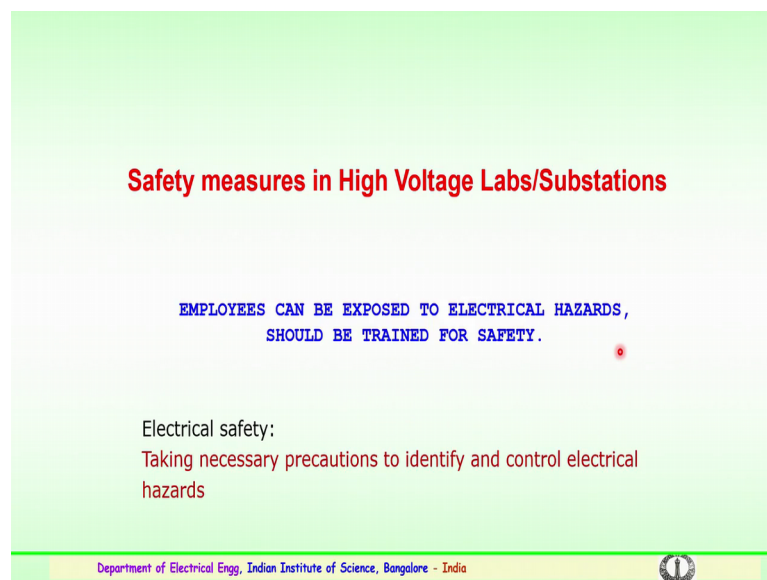


**Advances in UHV Transmission and Distribution**  
**Prof. B Subba Readdy**  
**Department of High Voltage Engg (Electrical Engineering)**  
**Indian Institute of Science, Bangalore**

**Lecture – 31**  
**Precautions and safety measures in substation**

So, good morning. We have a discussed about the substations equipment and also the importance of various substations. The final topic of discussions will be on the safety aspects, which is very important, the safety precautions which have to be followed in a high voltage laboratories or high voltage substations or high voltage transmission by the people of utilities who are working in the high voltage transmission.

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So, any employee or a staff could be a exposed to the electrical hazards. So, these electrical hazards could happen in a high voltage area. So, proper precaution, proper training has to be may available to the staff or employees who are working in the utilities or in the substations. So, electrical safety a measures and taking necessary precautions to identify and control particularly the electrical hazards is of very important concern to the people who are involved in the electrical utility activity. So, we will discuss a few of the important measures which are normally followed as per the standards, and how the safety aspects are important for the performance of the employees in the substations or in the high voltage transmission networks.

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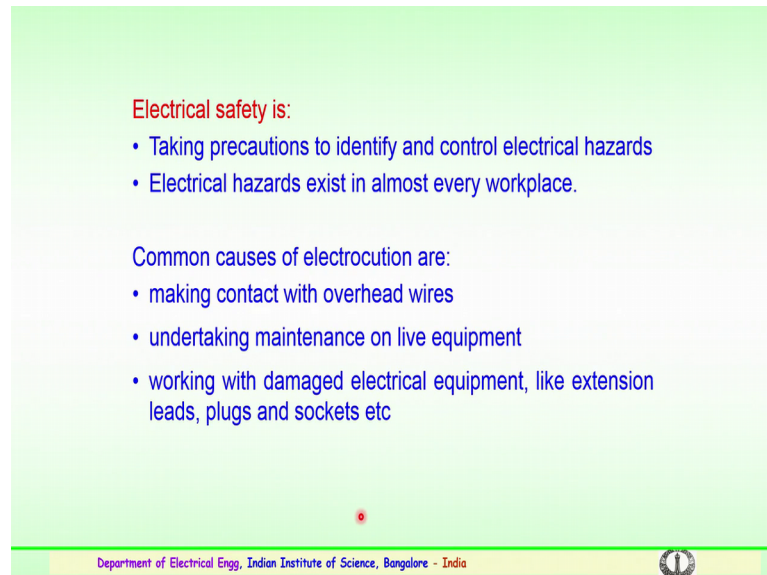


So, these figure shows various types of a safety equipment which are to be normally used in a substation or by the utility personal in functioning and saying that proper protection is taken care. So, there are several equipments which are available in the high voltage substation, it could be a partial discharge safety survey equipments where the discharges from the substation equipment, it could be a transformer it could be bus bars, it could be circuit breakers or it could be any of the equipment where the discharge could be happening. So, such measurements in a substation the about the activity is very important aspect to take necessary cautions about the exposure by the personal who are working in the substation.

