Electrical Safety

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1. Introduction

Electricity is as dangerous as it is useful. Unlike other products we use every day, we can't see, hear or smell electricity. So we may not always think about using it safely. A moment of carelessness, or a piece of faulty equipment, can cause an electrical accident. Minor electrical shocks could be fatal and minor errors while handling electrical equipment could hurt you. The more we learn about the safe use of electricity, the less our chance of injury. Electricity gives us light but do not take electricity lightly!

Power systems often have one side of the voltage supply connected to earth ground to ensure safety at that side, by keeping zero potential in between. The "grounded" conductor is called the neutral conductor, while the ungrounded conductor is called the phase or the live wire. Electric shock can only occur when contact is made between two points of a circuit; when voltage is applied across a victim's body. Electric burns, fires, arcing and explosion are other versions of electrical accidents. Effective implementation of Electrical Safety precautions can save lives and to prevent hazards.

2. Causes of Electrical Accidents

It is the current and not the voltage that causes electrical accidents. The voltage will cause a current to flow through a path created by the ground. Any opposition to that flow of current, called as 'resistance' results in a dissipation of energy, usually in the form of heat. This current or the heat generated is the basic cause of all types of electrical accidents.

2.1 Contact with the live conductor

Unexpected contact with the live conductor by the victim may happen in two ways;

(i) direct contact or
(ii) indirect contact.

2.1.1 Direct contact

An electric shock results from contact with a conductor which forms part of a circuit and would be expected to be live. A typical example would be if someone removed the plate from a switch and touched the live conductors inside. Over current protective systems will offer no protection in this case, but it is possible that a residual current device (RCD) with an operating current of 30 mA or less may do so.

2.1.2 Indirect contact

A shock may be received from a conducting part which is totally unconnected with the electrical installation, but which has become live as the result of a fault. Such a part would be called an extraneous conductive part. Danger in this situation results from the presence of a phase to earth fault. This makes the equipment case live, so that contact with it, and with a good earth makes the human body part of the shock circuit. If the protective system had zero resistance, a 'dead short' would be caused by the fault and the protecting fuse or circuit breaker would open the circuit.

2.2 Another classification of the causes are;

- Faulty appliance
- Damaged or frayed cords or extension leads
- Electrical appliances coming in contact with water
- Incorrect or deteriorated household wiring
- Downed power lines
- Lightning strike.

3. Types of Electrical Accidents

There are mainly five possible types of electrical accidents.

3.1 Electrical Shock

Electric shock is the sensation and muscular spasm caused when electric current passes through the body. There are 4 factors determining the severity of the shock.

(i) The amount of body resistance against the current flow. (Or the quantity of shock current flowing)
(ii) Path of the current takes through the body.
(iii) The length of time the current flows through the body.
(iv) Supply Frequency

3.1.1 Body resistance (or the quantity of current)

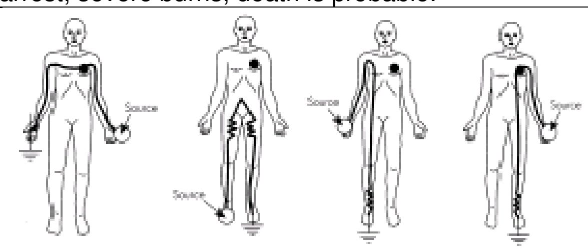
The human body is composed largely of water, and has very low resistance. The skin, however, has very high resistance, the value depending on its nature, on the possible presence of water, and on whether it has become burned. Thus, most of the resistance to the passage of current through the human body is at the points of entry and exit through the skin. A person with naturally hard and dry skin will offer much higher resistance to shock current than one with soft and moist skin; the skin resistance becomes very low if it has been burned, because of the presence of conducting particles of carbon.

When skin is moist, the body resistance could be as low as 300 ohms! Also, breaks in the skin at the point of contact could reduce the skin resistance to nearly zero! Skin resistance is only important when handling voltages of less than 240 volts. If one get shocked by more than 240 volts, the voltage arc will burn through the skin and leave deep, third-degree burns where it enters the body.

