10TH EDITION

ELECTRICITY 3

POWER GENERATION AND DELIVERY

JEFF KELJIK

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DELMAR CENGAGE Learning

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PREFACE

The tenth edition of *ELECTRICITY 3* has been updated to provide more topics and concepts to better reflect the current workplace. At the same time, the text has retained the features and style of previous editions that have made it so popular.

The text introduces the concepts of power generation and distribution. The material is broken down into short segments that concentrate on specific concepts or applications of particular types of equipment. The detailed explanations are written in easy-to-understand language and concisely present the needed information. Many illustrations and photographs help provide technical understanding and real-world references. This type of explanation and application better prepares the student to perform effectively on the job in installing, troubleshooting, repairing, and servicing electrical power generation and delivery.

The knowledge obtained in this book permits the student to progress further in the study of electrical systems. The study of electricity and the application of electrical products are continually changing. The electrical industry constantly introduces new and improved devices and material that lead to changes in installation and operation of equipment. Electrical codes also change to reflect industry needs. It is essential that students continue to learn and update their knowledge of current procedures and practices.

The text is easy to read and the units have been grouped by general subject areas. Summaries in each unit restate the most important topics of the unit. Summaries of unit groupings provide reviews of topical areas.

Each unit begins with the learning objectives. An Achievement Review at the end of each unit provides an opportunity for readers to check their understanding of the material in small increments before proceeding. The problems in the text sometimes require the use of simple algebra. Students should be familiar with the math before trying to solve the equations. It is also essential that readers have a basic understanding of the fundamentals of electrical circuits and basic electrical concepts.

It is recommended that the most recent edition of the *National Electrical Code*® (published by the National Fire Protection Association [NFPA]) be available for reference and use as the learner uses this text. Application of state and local codes and regulations should also be consulted when making actual installations.

Features of the tenth edition include the addition of a unit on alternative power sources which include wind-powered generation, hydrogen fuel cells, microturbine generation,

and solar photovoltaic power production. These alternative forms of power supplies are described and then linked to the *National Electrical Code®*, where applicable, to enhance the understanding of where and how these sources are used. An alternate form for a UPS system is described, to be used for short duration operation in place of battery backup systems.

Other features include

- Organization of topics into related topics and associated concepts
- Updated photos and artwork to reflect current equipment and practices
- Content updated to the most recent electrical code
- Additional information on generation systems
- Coverage of transformers and connections
- Summaries and Achievement Reviews at the end of each unit

An Instructor Guide for *ELECTRICITY 3* is available. The guide includes the answers to the Achievement Reviews and Summary Reviews and additional test questions. Instructors may use these questions to devise tests to evaluate student learning.

INSTRUCTOR SITE

An Instructor Companion Website containing supplementary material is available. This site contains an Instructor Guide, testbank, image gallery of text figures, and chapter presentations done in PowerPoint. Contact Delmar Cengage Learning or your local sales representative to obtain an instructor account.

Accessing an Instructor Companion Website Site from SSO Front Door

1. Go to http://login.cengage.com to log in using the Instructor e-mail address and password.
2. ENTER author, title or ISBN in **the Add a title to your bookshelf** search box, and CLICK on the **Search** button.
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ABOUT THE AUTHOR

Jeff Keljik has been teaching at Dunwoody College of Technology in Minneapolis for more than 30 years, where he was the head of electrical programs for more than 16 years. He is a licensed master and journeyman electrician and has a bachelor's degree in business communication. He currently teaches classes for corporate clients locally and nationally. He also manages the electrical construction and maintenance projects for the college campus buildings at Dunwoody College of Technology. He has worked as an electrician and as a consultant on international training projects in the electrical industry.

