The Principle of Human Electric Shock and Several Main Types of Electric Shock

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Abstract. In the modern production process and daily life, people use a lot of various types of electrical equipment. However, in the process of use due to the illegal operation of the operator, it will inevitably cause electric shock accidents. Study the principle of electric shock type and preventive measures are important. Through the in-depth study of electric shock, this paper analyzes the principle and different types of electric shock, and the harm of electric shock to human body. In the research, Multisim software is used to simulate the human body being electrocuted by lightning, and the specific value of the external resistance required to ensure the safety current of the human body is obtained through the experiment. The significance of this study is to increase the public's awareness and understanding of the problem of electric shock, and to provide the public with important information about the hazards of electric shock and preventive measures. At the same time, to improve the accuracy of the study and for the consideration of human safety, simulation software is chosen to study the experiment, which provides methods and ideas for further research on electric shock.

Keywords: Electrical shock, Human body, Current, Simulation.

1. introduction

With the wide application of electric equipment and the popularity of power supply electric shock accident has become one of the main factors causing personal safety problems. It is of great significance to deeply study the principle and type of electric shock and explore effective measures to prevent electric shock. This paper aims to fully understand the working principle of electric shock, different types of electric shock and its harm, and put forward a series of practical measures to prevent electric shock, in order to improve the awareness of electrical safety and protect personal safety.

This paper studies the principle and type of electric shock and explores the measures to prevent electric shock. By analyzing the phenomenon of electric shock, the influence of current on human body and the common types of electric shock, the harm and cause of electric shock accident are deeply analyzed. On this basis, a series of practical measures are put forward to prevent electric shock, aiming at improving the awareness of electrical safety, reducing the risk of electric shock accident, and providing effective protection for personal safety. This study is of great significance for understanding the phenomenon and hazards of electric shock and exploring preventive measures, which can improve the awareness of electrical safety, reduce the occurrence of electric shock accidents and ensure personal safety.

2. The principle and type of current passing through the human body

2.1. How electricity passes through the human body

According to Yaojun Lu's research, he internal impedance of the human body is 500Ω, human contact impedance is 2000Ω [1]. The principle of current to and through the human body involves the interaction between current, resistance and voltage. Voltage is regarded as a kind of force which could push the current flow into human body. There will be a rapidly changed voltage if someone contacts a voltage source who holding a mantal tool. Given a certain voltage, a certain amount of current will flow which depends on the resistance. It is the current which decides the Physiological effect. However, the voltage will influence the result of the electric shock in some cases. The resistance of the human body to current depends on the resistance of the human body. The resistance of the human body is mainly composed of skin, tissue, bone, etc., and these tissues have a certain blocking effect on the current which could protect body from serious injury. The path of current through the body usually enters the body from one point of contact, flows one or more paths through different tissues and organs, and finally exit the body through another point of contact. Current in the human body follows Ohm's law. The amount of current is equal to voltage divided by resistance, I=V/R. The human Body Electrical Impedance Measurement System is shown in fig.1.

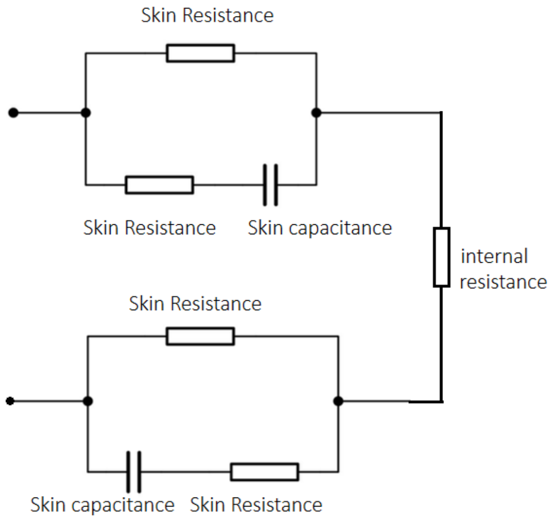

Fig. 1 Human Body Electrical Impedance Measurement System (Photo/Picture credit: Original)

Therefore, the amount of current depends on the voltage and the resistance of the body. Impact of current on human body: When current passes through human body, it will cause electrophysiological reaction, which may have different effects on the body, including tingling, muscle contraction, nerve irritation, etc. The amount and path of current have significant influence on human body. A human body receiving an electric shock must have at least two points of contact with the voltage source, one of which may be grounded. If one of the contacts is broken, no current will pass through.