Effect of electrical currents in the human body	
Currents	***Reaction***
Below 1mA	Generally not perceptible
5 mA	Slight shock felt. Not painful, but disturbing. Average individual can let go.
6 o 25mA (women)	Painful shocks. Loss of muscle control.
9 to 30mA (men)	The freezing current. If muscles are excited by shock, the person may be thrown away from the power source. Individual can not let go.
50 to 150mA	Extreme pain, respiratory arrest, severe muscle reactions. Death is possible.
1.0 to 4.3A	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur. Death is likely.
10 A	Cardiac arrest, severe burns, death is probable.

3.1.2 Path of the current flow

The two most dangerous paths that current can take through human body are (1) from hand to hand and (2) from left hand to either foot. The second path is the most dangerous since the current will flow through both the heart and other vital organs. Path created through head also has an increased chance of death.



(A) Touch Potential (B) Step Potential (C and D) Touch/Step Potential

3.1.3 Duration of the current flow

Fibrillation is the shocking of the heart into a useless flutter. The longer, one get shocked more chance there is for the heart to begin fibrillating. Most people who die from electric shock is due to fibrillation. In a normal adult it is unlikely if the current in milliamperes is less than 116/t, where "t" is the shock duration in seconds. The longer the duration of the shock, less current is needed to cause heart fibrillation.

Some examples of shock current levels and durations that could cause fibrillation are:

- 21 milliamperes for 30 seconds,
- 44 milliamperes for 7 seconds, or
- 67 milliamperes for 3 seconds.

But a shock current of 500 mA may have no lasting ill effects if its duration is less than 20 ms.

3.1.4 Supply Frequency

Direct current (DC), because it moves with continuous motion through a conductor, has the tendency to induce muscular tetanus (contraction) quite readily. Alternating current (AC), because it alternately reverses direction of motion, provides brief moments of opportunity for an afflicted muscle to relax between alternations. Thus, from the concern of becoming "froze on the circuit," DC is more dangerous than AC. However, AC's alternating nature has a greater tendency to throw the heart's pacemaker neurons into a condition of fibrillation, whereas DC tends to just make the heart stand still. Once the shock current is halted, a "frozen" heart has a better chance of regaining a normal beat pattern than a fibrillating heart. The effect of fibrillation is peak in the supply frequency around 9 to 12 Hz. High Frequency currents (MHz) are not dangerous and may not produce shock because of 'skin effect'.

3.2 Electric burn

Electric burns are not the same as those due to fire. They are due to the heating effect of electric current passing through the body tissue, and thus are usually associated with electric shock, often occurring in or on the skin at the point of contact with the electric system. Electric burns are usually very painful and slow to heal and often will result in permanent scaring.

3.3 Fires of electrical origin

Electricity can cause fire in a number of ways, including:

- Over heating of conductors and cables due to over loading.
- Current leaking to earth or between conductors due to low levels of insulation resistance.
- Over heating of flammable materials placed too close to electrical equipment, which is operating normally.
- Ignition of flammable materials as a result of arcing or the scattering of hot particles as a result of an electrical fault.

Injuries due to fire are usually burns, but may also be as a result of inhalation of smoke.

3.4 Electric arcing

An electric arc takes place when current flows through the air or through insulation between two conductors at different potentials. Injury from arcs may be as a direct result of burning from the arc, in which case it is not unusual for the severity of the burn to be increased because molten metallic conductor particles may enter the burn. Arc burns are usually very severe and are often fatal.

3.5 Explosion caused by the use of electricity

An explosion of any type is usually associated with the sudden release of a large quantity of energy. All sorts of electrical equipments such as motors, equipments and cables may explode violently when they are subjected to much higher levels of current than they are designed to carry.

4. How to avoid being shocked?

Preventing yourself from receiving an electric shock can be summed up in three words*: isolate, insulate and ground.*

4.1 Isolate: Isolate yourself from the source of electric shock. Secure the power to equipment before you attempt to work on it. Be sure to keep all electrical equipment covers, doors, and enclosures in place when you are not actually working on the equipment. If you must leave circuitry exposed, rope off the area, post appropriate signs, and warn your fellow workers of the danger.

