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Ensuring safety and Protection against Electrical hazards

Abstract

The risks associated with electrical hazards will remain a thing of concern to all, this fear is not unconnected with alarming number of injuries or even fatalities involving both specialist and non-specialist documented every year from electrical accident across the country.

This paper analyses the various types of hazards from dangers of electrical shock to exposure to electrical and magnetic fields and contact with hot surface and electric arc are considered, and their pathophysiological, biological and health effects. It recommends a number of solutions in respect to protection against these dangers by prioritizing safety issues, strict adherence to standards and regulations, regular maintenance and upgrading of electrical equipment. It also examines the existing equipment and procedures in alleviating these problems and believe that if they are strictly comply with and adhere to, the upsetting dangers will be minimal.

Keyword: Hazards, Safety, Protection, Health effects and Regulation

1.1 Introduction

Electrical mishaps cause millions of injuries every year, involving both professionals and non-professionals all over the world some of these accidents are caused by indoor installations, whereas the other series of causes cover contact with overhead lines or lightning [1]. Electric current passing through the body can lead to two major effects of tetanisation of the hands on the part with which contact was made by not letting go of the person, or on the contrary occurs with the person's muscles relaxing, causing him to be thrown back, with the attendant danger of injury resulting from falling off a ladder. Although accidents can be connected with recklessness or carelessness, but most at times, it is the bad state of connections or equipment that causes the risk. Adherence to legal obligations to guarantee safety is the route to the assurance of protection, provided that maintenance and upgrading are done properly; unfortunately, there is no legal obligation providing for this. So the significance of guaranteeing that we are all conscious of the risks lies in the necessary regulatory framework. The protection of person in relation to the risks identified must take precedence position at every stage of any project and during the design period, all the installation calculation rules based on the relevant guidelines must be complied with, while at the installation phase the choice of reputable and safe materials must be ensured to guarantee proper performance and lastly at the operating phase ,the precise instructions for handling and emergency work should be well defined with concise maintenance plan and continuous training of personnel.

Electric current is hazardous since it cannot be seen. Its effects on individuals are already familiar to us to enable effective protection from it. The danger can affect the equipment itself and the surrounding property and must form the topic for an investigation that can lead to the implementation of the most suitable protection solutions. The effects of electric current on the body is dependent on two things: the period of the current flow through the body and the strength and frequency of the current and these two issues are detached from each other, but the intensity of risk will vary in accordance to the level of each factor. The strength of the current that is unsafe for body depends on the voltage and the resistance of the human body. In practice, the intensity of the current is defined based on a limit voltage, taken as being 50 V. This voltage takes into consideration the peak current that a human being with minimum internal electrical tolerance can bear, under define conditions. It also takes into account the maximum admissible period of the current flow through the body, with no risky of physio-pathological effects or cardiac fibrillation.

