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| RESEARCH ARTICLE

Voltage and Electrical Safety

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| ABSTRACT
As is clear, the human body is mainly composed of water and electrolyte fluids. Accordingly, we can say that the human body generally acts as a conductor. The body also has resistance, due to which part of the electrical energy inside the body is converted into heat. The main factors affecting electric shock are voltage, current, resistance and other factors. Voltage, current and electrical safety are considered vital aspects in the design and operation of electrical systems. This article examines the effects of current-voltage and related matters on electrical safety and analyzes voltage drops and power fluctuations in cables and transmission lines, as well as the effects of different currents on the body. The main objective of this research is to evaluate the effects of high voltage and different currents on the health and safety of the body, maintain equipment and investigate methods for reducing voltage drops in electrical circuits. To achieve this goal, analytical and computational methods have been used to examine the effects of current and voltage drops and compare them with existing safety and security standards. The results of the study show that voltage drops in many of the systems studied are beyond the permissible limits of the standards, which can lead to reduced efficiency and increased electrical safety risks. Based on these findings, suggestions are made to improve the design and appropriate selection of cables and protective systems. This research can help improve the understanding and management of electrical safety and protection in various systems and help designers and engineers reduce risks and increase the efficiency of electrical systems.

| KEYWORDS

Current, Electrical safety, Human body, Hazards, Voltage

| ARTICLE INFORMATION

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1. Introduction

With the increasing use of electrical systems in industries, buildings and various equipment, the issue of electrical safety has become one of the main priorities in the design and operation of these systems. Current and voltage, as key parameters in the performance and efficiency of electrical systems, play a very important role in the safety and health of equipment and people. Voltage drops, which are caused by the resistance and length of cables and transmission lines, can have significant effects on the efficiency and safety of electrical systems.[1] [2], [3]

High and low voltages can lead to serious problems, including reduced equipment efficiency, increased energy consumption, and even safety hazards such as electric shock and fire. For this reason, calculating and managing voltage drops in cables and transmission lines is very important to ensure the proper operation and safety of electrical systems.[3]

The main objective of this research is to investigate the effect of voltage on electrical safety and security and to analyze voltage drops along cables and transmission lines [7], [8], [9]. In this paper, the fundamental principles of voltage and its effects on safety, methods for calculating voltage drops, and its practical effects on the operation and safety of systems will be analyzed. Also, standards and regulations related to electrical safety will be reviewed and suggestions for improving and optimizing electrical systems will be presented. This paper consists of different sections that deal in detail with various topics related to voltage, current, and electrical safety. First, the fundamental principles of voltage and its importance in electrical systems will be explained. Then, voltage drop calculations and its impact on safety are examined, and finally, practical solutions and improvement suggestions are presented [9], [10].

2. Problem Statement

In today's modern world, the widespread use of electrical energy in all aspects of daily life, from domestic to industrial uses, is undeniable. However, the increasing dependence on electricity and electrical equipment has raised serious concerns about electrical safety and voltage management. Unauthorized voltages and voltage fluctuations can lead to serious damage to electrical equipment and even pose a risk to life.

The main issue is what effects do fluctuations and unpredictable changes in the voltage of the power grid have on the safety and performance of electrical equipment? Are current systems sufficient and effective to protect consumers from the dangers of unauthorized voltages and fluctuations?

In this context, a comprehensive review and scientific analysis seem necessary to identify weaknesses and provide effective solutions to improve electrical safety and voltage management. This research seeks to answer these questions: how can we increase electrical safety against voltage fluctuations and reduce possible damage by using new technologies and optimal methods.

In stating this issue, the importance of voltage and electrical safety is clearly made clear and provides the basis for further research and studies.

3. Research Objectives

Today, electricity is an inseparable part of human life. Regarding the effective and correct use of electricity, many principles and regulations have been determined. If these principles are observed, the use of electricity will be free from potential problems and dangers. However, if these principles and regulations are not observed and the explanation and transmission of electricity is not carried out based on the specified standards, many problems, including safety, economic and social problems, will arise for electricity subscribers and users. One of these serious problems is electrical safety and security. It is obvious that many electricity users do not know the principles and basics of electrical safety as they should or are hesitant to observe these principles. Accordingly, the aim of this research is to serve electricity users in this regard in order to increase awareness and clarify up-to-date facilities and information, and to raise the level of safety among high-voltage electricity users.