Hai Jiang and his research group investigated DC (direct current) human body resistance and the effects of electrode contact material, wet or dry conditions of the skin. Through the study of the human body resistance of DC under humid conditions, the data of human DC impedance are comprehensively studied. There are four distinct electrical shock physiological effects for either DC or AC (alternating current): perception, inability of let go, ventricular fibrillation, and burn [2].

Contact current can be measured by measuring the equivalent circuit with an ammeter or by measuring the current flowing through the body. Y. Kamimura and his group measured human impedance in the frequency range of 75kHz to 15MHz with an equivalent circuit, which inspired me to measure the safe current passing through the human body with an equivalent circuit [3].

According to Fanming Ruan, they investigate the problems on average electrical impedance of human bodyIn the new circuit model, each capacitor with parallel resistors in the circuit model can replace a part of the human body (head, torso, arms, and legs) The circuit model of human body is shown in fig. 2 [4].

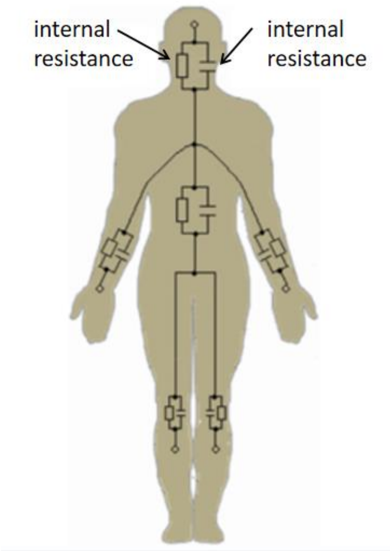

Fig. 2 Circuit model of human body [2]

2.2. Types of electrical shock

At present, the four most common situations in which lightning strikes occur are step and touch potential, high voltage arcs, lighting and direct shock. For details, see Table 1 below.

Tab. 1 Details of electrical shock

Type of electrical shock	Characteristic
Step and touch potential	Hidden, persistent, triggering an electric shock, causing muscle spasms, stopping the heart
High voltage arcs	Deadly, intense, instantaneous, and can produce burns, explosions, and fires
Lightning	Instantaneous high current, high temperature, high risk
Direct shock	Electric current through the body, resulting in electric shock injury, high risk

2.2.1 Step and touch potential

If a person stands on the ground, the voltage between his or her feet should be 0V. Lines may break or loosen from insulating supports and come into contact with the ground itself or with some structures attached to the ground. The support wires may come loose from their connections near the ground, and when support wires touch the power cord, they become energized, and after touching the ground the ground is no longer 0V and there will be current flow within two different voltages.

In low-voltage circuits below 1000V, when the live wire of the power grid lands, the radius of the danger zone where the live wire is centered is 0.82m. The human body directly or indirectly connected to the fire line is the main cause of the low voltage circuit electric shock accident. For high-voltage cables and high-voltage devices, the minimum radius of the safety zone around the live cable landing site is 10.3m [5].

According to Feng He, in this paper, the maximum step voltage tolerated by human body is 7.19 x 10^5V, and the maximum contact voltage tolerated by human body is 6.15 x 10^5V. Given the calculation method of the voltage endured by people when standing and walking, the maximum stride voltage tolerated by the human body is 7.19 × 10^5V, and the maximum contact voltage tolerated by the human body is 6.15 × 10^5V [6].

2.2.2 High voltage arcs

High voltage arc electric shock refers to the phenomenon of electric shock when the human body touches the high voltage arc. Arc is a discharge phenomenon, when a high voltage produces a large enough electric field intensity, the electrons in the air will be accelerated and ionized, forming a current path. The high voltage arc creates a shock wave, causing blunt impact injuries such as a fall or internal organs, the heat from the arc causing flash burns, and other injuries. If it touches a person and the current passes through the body, there will be other injuries. High voltage electric arc shock can cause varying degrees of injury, including burns, muscle contraction, arrhythmia, etc. The effect of current on human tissue depends on current intensity, current duration and current path.