2.0 Related work

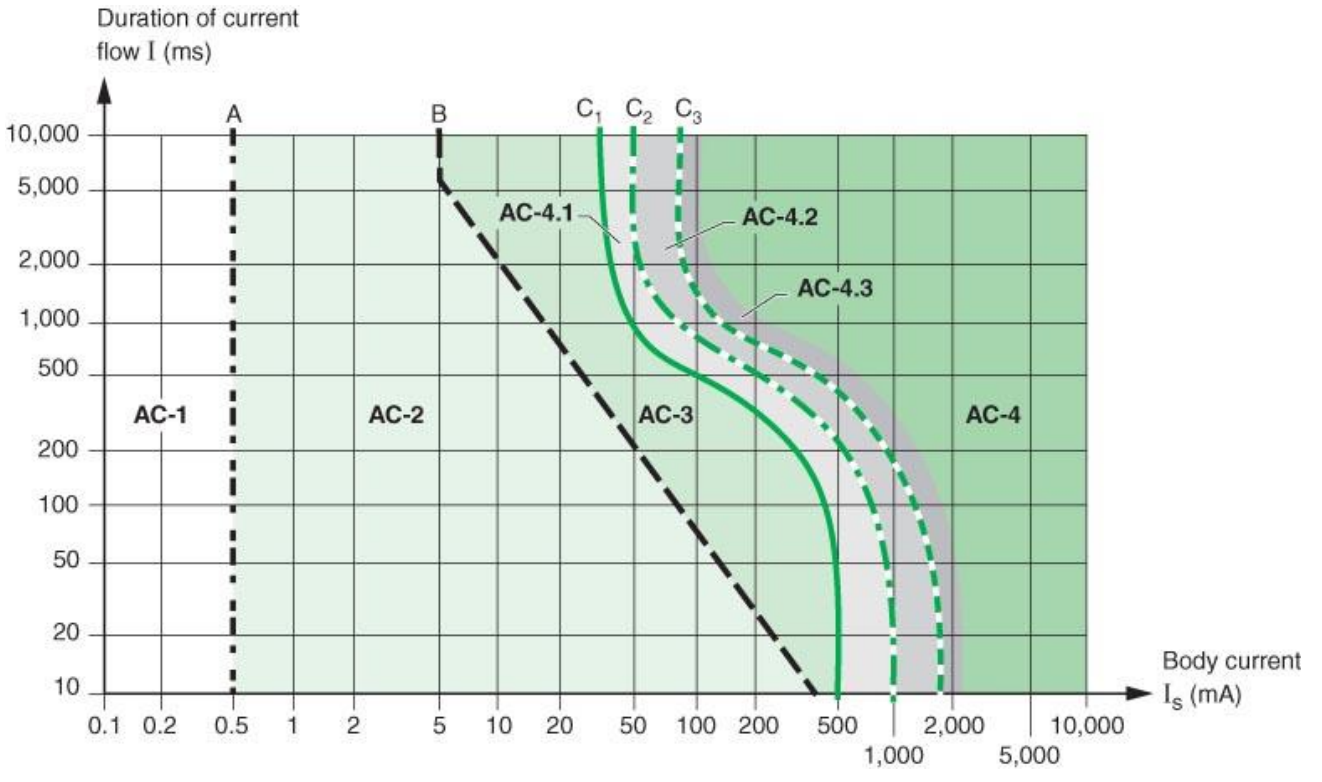
When exposed to electrical current, the human body responds like a standard receiver that has a given internal tolerance. Electric current flowing through the body has some grave consequences that include tetanisation whereby the current constricts the muscles after passing through, and if this involves the ribcage, this can cause to respiratory failure, ventricular fibrillation which is a complete disruption of the cardiac beat and thermal effects leading to varying extents of tissue damage and severe burns. The table 1 show a touch voltage of 220 V, a current of 147 mA will pass through the human body; this current must therefore be broken in less than 0.18 seconds to avoid any risk. These two factors are taken into considerations when assessing the hazard; the specifications define the time over current limit curves.

Prospective touch duration voltage of flow U_C (V)	Electrical impedance of the human body Z(Ω)	Current flowing through the human body I(mA)	Maximum duration of flow t(s)
≤ 25	[1075]	[23]	∞
50	1725 [925]	29 [54]	∞ [0,48]
75	1625 [825]	46 [91]	0,60 [0,30]
100	1600 [800]	62 [125]	0,40 [0,22]
125	1562 [762]	80 [164]	0,33 [0,17]
220	1500 [700]	147 [314]	0,18 [0,05]
300	1460 [575]	205 [521]	0,12 [0,025]
400	1425	280	0,07
500	1400	350	0,04

Table 1: Maximum breaking time according to prospective touch voltage

(values in brackets are for double contact, both hands, both feet) (UTE C 15-413)

The curves, gotten from IEC 60479-1, give the different limits of the effects of 50 Hz alternating current on humans and define 4 main risk zones [2]. See table 2 for the curve below:



AC-1 zone: Imperceptible A curve: Threshold of perception of current

AC-2 zone: Perceptible B curve: Threshold of muscular reactions

AC-3 zone: Reversible effects: muscular contraction C_1 curve: Threshold of 0% probability of ventricular

AC-4 zone: Possibility of irreversible effects fibrillation

AC-4-1 zone: Up to 5% probability of heart fibrillation C_2 curve: Threshold of 5% probability of ventricular

AC-4-2 zone: Up to 50% probability of heart fibrillation

AC-4-3 zone: More than 50% probability of heart fibrillation C_3 curve: Threshold of 50% probability of ventricular fibrillation

An electric shock is the pathophysiological effect of an electric current through the human body. Its passage affects essentially the muscular, circulatory and respiratory functions and sometimes results in serious burns. The degree of danger for the victim is a function of the magnitude of the current, the parts of the body through which the current passes, and the duration of current flow.

2.1 Electric Arcs

This can lead to very harmful effects on equipment and installation, the risks of an electric arc outweighs all thermal and light-related or intense flash dangers. The electric arc may result from the breaking or making of an electric circuit or during short-circuit. For the second situation, it can be very high-energy as it is only restricted by the power from the mains.

2.2 Risk of Burns

The danger of burns can only be appraised, after taking into account the temperature of the contact surface, the metallurgical material with which the contact surface is produced with and the length of time the contact was made. Other facts, such as shape, the presence of a covering, or the contact pressure, may be important before the evaluation. There is no particular protection against electric arcs, which are an unpredictable phenomenon although shields can reduce their effects, but the paramount thing to do is apply the preventive rules by to adhering to the best professional practice and conform to the regulations when designing installations. The parts of equipment that are not secure must be subjected to specific precautionary procedure so as to decrease the chance of short-circuit.