4. Research questions

Main question:

- What is electrical voltage? And what is its relationship with human safety and security?

Sub-questions:

- What problems do voltage fluctuations pose to electrical devices?
- What is the relationship between high voltage and electrical or electronic safety?
- What is the relationship between voltage and electrical energy consumption?
- What is the body's response to electric shock?

5. Materials and methods

In this article, the method of library and statistical data collection and voltage drop calculations and current investigation has been carried out, which can be a good help for students and engineers in the field of electricity. In this article, information was first collected from reliable sources of the library of reputable global Internet sites, and then it was studied and analyzed. And its computational aspects have also been mentioned.

6. The importance of voltage in electrical systems and its relationship with current

Voltage, as one of the main parameters in electrical and electronic systems, plays a vital role in the performance, efficiency and safety of these systems. Voltage, which means the difference in electrical potential, determines the electric current in the circuit and affects the performance of various electrical components [11].

Appropriate voltage is essential for the proper functioning of electrical systems. In the design of electrical circuits, the supply voltage must be carefully adjusted to ensure the desired performance of electrical components [12]. For example, in digital circuits, the supply voltage must remain within a certain range to ensure the proper functioning of chips and logic components [13] [14] [15].

6.1 Safety and voltage

In general, the amount of potential difference that a person's body can tolerate without any complications or damage depends on factors such as the type of current and time. Generally, the threshold of tolerance of people to direct current is low in alternating current. According to the British Standard, the maximum permissible contact voltage at 50 Hz for alternating current is 50 V, and in the German Standard it is 65 V. However, for direct current, both standards specify 120 V. For animals, this voltage is specified as 25 V for alternating current and 60 V for direct current; however, high voltages can pose serious safety and security risks. Contact with high voltages can lead to electric shock and serious injury to humans. Also, inappropriate voltages can lead to damage and fire in electrical equipment. Therefore, compliance with safety standards and regulations is essential in the design and operation of electrical and electronic systems [16] [1].

6.2 Voltage and energy consumption

Voltage also has a direct impact on energy consumption. In electrical systems, voltage drops along cables and transmission lines can lead to increased energy consumption and reduced system efficiency. Therefore, calculating and optimizing the voltage in these systems is very important to reduce energy losses and improve efficiency. Of course, other factors such as the type of wire, cross-sectional area and length of the wire also have a direct effect on electrical energy consumption. In the following formula, we can calculate these parameters [15] [11].

$$\boldsymbol{R} = \boldsymbol{\rho}.\frac{\boldsymbol{L}}{\boldsymbol{A}} \qquad (1)$$

In the above equation, R is the resistance ρ is the coefficient of the private resistance, L is the length of the wire, and A is the cross-sectional area of the wire. It can be seen from the above formula that the resistance that increases the consumption in a conductor is directly proportional to the length of the wire and inversely proportional to the cross-sectional area of the wire.

6.3 Voltage and the useful life of equipment

Variations in voltage can affect the useful life of electrical and electronic equipment. Unauthorized voltages and voltage fluctuations can damage electrical components and lead to their premature failure [7]. Therefore, voltage control and stabilization are important to increase the useful life of equipment and reduce maintenance costs. [17], [18], [19]

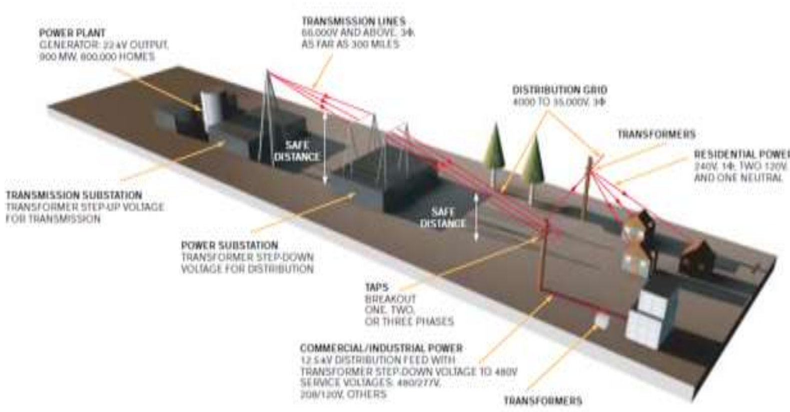


Fig1: the electrical power distribution system

7. How does electricity harm the body?

Electricity causes injuries and deaths for three reasons: (a) electrocution. (b) burns, (c) ignition and fire of objects.