The second being the insulated mats insulated ladders, which are normally employed by the person including the insulating gloves people who are working at a very high voltage. So, these will help in proper insulating them when there are working high voltages. So, apart from these insulating gloves, there are there are rescue kits and also there are rescue rods for in case of emergency. So, these could be the earthing kits, various type of earthing rods and earthing clamps which are to be used for grounding the equipment or earthing the equipment during the maintenance when the equipment is to be checked for routings maintenance or the replacement of the parts connected with the equipment. So, various type of detectors for voltage and currents, protective clothing and general information and in case of the work which is being going on proper sign boards are also

to be made available for the proper safety of the people to make aware about the various works which are being undertaken in the substation.

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**Electrical safety is:**

- Taking precautions to identify and control electrical hazards
- Electrical hazards exist in almost every workplace.

Common causes of electrocution are:

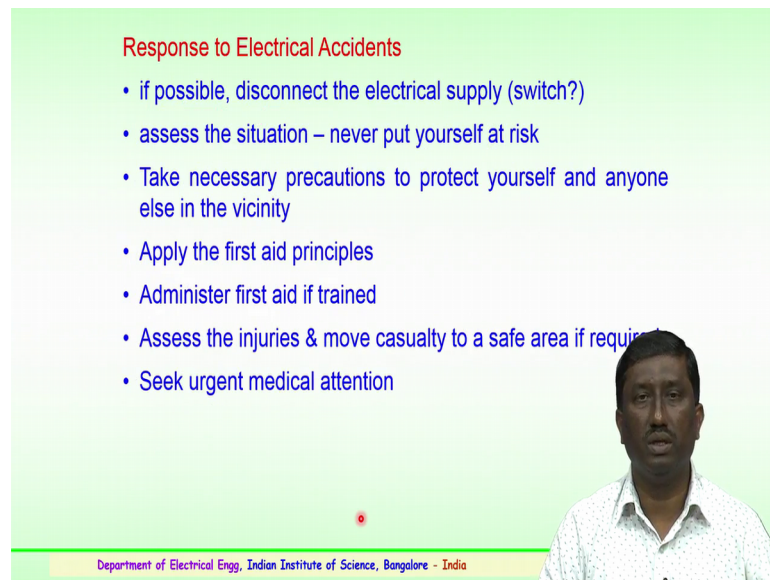
- making contact with overhead wires
- undertaking maintenance on live equipment
- working with damaged electrical equipment, like extension leads, plugs and sockets etc

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So, electrical safety is a very important concern. So, taking necessary precautions in identifying and controlling this electrical hazards is a very important aspects by the utility engineers. So, the electrical hazards could exist in all most any work place, it could be the high voltage related laboratories, or high voltage substation or it could be the electrical networks which has cities, spites or it could be domestic networks where the personals have to attend the regular electrical maintenance work.

So, these hazards could cause some of the common causes could be electrocute a person when he makes contact with the overhead wires conductors. Or during any undertaking of the maintenance a particularly on the live equipment or when working with a damage electrical equipment it could be like the extension of the leads or the conductor where the insulating material has been damaged. And also when is working near the sockets or a plugs where the connection are to the plugs or sockets could have been a damaged. So, these causes of could cause an electrocution to the human who are working in the concerned utilities.

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**Response to Electrical Accidents**

- if possible, disconnect the electrical supply (switch?)
- assess the situation – never put yourself at risk
- Take necessary precautions to protect yourself and anyone else in the vicinity
- Apply the first aid principles
- Administer first aid if trained
- Assess the injuries & move casualty to a safe area if required
- Seek urgent medical attention

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The slide features a light green background with a white rectangular area containing a bulleted list of seven steps for responding to electrical accidents. A small red dot is positioned below the list. In the bottom right corner, there is a video inset showing a man with dark hair and a mustache, wearing a light-colored patterned shirt, looking towards the camera. At the bottom of the slide, a yellow banner contains the text 'Department of Electrical Engg, Indian Institute of Science, Bangalore - India'.

