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Investigation of Voltage and Current Source Equivalents in Network Theory

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Abstract

Electrical power sources play a crucial role in electrical and electronic systems by supplying the energy necessary for circuit operation. This paper examines the fundamental concepts, classifications, and properties of voltage and current sources. Different forms of electrical energy sources, including batteries, generators, rectified power supplies, alternators, and signal generators, are described along with their working mechanisms.

The study also explores the concept of internal impedance and its impact on the terminal behavior of sources, providing a clear distinction between ideal and practical models. An ideal voltage source is characterized by a constant output voltage independent of load conditions, whereas a practical voltage source exhibits internal resistance that influences its output. In a similar manner, ideal and practical current sources are discussed, emphasizing how load impedance affects current delivery.

Additionally, the relationship between voltage and current sources is explained through source transformation techniques, demonstrating their external equivalence. A thorough understanding of these principles is essential for effective circuit analysis, design, and real-world applications.

Keywords: electrical power sources, voltage source, current source, internal impedance, source transformation, circuit analysis

1 Introduction

Sources of electrical energy are essential for the functioning of both electronic and electrical circuits, as they deliver the power required to operate various components and loads. Any practical electronic system depends on an appropriate power source capable of supplying energy in a usable electrical form. These sources convert energy from other domains—such as chemical, mechanical, or electromagnetic—into electrical energy suitable for circuit operation. A clear understanding of voltage and current sources is therefore fundamental in circuit analysis and system design.

Electrical sources are broadly categorized based on the type of current they deliver, namely direct current (DC) and alternating current (AC). DC sources provide a steady and unidirectional flow of current, whereas AC sources generate currents that vary periodically over time. Typical DC sources include batteries, DC generators, and rectified power supplies. In contrast, alternators and signal generators are commonly used AC sources. Such power sources find applications in a wide range of areas including power distribution, communication systems, laboratory equipment, and general electronic devices.

A thorough knowledge of the characteristics of voltage and current sources, including their internal properties and equivalent models, is crucial for effective analysis and design of electrical systems. These foundational concepts support more advanced studies in electronics, electrical engineering, and power system applications.

2 Current and Voltage Sources

2.1 Sources of Electrical Power

The primary function of any electrical source is to deliver energy to a connected load, as illustrated in Fig. 2.1. Depending on its nature.

The term DC refers to electrical quantities that remain constant in magnitude and flow in a single direction. In contrast, AC describes quantities that vary with time and periodically reverse direction, taking both positive and negative values. Unless specified otherwise, AC quantities are typically assumed to have sinusoidal waveforms.

Common examples of DC sources include:

- Batteries
- DC generators
- Rectified DC power supplies

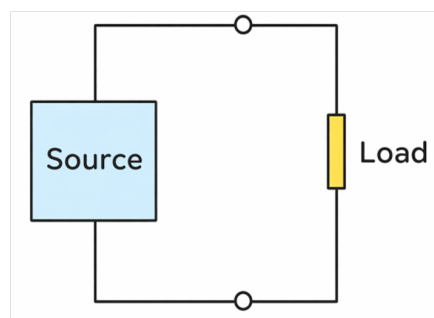


Figure 1: Energy transfer from source to load.

2.1.1 Batteries

Batteries are among the most widely used sources of DC voltage. The term originates from the concept of a collection of cells connected together. A battery typically consists of two or more electrochemical cells arranged in series or parallel configurations.

An individual cell serves as the basic unit for generating electrical energy and is broadly classified into:

- Primary cells
- Redudent cells

For instance, automotive batteries are secondary cells, while those used in flashlights are generally primary.

Electrical energy in cells and batteries is produced through chemical reactions. Each cell contains two electrodes:

These electrodes are immersed in an electrolyte, which is a substance that dissociates into charged ions when in solution. The movement of these ions enables charge transfer within the cell, facilitating current flow.



Figure 2: Battery and representative cells.

2.1.2 Generators

A DC generator operates on a principle distinct from that of a battery. It includes a mechanical rotating component, and when driven at a specified speed by an external source such as a steam or water turbine, it produces an electrical voltage across its terminals.

In general, generators are capable of delivering significantly higher power and voltage levels compared to batteries.

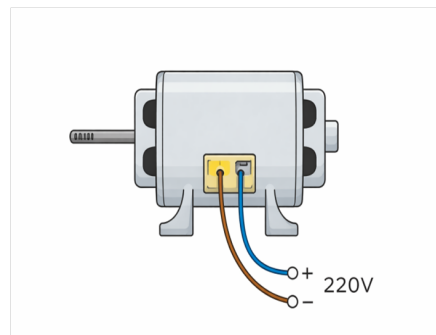


Figure 3: DC generator.

2.1.3 Rectification-Type Supply

Rectified power supplies are commonly used in electronic laboratories to obtain DC voltage. These systems employ rectifier circuits to convert AC input—such as that from standard power mains—into a steady DC output.

Examples include laboratory DC power units and battery eliminators used with small electronic devices like radios and calculators.



Figure 4: DC laboratory power supplies.

3 Conclusion

This study presented a comprehensive overview of electrical power sources and their significance in circuit operation. Various types of sources, including batteries, generators, and rectified power supplies, were discussed with emphasis on their working principles and practical applications. The distinction between direct current and alternating current sources was also highlighted to provide a clearer understanding of their roles in different electrical systems.

In addition, the fundamental concepts of voltage and current sources, along with their internal characteristics, were examined to support accurate circuit modeling and analysis. The discussion reinforces the importance of selecting appropriate sources based on application requirements and operating conditions.

Overall, a strong understanding of these foundational concepts is essential for the effective design, analysis, and implementation of modern electrical and electronic systems.

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