4.2 Insulate: Make sure that the electrical tools and equipment you use are properly insulated. Use only approved insulated hand and portable electric power tools. Check power and extension cords frequently for deterioration, cracks, or breaks. Breaks in the insulation cause many electrical accidents.

4.3 Ground: Electric current always follows the path of least resistance. To prevent yourself from being the unintentional path to ground, make sure that your equipment is well grounded. Well-grounded equipment will direct any stray electric current to ground, thereby protecting you from electric shock. A good ground can also help protect your equipment from excessive voltage spikes or lightning.

5. How to treat victims of Electrical Shock?

The rescue of electric shock victims depends on prompt action. However, to avoid becoming a victim yourself, you must observe the following safety precautions:

i). Shut off the voltage at once.

ii). If you cannot shut off the voltage immediately, try to free the victim from the live conductor by using a dry piece of wood, dry plastic or wooden broom, or dry leather clothing or other non-conducting material. *Do not make direct contact with any part of the victim's body with any part of your body!* If you do, you will become part of the same circuit and may become an electric shock victim yourself!

iii). After you remove the victim from the power source, determine if he or she is breathing. If the victim is not breathing, apply cardiopulmonary resuscitation (CPR) without delay. Loosen the clothing about the victim's neck, chest, and abdomen so that breathing is easier. Once the victim is breathing, protect him or her from exposure to cold, with a warm cover, if possible.

iv). Keep the victim from moving. After a strong shock, the heart is very weak. Any sudden effort or activity may result in heart failure.

v). Send for a doctor, and stay with the victim until medical help has arrived. Do not give the victim stimulants.

6. How to prevent electrical accidents?

6.1 Awareness

It is essential to have a general awareness about the nature of electricity and how to handle it, among the public. The lay men should be warned not to attempt any job himself but always call a competent electrician.

6.2 Appropriate design of electrical circuits

Electric circuits control through a panel or box called a circuit breaker panel or fuse box. Fuses or circuit breakers are devices, which limit the amount of current a circuit will carry. They protect the wires and equipment from over heating, which could create fire hazards. They are designed to automatically open or break a circuit should the amount of current exceed the rated design of the circuit. Fuses contain a soft metal filament that melts when too much current flows through them. Circuit breakers are designed to trip a switch.

It is important and good practice to label fuses or circuit breakers with the location of the circuit. Labeling your devices will aid you in case of a power outage or when you need to turn the power off in a certain area, before doing repair or maintenance work. To prevent circuit breakers from sticking or malfunctioning, it's good practice to exercise your breakers once a year by turning them off and on three times.

In general the electrical design should take account of:

- ❖ The load and the probable fault conditions
- ❖ The rating of the equipments used
- ❖ The need of suitable fuses and circuit breakers
- ❖ The environmental conditions applying, such as the presence of water, dust, etc. which will affect the type of protection needed.
- ❖ The fault level at the supply position and the ability of the protective system to cope with such faults.

6.3 Direct contact protection

The methods of preventing direct contact described in section 2.1.1 above are mainly concerned with making sure that people cannot touch live conductors. These methods include:

(i) -the insulation of live parts - this is the standard method. The insulated conductors should be further protected by sheathing, conduit, etc.
(ii) -the provision of barriers, obstacles or enclosures to prevent direct touching.
(iii) -placing out of reach or the provision of obstacles to prevent people from reaching live parts.
(iv) -the provision of residual current devices (RCDs) provides supplementary protection.

6.4 Indirect contact protection

There are three methods of providing protection from shock after contact with a conductor which would not normally be live:

(i) - making sure that when a fault occurs and makes the parts live, it results in the supply being cut off within a safe time. In practice, this involves limitation of earth fault loop impedance.
(ii) - cutting off the supply before a fatal shock can be received using a residual current device
(iii) - applying local supplementary equipotential bonding which will ensure that the resistance between parts which can be touched simultaneously is so low that it is impossible for a dangerous potential difference to exist between them. It is important to stress that whilst this course of action will eliminate the danger of indirect contact, it will still be necessary to provide disconnection of the supply to guard against other faults, such as overheating.