So, the response particularly in case of any electrical accidents, so the other personal who are nearby it is very important a proper response to this accidents have to be made known. So, this could be if possible they have to disconnect the electrical supply which is nearby the main electrical supply that is a switch has to be immediately turned off. The other personal should assess the situation and he should take proper precautions before attempting to save a person. So, he has to insulate himself properly and go near the vicinity of the person whom he likes to help or whom he has to help during the electrical accidents.

So, in case if it is possible he should apply the first aid principles has mentioned in the manual, which is being a trained manual to the substation staff or the electrical utilities staff. He should assess the injuries in case and take immediate action and see that the person is moved to a safe area if required and better to seek immediate urgent medical attention, so that the proper care he is being attended.

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Effect of current levels	
AC current (mA)	Effect on human body
1	Slight tingling sensation
2 - 9	Small shock
10 - 24	Muscles contract causing you to freeze
25 - 74	Respiratory muscles can become paralysed; pain; exit burns often visible
75 - 300	Usually fatal; ventricular fibrillation; entry & exit wounds visible
> 300	Death almost certain; if survive will have badly burnt organs and probably require amputations



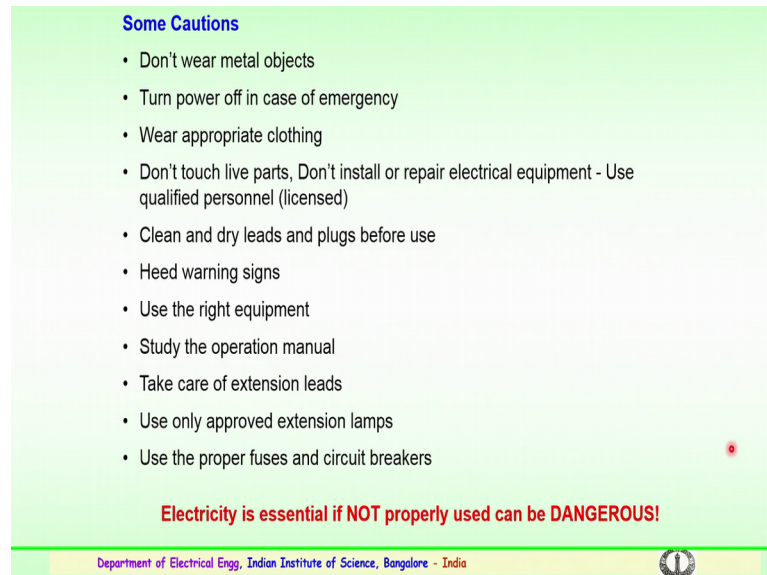
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So, these electrical contacts or electrocution with the humans are could a lead to a various effects on the human body. So, you can see here the table shows the current values in milliamps and the effect to which the human body could sustain. So, any current of a milliamps 1 milliamp flowing into the body could have a slight tingling sensation with the human body when a person comes in contact with the electrical live lines. So, if the current increases or if the current which is passing in to the human body is anywhere between 2 to 9 milliamps a person could experience a shock as minor shock aware he could be seen feeling from the electrical electrocution. So, in case the current exceeds between 10 to 24 milliamps, there is a chance where is muscles could contract and could cause him to freezes.

So, the larger the current above a 10 milliamps is a serious concern; and if it exceeds more than 25 range between 74 milliamps his respiratory muscles could become paralyzed. A pain heavy pain and exit burns often could be visible from the body of the human who has been electrocuted. Above 75 to 300 milliamps it could be a fatal the accident could be a fatal and there could be a ventricular fibrillation entry and exit wounds very clearly visible. And he has to be immediately attended. And any where above 300 milliamps of current passing to the body because of the accidents, it is certain that if person could cannot survive. If in case is survives it will be a badly burnt, the organs could be majorly affected and sometimes you may probably require amputations are that area incase if the contact has happened. So, very important is to see that a proper

precautions, a proper safety, a proper before attending, the job trying to switch of the mains and try to see that no live connections are nearby during the personal at work.