7.1 Deaths caused by electrocution

The above issue is related to the following four things: the amount of electric current, the path of the electric current, and its volumetric density, the type of current (direct or alternating) and the duration of the current.

7.1.1 Current

Electric current means its transfer from one place to another, and based on the concept of electricity, the transfer or flow of electrons from one place to another, which is shown in the SI system as (A) amperes, and one ampere is the amount of current of 6.24×10^{18} electrons in a time period of one second. The amount of current is determined according to Ohm's law with the following formula [18].

$$\boldsymbol{Current} = \frac{\boldsymbol{Voltage}}{\boldsymbol{Resistance}} \quad \rightarrow \quad \boldsymbol{I} = \frac{\boldsymbol{V}}{\boldsymbol{R}} \qquad (\mathbf{2})$$

Accordingly, high voltage is proportional to high current and low resistance; More precisely, Ohm's law applies to voltage and direct current across a resistor. Alternating current flows not only through resistors but also through capacitors. Different standards for alternating and direct currents of different frequencies have considered different current intensities as permissible limits; according to the International Electrotechnical Commission standard, the safe limit of electric current for humans is 10 milliamperes and the lethal limit is 25 milliamperes for alternating current. Accordingly, the current that causes death in direct current has been determined to be 50 milliamperes. However, it should be noted that organs such as the retina, tongue, skin and some other parts are most sensitive to current intensity [20], [21].

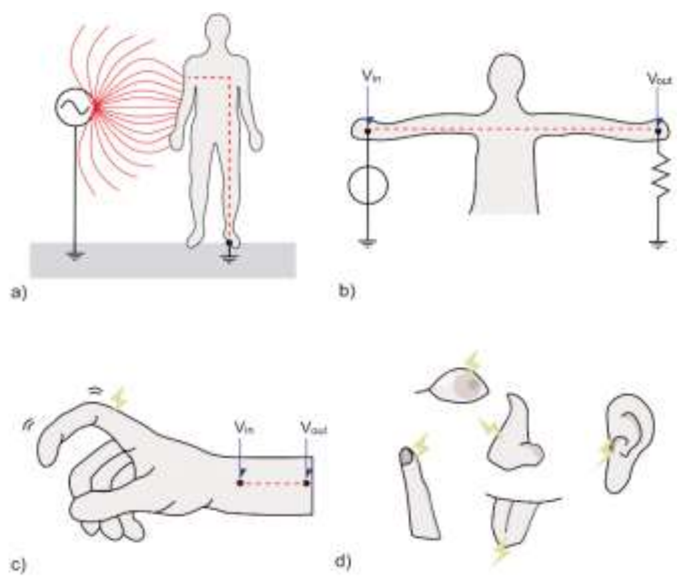


Fig.2: The path of current flow in the body and sensitive organs in terms electricity

7.1.2 Volumetric density and current path

The path that the current takes through the body determines which organs are damaged or burned. For example, a current passing through the chest may cause heart palpitations and suffocation due to spasms of the respiratory muscles. While a current passing vertically through the body can cause anesthesia and spinal cord injury [22].

The effect of the current magnitude and current path is considered together as the current density. This indicates the amount of current flow per unit volume. For example, an alternating current of 50 Hz flowing between the hands produces the following effects:

- 1 milliampere ⟸ tremor

- 15 milliampere ⇐ muscle contraction, pain, and suffocation
- 75 milliampere ⇐ heart palpitations

In this example, the current passes through the entire body, with a small fraction passing through the heart.[22] This means that the current density through the heart is very low. However, if the current passes directly through the heart or very close to it, the current density will be very large for any given current. In this case, a very small current (50 mA at 50 Hz) can cause a cardiac shock, known as a micro shock [23], [24], [25], [26].