In addition to his teaching and administrative positions, Mr. Keljik serves the North Central Electrical League on the Education Committee and as Chairman of the Board of Directors. He also serves as an advisor on the Education committee member for the Minnesota Electrical Association (MEA). He has written several texts on motor and motor control systems and on power generation and distribution, including *Electricity 4* and *Electric Motors and Motor Controls.*

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Phillip Serina
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Brooklyn, Ohio

DEDICATION

I would like to dedicate this tenth edition to my children. Their love of learning encourages me to continue to write texts that help others learn. —*Jeff Keljik*

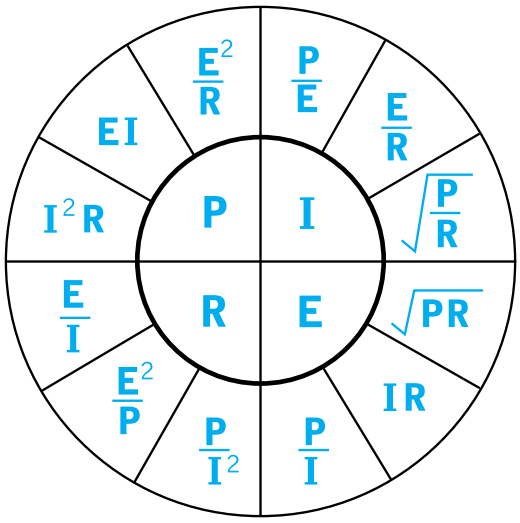
ELECTRICAL TRADES

The Delmar series of instructional material for the basic electrical trades consists of the texts, text-workbooks, laboratory manuals, and related information workbooks listed below. Each text features basic theory with practical applications and student involvement in hands-on activities.

Electricity 1
Electricity 2
Electricity 3
Electricity 4
Electric Motor Control
Electric Motor Control Laboratory Manual
Industrial Motor Current
Alternating Current Fundamentals
Direct Current Fundamentals
Electrical Wiring—Residential
Electrical Wiring—Commercial
Electrical Wiring—Industrial
Practical Problems In Mathematics For Electricians

Equations based on Ohm's law.

P = Power in watts
I = Intensity of current in amperes
R = Resistance in ohms
E = Electromotive force in volts



INTRODUCTION

ELECTRICAL SAFETY

Working on electrical systems can be dangerous. If you are working on live exposed conductive paths and the voltage is over 50 volts to ground, the potential for electrocution exists. The potential for arc burns or explosions also exists when working on live electrical systems. The United States Occupational Safety and Health Administration (OSHA) has specific guidelines to follow when working on live equipment. The OSHA documents that primarily affect practicing electrical workers are found in the OSHA Code of Federal Regulations (CFR) 29–1910. The regulations have many subparts that specify requirements whether you are doing electrical construction or electrical maintenance. In addition to OSHA, the *National Electrical Code®* refers to the *National Fire Protection Association (NFPA) document 70E.* This NFPA document was developed by the organization that develops the *National Electrical Code®* (*NEC®*).

NFPA 70E correlates the requirements of OSHA and interprets them for use by electrical personnel. The *70E* document is considered a consensus standard, which means governing agencies may adopt or consent to use it as a standard. *NFPA 70E* and OSHA standards are very similar in intent; *70E* interprets the standards in application-related terms. *NFPA 70E* provides guidelines on safe work practices, information on how to determine arc flash boundaries, and guides on what personal protective equipment (PPE) to use in various situations.