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**Some Cautions**

- Don't wear metal objects
- Turn power off in case of emergency
- Wear appropriate clothing
- Don't touch live parts, Don't install or repair electrical equipment - Use qualified personnel (licensed)
- Clean and dry leads and plugs before use
- Heed warning signs
- Use the right equipment
- Study the operation manual
- Take care of extension leads
- Use only approved extension lamps
- Use the proper fuses and circuit breakers

**Electricity is essential if NOT properly used can be DANGEROUS!**

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So, some important cautions before attending the work in a substation or in any utility is to see that the personal who are had the substation avoid wearing the metal objects in the metal objects could be the wrist watches or some metallic connected with the personal who way any it could be objects which he has which he puts on his body. So, try to avoid the metal objects. And see that the power is turned off in case of emergency. And clothing appropriate insulated clothing particularly person who were working in live line maintenance and in the substations. So, using appropriate clothing is advisable.

And it is advised not to touch the live parts without proper insulating or without disconnecting the electrical equipment, which is connected to. And it is advised to see that any a repair of the electrical equipment or insulation of the new equipment or replacement has to be conducted or has to be performed a by qualified licensed personal. It could be a licensed electrician, who are qualified to working a high voltage substations or a licensed supervising personal who have examination qualified and obtaining the license from the authorities. So, such personal should be allowed to install are repair any electrical equipment in the substation particularly at higher voltage a levels.

It is advisable to see the leads particularly the connections should be properly cleaned and properly plugged before the use. So, contact points should be verified. There should

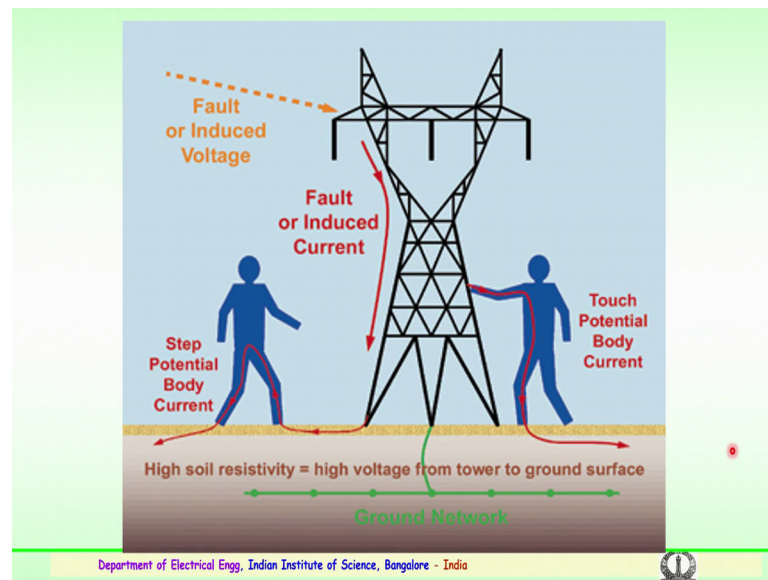
be no loose contacts in the connections, then all the personnel have to heed to the warning signs, which are specified in the standards. And right type of equipment is to be used. The tools and the equipment which are required for the installation or for the operation of that equipment necessary correct equipment have to be used. And the manual which is being available in the substation have to be properly followed particularly related to the safety information and safety conduct of the changes in the substation.

And it is necessary to see that proper care has to be taken when the extension leads or extension connections are required near the equipment. These extension leads or connections have to be properly insulated and see that this do not interfere with the other a live equipment, which are nearby and could create a short circuit or could electrocute person. And in case of the lamps particularly working lamps so proper extension lamps have to be used with the necessary protection particularly when current exceeds there should be proper fuse element or miniature circuit breakers or a circuit breakers to trip the connections during the flow of current or during the flow during the electrocution which could happen.

So, very important precautions which have to be followed in the substations. So, these are some of the precautions there are many which are available in the standard operating manual which is kept in the substation or at the utility points for the staff who are working in the utilities. So, electricity is essential fact, it is a very important requirement of for the humans for the industry for the agriculture activities for many of these aspects, but in case if it is not properly used, it could be dangerous. So, working with electricity has to be very given an at most importance and at most precautions and care has to be followed.