6.5 Insulation

Low quality insulation will always lead to the break down of the material even at normal voltage. Insulation failure is a source of many accidents. A low resistance between phase and neutral conductors will result in a leakage current. This current will cause deterioration of the insulation again as well as involving waste of energy. So the type and grade of insulation used must be suitable for the voltage concerned. Always prefer double insulated wires. The flexible cords should not be twisted cable, but 3 core PVC sheathed cable.

6.6 Earthing

The electric shock received by touching the metal parts of an appliance which might become live due to detective insulation is because of the current flowing through the human body caused by the voltage between the metal parts and earth. Effective earthing will keep zero potential in between such points and thus the accidents will be prevented.

7. Classification of Electrical Installations.

Generally, electrical installations are of two types; domestic & non-domestic. Safety can be assured with the following guide lines.

With the domestic installations:-

(i) An ELCB of high sensitivity should be incorporated.
(ii) The plug pin should be of 3 pin with finger grips. Two pin plug should only be used for plastic moulded or plastic clad devices.

(iii) The flexible cords should not be twisted cable, but 3 core PVC sheathed cable. The terminations should often be visually observed and if found charred should be trimmed and reconnected.

(iv) Never an appliance be handled with wet hands or on a wet floor. The floor in the kitchen should be dry.

With the non-domestic installations:-

(i) The main control panel must be located at ground floor, out of reach of general public.

(ii) The staff in charge should be made aware of the work entrusted to and expected of them.

(iii) Periodic inspection, measurement of insulation level of equipments and of installations, resistance of earth system must be made and documented. Remedial action initiated to conform to relevant standards.

(iv) The equipment/premises under repair should be cordoned off and caution notices prominently displayed.

(v) 'First-Aid' and fire-fighting' facility should be located at the easy access.

8. Case Studies

8.1 Downed Power Lines

8.1.1 A live wire touching the ground causes electricity to travel through the ground, radiating outward from the point of contact. The electricity decreases in strength as it travels away from the centre. The effect is similar to when someone tosses a pebble in a pond of water resulting in ripple rings that travel from center. For a wire touching the ground, electricity forms rings of different voltages. Running from a fallen line may cause your legs to bridge current from a higher ring to a lower voltage ring and you may receive a shock. Instead, keep your legs together and shuffle away with both fee on the ground or hop away with both feet together. Shuffle a safe distance away (15m or more) and away from other utility poles.

8.1.2 Suppose the downed line is touching your car, while you are inside. The car body may be energized. So you remain inside the car, and wait for help. If you must get out of the car because of fire or some other hazard, jump free of the car so that your body clears the vehicle before touching the ground. Do not step out of the car, you may receive a shock.

8.2 A few children were playing on the open terrace. They all dispersed after and the child of that household was missing. It was lying dead on the terrace. It had urinated from the terrace establishing a connection to the LT line below, got electrocuted instantly and in all innocence. So, always be care in maintaining safe distance with the power lines while constructing buildings.

8.3 Several years back, a staff working on a telephone line fell down dead and on post mortem, it was revealed that he had severe electric shock. He had not shorted and earthed the dead lines. A short circuit on a 66kV overhead line 1km away could induce a voltage of 300V or so resulting in the causality. Whenever overhead lines or even busbars are under repair, the first job is to earth them.

8.4 Fatal accidents have occurred when Main Switches were not opened but 300A porcelain fuse cut outs have been pulled out on load instead. The eventual arc had chased the person even as he was pulling it out burning him to death.