In K. Yoshida and his members' research, the following results are obtained through the study of 200v, 300v, 500v, the opening velocity between 1~200mm/s and the constant current of 10A. The experiment shows that the arc duration and arc energy are inversely proportional to the opening speed, and the arc length before the arc is extinguished is determined by the source voltage, independent of the contact material and opening speed, and becomes a constant value [7].

The arc steady state equation is obtained from Elenbas-Heller equation by Huiping Xi's study of the arc of high voltage circuit shown in formula 1 [8].

$$\frac{1}{\mathrm{r}}\cdot\frac{\mathrm{d}}{dr}\left(r\lambda\frac{dT}{dr}\right)+\gamma^{E^2} \tag{1}$$

Where r means inside radius, γ means conductor density, λ means heat conductivity, E means the arc of arc potential.

The formula shows that the radial temperature variation per unit length is directly related to the cutoff and arc voltage around the arc, and the higher the conductor density, the longer the arc will be maintained.

2.2.3 Lightning

A form of electric shock in which a high concentration of electric energy is converted into heat energy in some area of the body, causing tissue damage and burns. This type of shock is commonly seen in high current through a small contact area. It can lead to ruptured eardrums bruising internal organs and cataracts.

The causes of lightning accidents are: bad weather conditions, frequent lightning activities, a large amount of flammable liquid in the oil depot, which is easy to cause lightning strikes, and the surrounding terrain and environment provide lightning strike path [9].

2.2.4 Direct shock

Direct electric shock refers to the way in which the human body directly touches a voltage source or energized object, causing an electric current to pass through the human body. For example, when you touch a bare wire or plug, the current will flow through the body and cause an electric shock.

The cause of direct electric shock is usually electrical maintenance personnel touching the exposed power slip wire. Once this kind of accident directly touches the power line, most of the maintenance personnel will be electric shock from the height of the fall resulting in serious casualties [10].

3. Measures to prevent electric shock

3.1. Use insulating tools

These materials have a high impedance that separates the body from the power source or live parts, creating an electrically isolated environment that effectively blocks the flow of current, thereby reducing or blocking the path of current through the body.

H. Nowikow and his group introduced two kinds of insulation tools. Hybrid hand tools mechanical resistance is smaller than insulated equivalent while hybrid hand tools are lighter. These two kinds of tools' leakage current are less than 10mA which is the maximum safety current for human body [11].

With the continuous development of the power grid towards the direction of large capacity and high voltage, the aging of power cables is accelerated. Lin Musong and his group analyzed the cause and mechanism of aging of insulation materials, summarizes the measures to prevent aging, and looks forward to the future development of insulation materials for the power equipment [12].

3.2. Protective grounding

Protective grounding is applicable to ungrounded high and low voltage power grid, that is, the metal shell of electrical equipment that is not charged under normal conditions is well connected to the grounding object. When the insulation of some electrical equipment is damaged and some shell collides, if someone touches the energized shell, the grounding current is divided into two branches: the grounding wire and the human body. The resistance of the grounding wire is not allowed to exceed 40 Ω. Far less than the human body's resistance. The current flowing through the body is almost zero.

According to J. R. White and S. Jamil, there are several important aspects of temporary protective grounding and the general rules for using temporary protective grounding [13].

With the development of power grid, the innovation of grounding methods and the characteristics of different grounding methods are introduced in this paper. Combined with the background of the rapid construction of offshore wind power in China, the neutral point of offshore wind power system is deeply studied, and the appropriate neutral point grounding method is selected [14].

3.3. Protective measures of zero

The principle of protective measures of zero connection is to ensure that the metal shell or conductor part of the electrical equipment is connected with the neutral line of the power supply through good grounding and neutral line connection. That way, when a device fails, the current can flow back through a safe loop rather than through the body, reducing the risk of electric shock. At the same time, the use of fault detection device can find current leakage in time, quickly cut off the power supply, further improve the effect of electric shock protection [15].