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So, this is one of the example where gives about the step or a touch potential for the human body which he could experience in the field. So, it is advisable to see that personal particularly during the monsoon season because of the lightning activity, it is a advised the personal should not come in contact with the metal tower or a that huge trees or any conducting equipment or the high raised objects. So, this could induced the current and could see that person could be electrocuted during the lightning aspect or because of the wet or a contamination on the surface. If there is a induced current personal is likely to get electrocuted because of the contact which he could be because of either as a step potential as step potential as just example which is shown here.

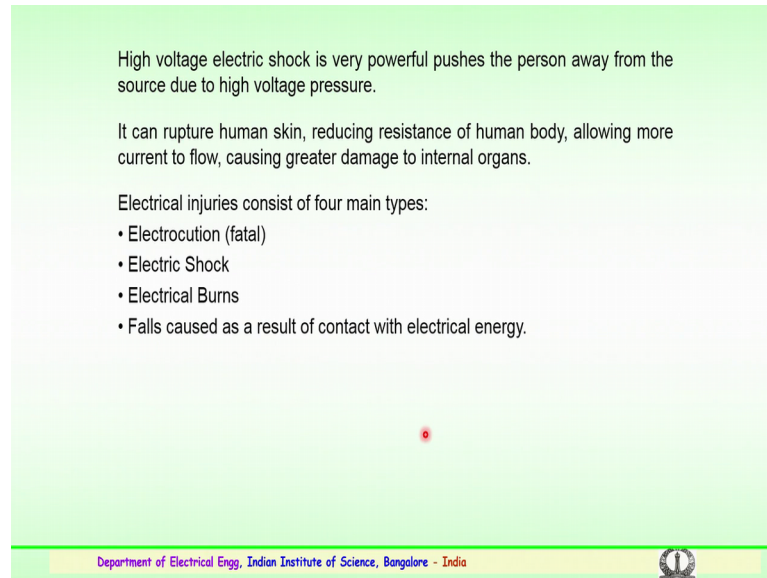
In case there is fault induced, so this fault induced has the current has to go to the ground through proper connecting a media. In case if it happens is on the disturbing the way and if it is not properly earthed they are he could face what is known as the step potential and the potential the currents could flow in to the body of the human. And later could be grounded which is very serious part where a person could be electrocuted.

Similarly, it could be a touch potential where the tower metal object or any other object could be because of the fault induced likely the current could be flowing to the earth in such instance for a person touches the metal object or a tree he could also faced the touch potential and he could experience that. And later it could be he is showing the path for the grounding. So, the it could take the path through his body and later it could be



grounded. So, proper grounding of the equipment and also these types of hazards are likely to happen. So, proper care has to be taken by the personal who are near working near the high voltage tower particularly in substations.

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High voltage electric shock is very powerful pushes the person away from the source due to high voltage pressure.

It can rupture human skin, reducing resistance of human body, allowing more current to flow, causing greater damage to internal organs.

Electrical injuries consist of four main types:

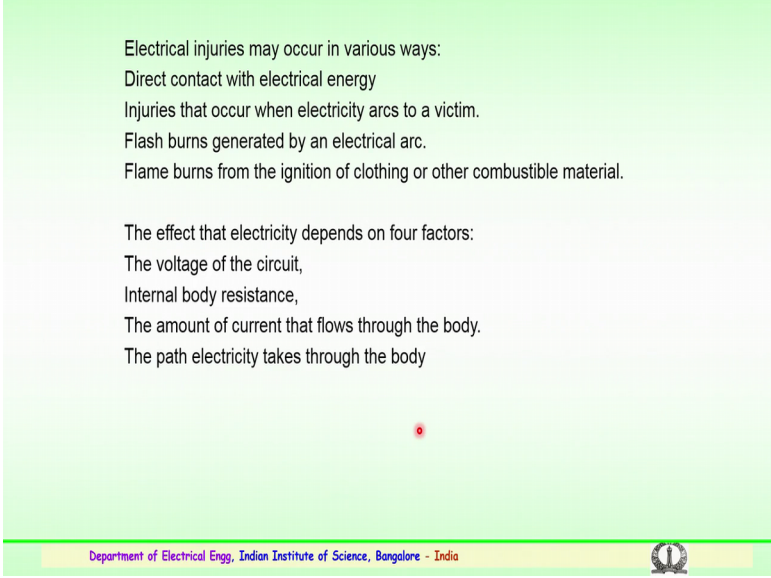
- Electrocution (fatal)
- Electric Shock
- Electrical Burns
- Falls caused as a result of contact with electrical energy.