7.1.3 Type of current

Direct and alternating currents act differently on the body; an alternating current (50 Hz) is extremely dangerous.
If the frequency is greater than 1 kHz, the susceptibility to this phenomenon is significantly reduced. At high frequencies (in the MHz range), the thermal properties of such frequencies are exploited (diathermy).

7.1.4 Duration of current

Ultimately, the damage and injury caused by an electric shock are related to the duration of time that the current flows through the body. The shorter this duration, the greater the amount of current needed to cause damage.

7.1.5 Burns

When an electric current passes through any object that has resistance, heat is generated. This heat can cause burns, depending on the amount and type of heat. The skin (especially when dry) is much more resistant than the moist tissues beneath it. Accordingly, electrical burns are generally located on or near the skin [27].

7.1.6 Fires and explosions

Sparks caused by pulling switches and plugs out of walls can ignite flammable gases and vapors. This problem can be solved by installing spark-proof switches and outlet covers that prevent the plug from being pulled out when the switch is turned off [28], [29].

8. How does electricity flow through the body?

Here, the body forms two parts of an electrical circuit, and electricity flows through the body. This connection comes in two forms, one is a resistive connection and the second is a capacitive connection. When the body is directly exposed to an electric shock, a resistive connection is created here.

8.1.1 Resistive connection

When the body is in contact with an electrical source and the ground, either directly or indirectly in the form of contact with an object connected to the ground such as a drain stand, a connection is created. There are two sources of electrical potential here. Inefficient devices and leakage current.

Inefficient devices may cause contact with live lines. Leakage currents occur due to the high potential of electrical devices with respect to the ground.

By establishing sufficient contact, a certain amount of current leaks to the ground, even if these devices are properly insulated. Because we do not have something in the form of absolute insulation or infinite resistance. Although these currents are normally very small, they can be fatal (micro shocks). Modern equipment is designed to greatly limit these challenges [27], [30].

8.1.2 Capacitive coupling

The body can form a connection between a source and ground by becoming a capacitor layer (capacitive coupling). In their simplest form, capacitors consist of two conducting plates separated by an insulating material (dielectric).[31], [32].

These plates store charge. The amount of charge a capacitor can store is called its capacitance, measured in farads [2].

If a direct current is applied to a capacitor, the current flows through the plates for only a short time, until the positive plate is charged to the same potential as the source. If an alternating current is applied to a capacitor, the plates of the capacitor change polarity based on the rate of the alternating current. The capacitor is then charged or discharged, causing electrons to move back and forth from one plate to the other, causing the electrons to flow in a circuit. This is why the concept of impedance should be substituted for resistance when discussing alternating current.

The impedance of a capacitor is given by:[2][33], [34]

$$Impedance = \frac{plate\ spacing}{[current\ frequency \times\ plate\ area]} \qquad (3)$$

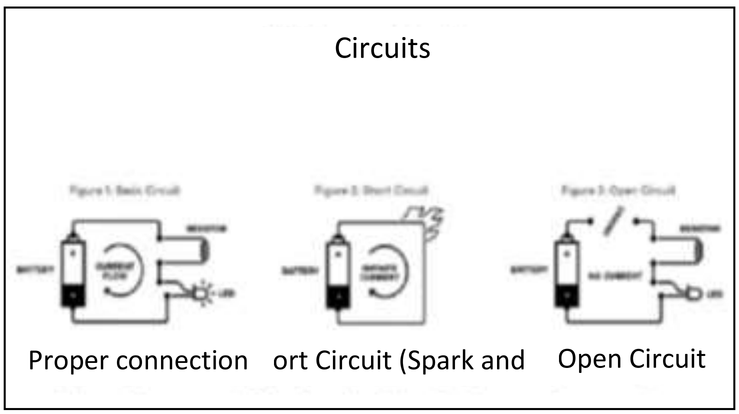
Therefore, the contact increases as the frequency of the power source and the plate surface area increase, and the distance between the plates decreases. An example of capacitive coupling in a clinical setting occurs in MRI scanners. These scanners create a variable magnetic field that can induce current in conductors such as wire or metal, as in a standard pulse oximeter. Although the patient is not in direct contact with these conductors, the capacitive connection allows the patient's body to become part of the electrical circuit, which can cause burns [35], [36], [37], [38].

