an element. Determine the (i) current in time domain, and (ii) value of the current if $t = 2\,\text{s}$.

Solution

(i) The current in time domain is,

$$i = \frac{d}{dt}(4t^2 + 3t) = 8t + 3 \text{ A}$$

(ii) At $t = 2\,\text{s}$, the value of the current is,

$$i = 8 \times 2 + 3 = 19 \text{ A}$$

Example 1.2

The expression of current is $i = 8t - 3$ A. Determine the charge from the interval 0 s to 2 s. Consider initial charge is 2C

Solution

The value of the charge can be determined as,

$$q = \int_{0}^{2} (8t - 3)dt + 2 = \frac{8}{2}\left[t^2\right]_{0}^{2} - 3\left[t\right]_{0}^{2} + 2$$

$$q = \frac{8}{2} \times 4 - 3 \times 2 + 2 = 8\,\text{C}$$

Practice problem 1.1

A charge of $q = 8t$ C enters through an element. Determine the current.

Practice problem 1.2

The expression of a current through an element is $i = 20t - 5$ A. Find the value of the charge from the time interval 0 s to 1 s. Consider initial charge is $2.2\,\text{C}$.

1.4 Direct Current

The magnitude of the current does not change with time is known as direct current. It is normally represented by the capital letter I. A direct current with a magnitude of 4 A is shown in the Fig. 1.4.

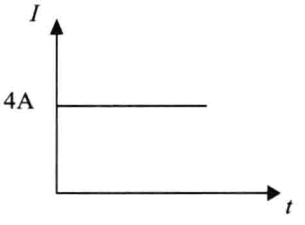

Fig. 1.4 Representation of direct current.

Example 1.3

A charge of 5 C enters through an element by 1.5 s. Determine the value of the current.

Solution

The value of the current is,

$$I = \frac{Q}{t} = \frac{5}{1.5} = 3.33\,\text{A}$$

Practice problem 1.3

A current of 3 A passes through an element by 2 s. Determine the value of the charge.

1.5 Alternating Current

Alternating current is the most common current that is found everywhere. In the household, it is used to run washing machines, fridges, electric irons and many other electrical appliances. In addition, in the industry, it is used to run different types of ac machines. Alternating current is a time varying current i. e. the magnitude of the current changes with time. Alternating current is normally generated in the power station with a suitable arrangement of a three-phase alternating current generator and a mechanical turbine. The alternating current is denoted by the small letter i. A waveform of an alternating current is shown in the Fig. 1.5.