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So, high voltage shock or electrical shock is a very powerful, which happens and it tries to push the person away from the source due to the high voltage pressure. So, some of the cases, it can because of the shock or electrical high voltage contact person getting contact with the high voltage, it can rupture human skin it could reduce the resistance of the human body during the contact on which could allow more current to flow in his body. And can cause at greater damage to mainly to the internal organs of his body. The electrical injuries consists of four main types this could be electrocution and it could be fatal very serious. There could be an electrical shock which a person could recover it could not be very serious, but shock could feel the affect.

The third could be a major shock contact with the electrical equipment or electrical connection and is there could be what is known as electrical burns on the body of person who comes in contact. And finally, the electrical injuries can cause a result of contact with the electrical energy and the person could fall because of the touch or a step potential when comes in the contact with the equipment.

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Electrical injuries may occur in various ways:

- Direct contact with electrical energy
- Injuries that occur when electricity arcs to a victim.
- Flash burns generated by an electrical arc.
- Flame burns from the ignition of clothing or other combustible material.

The effect that electricity depends on four factors:

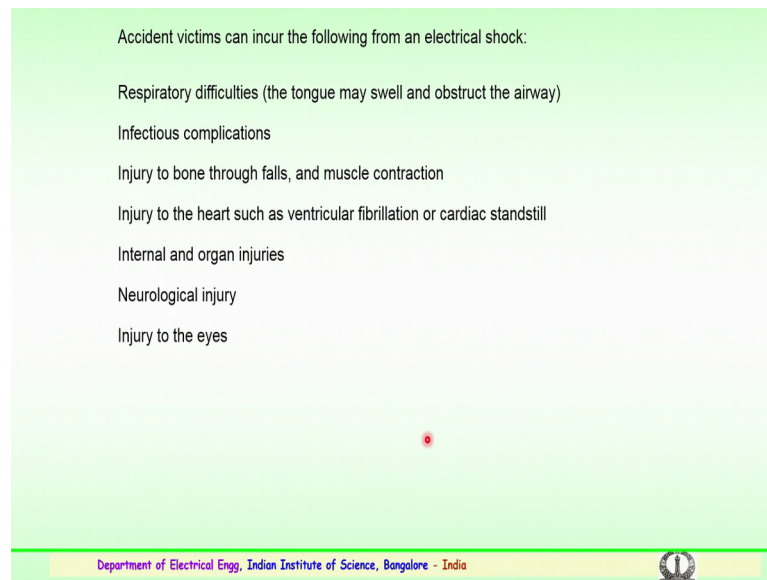
- The voltage of the circuit,
- Internal body resistance,
- The amount of current that flows through the body.
- The path electricity takes through the body

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So, these electrical injuries which could happen during the contact of the live lines or the live equipment by the personal could occur in various ways. It can be because of the direct contact with the electrical sources or electrical equipment or the live line or because of the insulation, which is degraded or because of the damage which could have happened because of the conducting wires. So, these injuries that occur when electricity touches to a victim or could also be because of the flash, burns which could be generated by the electrical arcs particular near the furnish or the person who are working in industries. So, he also could face of burns because of the electrical arcs.

Similarly, flame burns during the ignition could happen on clothing or any other combustible material, which are nearby. So, proper necessary precaution have to be taken for such cases. The effect that electricity depends on electrical injuries, which could happened depends on four factors. The voltage of the circuit at which it is being operated. And the internal body resistance when the person comes in contact. The amount of current that flows during the time through the body when electrocution or he comes in contact with the live equipment. And finally, the path with conduction or electricity takes through the body to the ground. So, the effect depends on these a four factors are the seriousness of the effect could be judge by this parameters.