9. Electrical Hazards to Humans

Electrical hazards to humans can manifest in a variety of ways, and it is important to be aware of and take precautions to avoid these hazards. Below are some of these hazards and sources that may be useful for further information:

Theoretical and experimental studies have investigated the effects of electricity on biological organs. For example, an electric shock causes the heart and vascular muscles to contract. Electric shock slowly affects the activity of cells without killing them [37], [38].

Electric currents burn internal and external organs sufficiently to cause structural damage to these organs through electrical burns. Electrical burns have devastating effects on human health by damaging the nervous system, heart, blood vessels, and skin [13].



9.1.1 Types of Electrical Hazards:

Direct contact with electrical wires or electrical devices may cause electric shock, which can lead to serious injuries or even death. These injuries include thermal injuries, cardiovascular injuries, neurological injuries, fires, etc. [35]

In thermal injuries; the electric current rapidly increases the body temperature and causes serious burns to the points of contact of electricity in the body, sometimes they cannot be easily treated. Similarly, electric shock can affect the cardiovascular system and even cause death. Future diseases and problems can be stated in this regard [39].

9.1.2 Cardiac injuries caused by electric shock

1. Heart rhythm disorders (arrhythmia):

- Ventricular fibrillation: (Ventricular Fibrillation) is one of the most dangerous problems in which irregular and rapid contractions occur in the atria of the heart, which can lead to cardiac arrest.
- Atrial Fibrillation: Irregular contractions in the atria of the heart that may lead to a decrease in heart efficiency [39].

2. Cardiac Arrest:

- If exposed to a strong electric current, the heart may suddenly stop, requiring immediate treatment with electric shock (defibrillation) and cardiopulmonary resuscitation (CPR).

3. Myocardial Injury:

- Electric shock may damage the heart muscle and cause chest pain, heart attack, or other injuries.

4. Chest Pain and Shortness of Breath:

- Even if no more serious injury occurs, a person may experience chest pain and shortness of breath after being electrocuted.

9.1.3 Vascular Damage from Electric Shock:

9.2 Changes in Blood Pressure:

Electric shock can suddenly change blood pressure, which may result in high or low blood pressure, and fluctuations in blood pressure can damage the walls of blood vessels. Exposure to electric current can damage the body's nervous system as a whole; and lead to chronic neurological problems. With electricity leakage and short circuit, it may cause a fire that can cause great damage to life and property.

9.2.1 The body's response to electric shock

Various factors can affect the severity of injuries caused by electric shock, including voltage, current intensity, duration of contact and the path of current through the body. Here are a number of voltages and their effects on the human body. Low voltage (less than 50 volts) at this voltage does not cause serious damage to the body, but it can cause mild shocks, especially if the current entering the body is high.

Medium voltage (50-1000 volts) This voltage can cause severe shocks, muscle contractions and even heart problems. The severity of the damage depends on various conditions such as the path of the current, duration of contact and the health of the person [40], [41].

High voltage (more than 1000 volts) This voltage can pose serious risks to the human body. Severe burns, internal injuries, and serious heart problems can result from this amount of voltage.

Similarly, electric current is also a serious cause of electric shock:

Low current (less than one milliampere) causes mild shocks to the body and does not cause serious injury.

Moderate current (1 to 10 milliamperes) may cause internal pain and muscle contractions.

High current (10 to 100 milliamperes) can cause serious damage to the heart, cause severe muscle contractions, and cause serious damage to body tissues.

Very high current, i.e., currents above one hundred milliamperes, can cause severe injury, extensive burns, and even death [10][36].