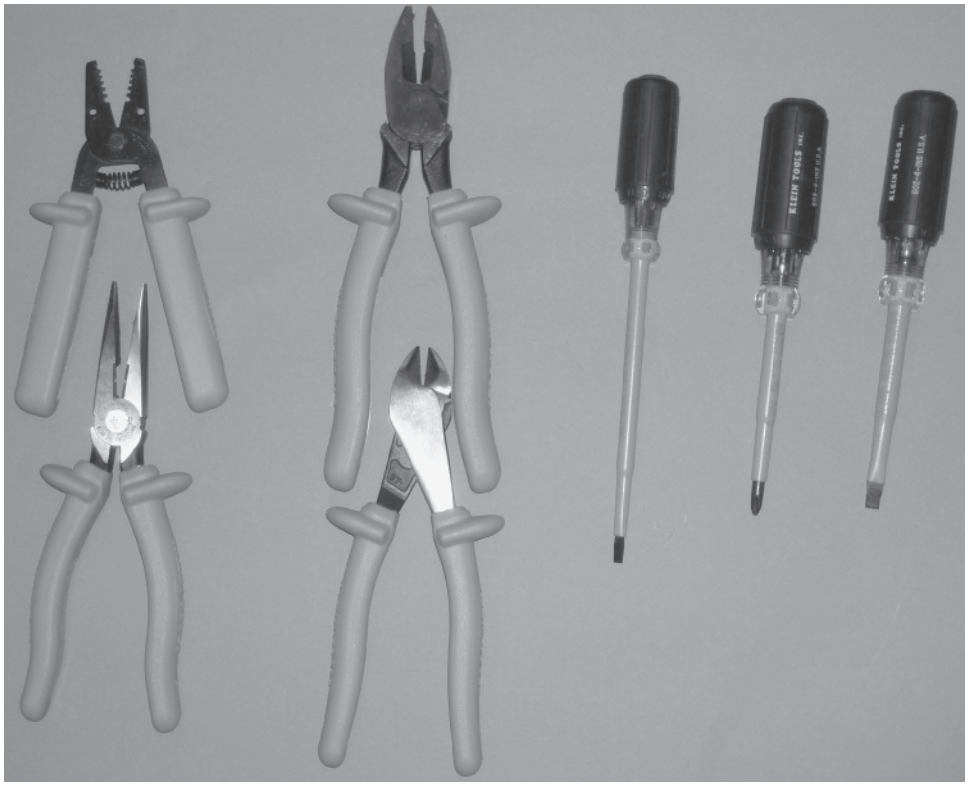
YOUR SAFETY IS YOUR RESPONSIBILITY. Although agencies and organizations try to provide guidelines and practices to follow, it is up to you to be as safe as possible in your work responsibilities. If at all possible, disconnect power from all the circuits with which you will come in contact. You must check for the presence of electrical energy, and then you must lock out the system to prevent accidental re-energization. The term "Lock-Out/Tag-Out (LOTO)" is often used to ensure that you place your personal lock on a disconnection point and then tag it with your name to identify that you are working on the circuit. No one should remove your lock without your knowledge and consent.

There are cases when you will work on systems that are energized. OSHA requires that you have a thorough knowledge of the precautions and procedures to follow. You must have documented training and verification that you are knowledgeable of the dangers involved, you know the precautionary techniques to use, you are aware of the electrocution hazards, and you

understand the hazards of arc flash. You must wear appropriate PPE that has been determined adequate to protect you from the inherent hazards. The PPE includes specifications for the proper clothing and hand and face protection as well as properly rated tools. You must use meters and test gear that accurately test for conditions that are present. You must have a plan to follow if an accident occurs and you need help. There are rules for the number of people who need to be present and there are rules for entering a confined space. Be aware of underground installations and the need for fresh air to breathe. If the environment is hazardous, for example, if gas vapors, dust, or fiber material are present, take further precautions as required.

Arc flash is a danger that is present as you work on live equipment, even if you do not physically touch the conductors with your hands. Electrocution or severe shock may result in contact with the live conductors, but the arc causes damage without contact. The arc that can occur between live parts, or live parts and a grounded surface, releases a great deal of thermal energy. The arc produces magnetic energy and air pressure energy known as the blast. This energy can knock you down or knock the air from your lungs. This same blast creates noise that can damage your hearing. The light produced from the arc may damage your eyesight. The amount of energy that may affect you depends on the type of fault, the amount of short-circuit current available at the arc, the voltage available, and your proximity to the fault. The arc heat energy is rated in calories, and the protective clothing you wear must meet or exceed the number of calories present in a possible arc. Your hands must be protected from accidental contact by using gloves that meet or exceed the voltage rating of the circuit. See the figure showing voltage-rated gloves with leather protection. Your tools must be marked with the voltage rating for the circuit. Voltage-rated tools are pictured in the accompanying figure.