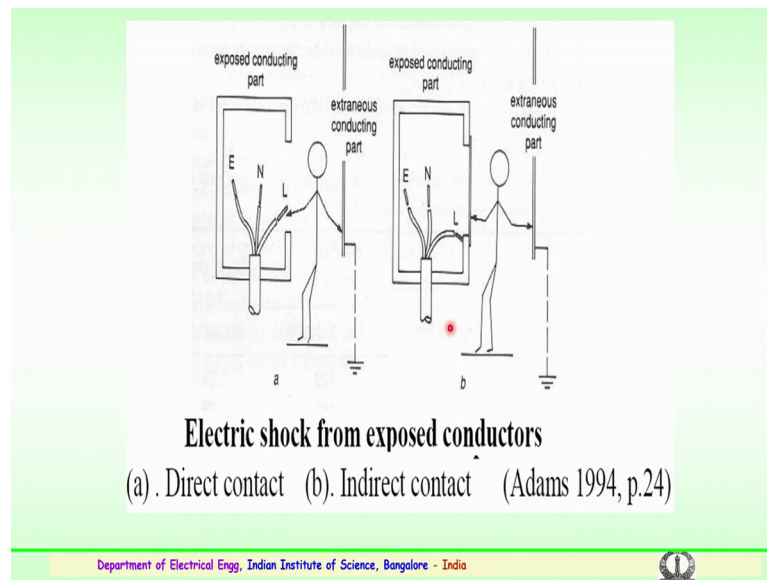
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So, the accident person or a accident victim who comes contact can incur the following from the electrical shocks when he experiences electric shock, these are the some of the experience or he could face the difficulties. It could be the breathing or respiratory difficulty. Sometime if the shock is of a high intensity, his tongue may swell and it could abstract the breathing.

The second being the infectious complication which could develop because of accident. The next could be injury to the bone when you falls or it could be muscle contraction which can happen during the sudden dynamic shock when he experiences by the contact of the live lines. Or it could be the injury to the heart, very dangerous. It could be such as the ventricular fibrillation or the cardiac standstill or cardiac arrest could also happen. There may be injuries minor or major injuries to the internal or other organs in the body. Again this depends on the nature and the magnitude of the shock which a person experiences. There are reports which are experiences a person could have a major neurological injuries or injury to the eyesight injury to the eyes. So, several of these could be incurred depending upon the fatal nature of the person coming in contact with the voltages and the currents which flow in his body.

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To this gives an example of the exposed conducting part, you have a line and neutral and other lead which are open and incase a person comes in contact with the line through the extraneous conducting part the current flows through the body and it is grounded. Similarly, in case of any exposed conducting parts which the exposed conducting part is connected to other equipment or other object in case the person comes in contact with the object he may not be directly come in contact with the line it could be in object, but that is again exposed and connected to the object.

In such cases the same current or the depending upon the nature of the voltage and the current, he gets electrocuted and the current flows through his body via extraneous conducting path and the he could be electrocuted or he could get a electric shock from these type of exposed conductors. So, this could be a direct contact, where a person comes in contact with the live wires or other live conductors. And this is an example of the indirect contact or the person coming in contact with not directly with the live line, but the lines which are touching the equipment or the lines contacting the equipment which a person touches.

So, these are again necessary precaution like using the proper insulating shoes or insulating gloves during the operation, he has to switch off the mains which ones he notices. So, directly touching the conductor is not advisable. A proper gadget have to be

used to verify to check the supply of the lines or the conductors, then he has to attend to the required work.

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**EFFECTS OF ELECTRIC SHOCK**

- 1. Damage and burns to tissue**  
Electric current can result in severe tissue damage through burning. They are mostly third-degree burns, as the burning occurs from the inside of the body where the growth centres are destroyed. If vital internal organs are involved, the burns can be fatal.
- 2. Involuntary muscle contraction**  
Involuntary muscular contraction is an effect of the current. At low currents the contraction may cause the "no-let go" effect where the hand is unable to release a live conductor when grasped. If the lung muscles are affected, respiration might stop and asphyxiation occurs.
- 3. Ventricular fibrillation**  
The last of the body's muscles to be affected are the heart muscles. If the heart is affected, ventricular fibrillation or irregular heartbeats can occur and result in electrocution.