10. Technological Advances in Electrical Safety

10.1 Recent Innovations in Electrical Safety Technology

Electrical safety technology has made significant advances in recent years, greatly improving the protection of people and equipment. Some of the recent innovations in this field are listed below:

10.1.1 Advanced Detection and Monitoring Systems

- Smart Sensors: Use advanced sensors to detect electrical leakage, voltage changes, and abnormal currents. These sensors can quickly identify problems and connect to alarm and circuit breaker systems.
- Remote Monitoring Systems: Internet of Things (IoT)-based monitoring systems that allow users to monitor electrical safety status online and remotely [42].

10.1.2 Smart Protective Equipment

- Smart Protective Bases: Automatic switches and smart fuses that are capable of automatically detecting electrical problems and cutting off power in the event of problems.
- Self-adjusting equipment: This equipment can automatically change their protection settings based on environmental conditions and electrical load.

10.1.3 Advanced protection systems:

- Other protection systems and circuit breakers: Residual current devices (RCDs) and circuit breakers with more advanced capabilities to prevent electric shock and electrical damage.

- Smart protection systems: Use advanced technologies to protect against electrical hazards and create specific safety profiles based on environmental needs [12].

10.1.4 Data management and analysis:

- Data analysis systems: Use software and intelligent systems to analyze data related to electricity consumption and safety, which helps identify risk patterns and optimize energy use.
- Problem prediction: Use machine learning algorithms to predict safety problems based on collected information [35].

10.1.5 Advances in Personal Protective Equipment:

- Wearable devices: Using wearable technologies to detect electrical contacts and warn users before serious problems occur.
- Anti-electric materials: Developing new materials and coatings that can effectively prevent electrical contact and provide better protection [16] [40].

11. Conclusion

In this article, we have reviewed the basic concepts of current and voltage, as well as the hazards associated with electricity. Electric current, as the movement of electric charges, and voltage, as the driving force, are two key elements in understanding electrical phenomena. However, a lack of awareness and adherence to safety precautions can lead to serious and dangerous accidents.

To reduce the risks of electricity, it is essential to be aware of safety standards, use protective equipment, and conduct periodic inspections. Also, proper training on how to work with electrical devices and recognize hazards can help prevent accidents.

Finally, with a better understanding of current, voltage, and the associated hazards, we can use electricity safely and effectively and reap the benefits of this energy source.

This conclusion provides a summary of the paper's discussions while emphasizing the importance of safety.

11.1 Summary of Findings and Importance of Electrical Safety

In this article, we reviewed the key concepts of current and voltage and examined their effects on electrical systems. The findings of this article point to the following:

1. Electric current, as the flow of electric charges, plays a fundamental role in the operation of electrical devices.
2. Voltage, as the driving force of current, determines the amount of energy transferred to devices and equipment.
3. Electrical hazards include injuries from electrocution, fire, and equipment failure that can result from ignoring safety principles in the use of electricity.

11.1.1 The importance of electrical safety depends on several key factors:

Hazard awareness: Recognizing and understanding the hazards associated with electricity can help prevent accidents.

Standard compliance: Following safety instructions and standards can prevent accidents.

Training and skills: Educating users on safe methods of working with electrical equipment and recognizing hazards can have a great impact on reducing risks.

Ultimately, paying attention to electrical safety not only protects lives, but also helps preserve capital and equipment, and prevents the economic foundation of families and companies from being damaged.

11.2 Suggestions for improving electrical safety in the future

Continuous training:

1. Conduct regular training courses for employees and users on electrical hazards and safety methods.

Installation of safety equipment:

2. Use fuses, circuit breakers, and current leakage protection systems to reduce risks.

Periodic inspections:

3. Conduct regular inspections of electrical systems and equipment to identify problems before accidents occur.

Public information and awareness:

4. Create information campaigns to increase public awareness about the dangers of electricity and safe methods of using it.

Use of standard equipment:

5. Ensure that all electrical equipment is manufactured and installed in accordance with national and international safety standards.

Proper labeling:

6. Labels hazardous equipment and areas to alert users and prevent unauthorized access.

Establish safety protocols:

7. Develop and implement specific safety protocols for working with electrical equipment and emergency procedures.

8. By implementing these suggestions, we can create a safer and better environment for working with electricity and minimize the risks associated with it.

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