Rubber gloves rated for circuit voltage and leather gloves to protect the insulating qualities of the rubber.



Tools used when working with live electrical circuits have to be electrically insulated and marked with the maximum circuit voltage.

UNIT 1

OPERATING PRINCIPLES OF DC GENERATORS

OBJECTIVES

After studying this unit, the student should be able to

- state the function of a direct current (DC) generator.
- list the major components of a generator.
- describe the difference between a separately excited and a self-excited generator.
- explain how the output voltage of a generator can be varied.

A *DC generator* changes mechanical energy into electrical energy. It furnishes electrical energy only when driven at a definite speed by some form of prime mover, such as a diesel engine or a steam turbine.

DC generators are used principally in electrical systems for mobile equipment. They are also used in power plants supplying DC power for factories and in certain railway systems. DC power is used extensively in communication systems and for battery charging and electroplating operations. The generation of electromotive force (EMF) is described in detail in *Electricity 1.*

In a DC generator, the output voltage is a DC voltage, even though alternating current (AC) is generated in the generator coils. In other words, one of the output terminals is always negative (–), and the other output terminal is always positive (+). The external circuit is the load connected to the generator. It receives current from the negative terminal of the generator and returns it to the positive terminal of the generator.

DC GENERATOR COMPONENTS

The essential parts of a DC generator are shown in Figures 1–1 and 1–2. The member that spins is called the *rotor.* The rotor is a cylindrical, laminated iron core that is mechanically coupled to the drive shaft of the generator. An armature winding is embedded in the slots on

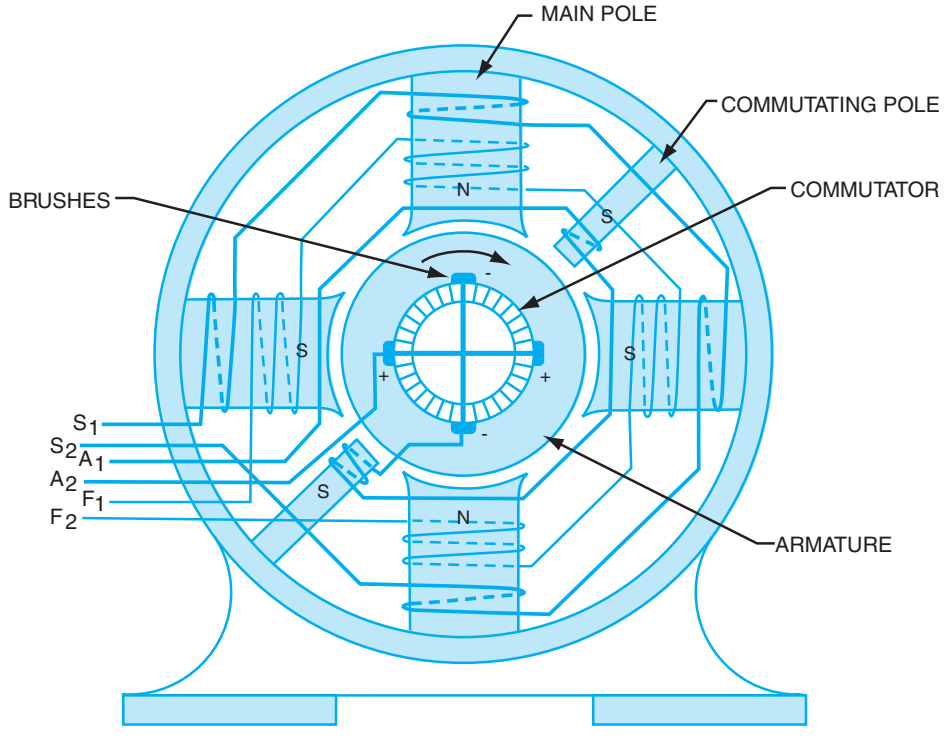


FIGURE 1–1 Compound generator fields with commutating poles.