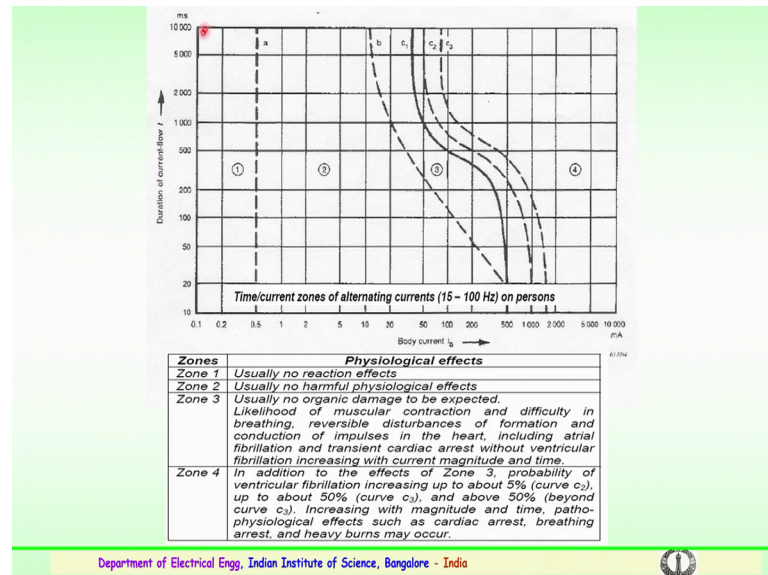
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So, the effects of these shock as earlier also mentioned could damage and burn tissue. This happens because the electric current could result in severe tissue damage as discussed. Some of the hazards which could happen during the shock and damage through the burning there are mostly third degree burning very dangerous as these burning could occur from inside the body when the growth centers are destroyed particularly. If the damage is higher or the magnitude of the shock is very higher, the vital internal organs the burns because of these could cause a fatal to the victim who is coming in contact with such live lines. So, there could also be involuntary muscle contraction this point we try to discuss earlier where because of the dynamic shock a person could experience the muscular contraction in an effect because of the flow of current in the body.

So, as low currents which flow could cause the contraction effect and where hand is unable to release a live conductors sometimes when you comes in contact. If the lung muscle are affected the respiration might stop and the asphyxiation could occur of or a person. The other could be ventricular fibrillation, this point we have seen earlier. The lost of the body muscles which could be affected are the heart muscles. So, in case the heart is affected, the ventricular fibrillation or the irregular heartbeats could occur and it could result in serious fatal accident, where a person could see the functioning of the

heart or there could be an arrest for the functioning of the heart because of the electrocution.

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This curve is important we shows the duration of current flow over a period in terms of milliseconds the time and the x-axis shows the time currant zones particularly for alternating currents AC in the frequency range of 15 to 100 mega hertz which a person experience. So, it is very clear there is a division here 1, 2, 3, 4. So, various divisions or zones have been a categorized. And it is a explained here depending upon the zones say example if the zone 1, if person has experienced this a range of current for a time usually not much of reactions are being seeing by the personal. And this shows the body currents which have been passed the x-axis shows a body currents and this duration the time has to mention. So, in case the body currents happened to be very, very less that is 0.5 milliamps or less than that not much of feeling could be observed in patient or a person.

In case zone 2, it is between 0.5 to 5 milliamps. So, usually they are could experience a shock, but it could not be very harmful or no psychological affects could be observed in persons experience in this category. But in case of 3, anywhere between 10 to say 500 micro amps that is a zone three usually no organic damage could be expected here currents could not cause serious injury. And it could likelihood be muscular contraction and sometime difficulty in a breathing where reversible disturbance of formation and conduction of impulse in the heart could be felt, including artillery fibrillation and

transient cardiac arrester arrest without ventricular fibrillation which could increase the current magnitude and time. So, these effects could be observed in a person experiencing in the currents during the contact were currents flow the zone 3.

In case of zone 4, in addition to effect of all the above there is particularly in zone 3, the probability of ventricular fibrillation increases more than 5 percent. By observing the curve 2, you can see here the curve 2 is here and curve 3 and curve 1 up to about 50 percent in case of curve 3 and above 50 percent beyond curve 3, this is the curve 3, above 50 percent. So, once the curve increases be beyond this, there should be there could be any increase of the activity or the effect of ventricular fibrillation could increase as per the percentage mentioned. So, this could increase the pathological effects such as the cardiac arrest or major breathing problem the breathing arrest and heavy burns could occur to the patient. So, this gives an importance information for the exposure to the body over period of time.