The selection of protection zero contact and the application range of protection zero contact and protection ground are analyzed from the technical point of view [16].

4. Simulation

The core principle of the above three ways to prevent human overcurrent is to increase the grounding resistance and reduce the current through the human body. This paper takes lightning as an example to demonstrate its actual effect by Multisim.

4.1. Software introduction

Multisim 14.3 is an electronic circuit simulation software. It is a circuit design and simulation tool based on graphical interface. Users can simulate DC, AC and mixed signal circuits, and can perform parameter analysis, optimization and waveform display operations.

4.2. Parameter setting

This paper selects 100kV and 50Hz lightning for analysis. In order to obtain a safe current for the human body, it is necessary to connect an external resistance of 10MΩ. The simulation of human body directly contacted to the lighting is shown in fig. 3.

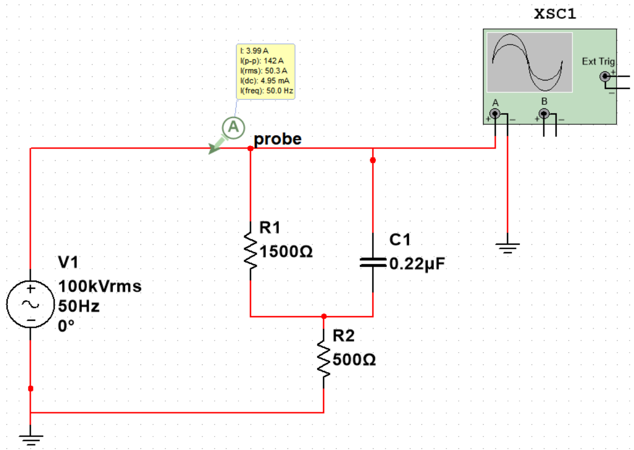

Fig. 3 The human body is in direct contact with lighting (Photo/Picture credit: Original)

Another simulation of the maximum safe current flows through human body is shown in fig. 4.

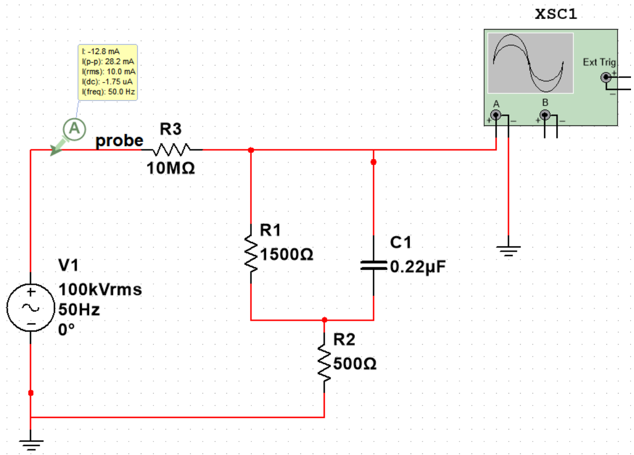

Fig. 4 The maximum safe current that can flow through human body (Photo/Picture credit: Original)

5. Conclusion

The function and application characteristics of Multisim software are introduced in detail, including circuit design and simulation and parameter analysis. Human being electrocuted by lightning simulation experiment design, describes the design steps and parameter Settings of simulation experiment, including model construction, voltage input, resistance parameters, etc. The results of simulation experiments are presented, and the experimental data are analyzed and explained in detail. In particular, the safety current of human body under different voltage conditions is concerned, and the limit of safety current is ensured by changing the value of external resistance. The experimental results are discussed and verified and compared with the existing theoretical knowledge and experimental data to verify the accuracy and reliability of the simulation experiment. These results provide scientific basis for formulating reasonable protective measures and safety standards.

When someone need to touch power or electrical equipment, make sure to use insulated tools and equipment, such as insulated gloves, insulated shoes, etc., to prevent current from passing through the body. Ensure that the insulating materials in the work area are intact, such as insulated floors, insulated walls, etc., to reduce the risk of current passing through the human body. Avoid being outdoors or near tall objects during thunderstorms. Find a safe indoor lightning shelter or place to live and avoid touching metal objects.

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