9. Safety Precautions

9.1 General

- Inspect power cords regularly and replace when needed;
- Always use ground fault circuit interrupters (eg:-ELCB) around areas where there is water, i.e., bathrooms, kitchens, deep sinks, or outside;
- Wear rubber-soled shoes and safety gloves when operating power tools, replacing fuses, or working where there is a possibility of electric shock;
- Use double insulated tools;
- Utilize nonconductive tools and ladders;
- Use rubber floor matting, when available;
- Clean and inspect tools when the job is finished;
- When working outside, look up to be sure you will not come in contact with power lines;
- Make sure kids fly their kites in open fields;
- Make sure kids do not build their tree houses near power lines;
- Never use electric appliances or tools around water;
- Do not use power tools with defective or broken insulation;
- Always disconnect the power source before repairing electrical equipment;
- Never touch electrical outlets with your fingers or with objects.
- Never play with electrical cords, wires or switches and keep them away from heat and water.

- ❖ If you are in contact with water never touch anything electrical like a light switch or hair dryer.
- ❖ Never play around electrical wires or equipment.
- ❖ Stay away from areas marked DANGER: HIGH VOLTAGE.
- ❖ If climbing trees, stay away from those near power lines.
- ❖ Never through objects at wires or utility poles.
- ❖ Stay out of open areas and away from trees during electrical storm. Go indoors.
- ❖ Stay in the car during a storm because the rubber tires stop electricity from passing through it, if the car is struck by lightning or a fallen cable.
- ❖ Turn off lamps when changing light bulbs.
- ❖ Do not put your fingers in a light bulb holder.
- ❖ Keep combustible materials away from lamps or heating devices.
- ❖ Disconnect appliances before cleaning.
- ❖ Tell someone if you see a frayed electrical cord.
- ❖ Be sure all electrical equipment for your swimming pool is grounded properly.
- ❖ Call the fire station in case of an electrical fire. If safe to do so, unplug the appliance and use a DCP (Dry Chemical Powder) type fire extinguisher to douse the flames. Never use water! [Dry chemical extinguishers have an advantage over CO_2 extinguishers since they leave a non-flammable substance on the extinguished material, reducing the likelihood of re-ignition.]
- ❖ Call the concerned KSEB office, if you see a person who has been or is being electrocuted – they may be carrying the flow of electricity.
- ❖ Don't swim during an electrical storm.
- ❖ Don't plug in electrical appliances in the bathroom unless specific safety devices have been installed.
- ❖ Never remove the grounding wire on a three-pronged cord;
- ❖ Do not assume you have unplugged an electrical device (check it to be sure);
- ❖ Do not leave electric devices where small children may have access;
- ❖ Never climb utility poles, transmission towers or fences around substations.
- ❖ Before you work on a rooftop television antenna, be sure the area is clear of power lines. Install antennas where they won't touch or fall on electric lines.

9.2 Electrical Cords

- ❖ Always keep cords away from cutting blades of saws, inspect power cords regularly and replace when needed;
- ❖ Replace, don't attempt to fix cords that have been cut or damaged.
- ❖ Any exposed strand of wire could cause a shock or burn.
- ❖ Never pull out a plug by the cord.
- ❖ If a cord or plug is warm or hot to touch – unplug it immediately.
- ❖ Check wires, extension cords and appliances for signs of wearing.
- ❖ Never place electrical cords across traffic areas or under carpets. This could cause unnecessary wearing of the cord.
- ❖ Never bend or remove the ground (the third prong on a plug). It is designed to help prevent shock and may save your life.
- ❖ Don't use extension cords as permanent wiring as they are not designed for it.
- ❖ Using extension cords as permanent wiring indicates that your home wiring should be updated.
- ❖ Unplug and put away extension cords that are not being used. This will reduce the risk of children chewing on it or playing with it.
- ❖ Do not overload an extension cord. Recognize the signs of overheating, distortion, or discoloration and unplug the cord.
- ❖ Avoid overloading by first checking the cords electrical capacity.
- ❖ Never puncture insulation of electrical cords by nailing them to any surfaces.

10. Conclusion

More than 45 per cent of reported fire accidents in our country are due to electrical problems. According to a statistics of the National Crime Records Bureau, as many as 15.5 deaths per day (total 5,663) occurred due to electrocution in the year 2000 itself.

We all need electricity, but nobody needs accidents. Don't put your life on the line. Accidents can happen -- to you or someone you care about -- if you're not careful. Thanks for being careful!