2.3 Exposure to electromagnetic fields

At present, guidelines on exposure to electromagnetic fields have not been synchronized globally. Several epidemiological investigations have been conducted and have made deductions that are at times inconsistent or at the same time controversial. Many papers and analyses are available on the topic.

- **Low Frequency Magnetic Fields of Less Than 10 MHz**

Low frequency magnetic fields of less than 10 MHz are generated by currents and are related to the strength of the currents, they produce currents in the body that are at right angles to the magnetic field and the levels of the magnetic field vary from a few picotesla to a few millitesla. The exposure limit decreases very quickly with the cube of the distance and the maximum exposures can consequently be gotten with electrical device used very near to the body like electric razors, electric blanket and others.

- **Low Frequency Electric Fields of Less Than 1 MHz**

Low frequency electric fields of less than 1 MHz is fluctuated on the surface area of the body and it is related to the conductivity of the body with the strength of the field being in its crest at the head and it produces currents straight in line with the body. The degree is at the peak near high voltage power lines and transformers, welding machines and induction furnaces). The electric field is not directly proportional to the square of the distance. The arrival of information technology in every segments of the society like in voice, data and image transmission, mobile phone, television, etc. have expanded the spectrum of use towards high frequencies in all areas of daily.

- **High Frequency Electromagnetic Fields (Greater Than 1 MHz)**

In this range we are approaching the frequency in which the transition gap between near field and far field is important. Above this point, the electric and magnetic components are combined which is called the plane wave, and this is normally the case in respect to a fixed transmitter and lower than this point, the electric and magnetic fields must be studied independently and this is done with transmitters which are very close to human body for example when the mobile phone is pressed to the ear. For these frequency ranges, the boundaries that are set are intended to prevent generalised or localised thermal stress of the body, which would lead to excessive heating of the tissue.

Propagation of electromagnetic radiation also called specific Absorption Rate by definition is the amount of energy in a given time which is also the power absorbed per unit mass of tissue and it is measured in W/kg. The level allowable for the limbs which is 20 W/kg is for example is higher than that for the trunk and the head that is 10 W/kg [3]. Persons with medical implants must inform the company doctor of this case so that the real exposure states for both magnetic field and electric field and their compatibility can be verified. Biological effect represents the body’s sensory response to a stimulus. [3] It is not really hazardous to health but sweating is a form of biological symptom can indicate fear. Electromagnetic fields can lead to biological effects they are associated with the induction of currents in the human body, and the manifestation of thermal effects. Up to the present time, detrimental health effects owing to exposure to non-ionising electromagnetic fields, even for lengthy periods, have never been verified. The current application of complex signals such as pulsed, multi-frequency, transient, and also, slightly illogically, the constant exposure to very low levels fields has reawakened investigation and discussion on the subject. Hence, it is vital not to mistake biological effects and health effects, despite the fact of our current state of comparative unawareness of so broad and complex a subject, discretion must prompt a good judgment in everyone's attitude of the types of radiation which make up the magnetic spectrum since only those with the highest frequencies that is the cosmic rays that do not reach earth, gamma rays emitted by radioactive sources and x rays have the property of being able to break chemical bonds.[4]. These are called "ionising". Electromagnetic fields created by man in industrial activity, radio transmissions and communications, and even microwave frequencies of radar systems are in relatively low frequency ranges in relation to the whole range of the electromagnetic spectrum.[5].The quantum energy they transport is not able to break intra-molecular bonds: these are the non-ionising.

3.0 Methodology

3.1 Protection against Electrical Hazards

This requirement needs to apply under normal and single fault conditions and various measures are adopted to protect against this hazard, which include automatic disconnection of the power supply to the connected electrical apparatus. Additional arrangements involves the use of class II insulation materials, or an equivalent level of insulation, non-conducting location, out of arm's reach or interposition of barriers, equi-potential bonding and electrical separation by means of isolating transformers .

3.2 Direct and indirect contact

Two methods of protection against direct contact hazards are usually required, since, in practice, the first measure may not be reliable. A direct contact refers to a person coming into contact with a conductor which is live in normal circumstances. An indirect contact implies to a person coming in contact with an exposed conductive part which is not normally alive, but has become alive fortuitously due to insulation breakdown. or for some any other reason cause as a result of inadequate "protection against indirect contact" with the term "fault protection".

This protection consists of an insulation which complies with the relevant standards and by means of fences or enclosures This measure is in common use, since many components are installed in cabinets, control panels and distribution boards and to provide an effective protection against direct contact, these apparatus must have a degree of protection to meet standard demand. Additionally, the door of the enclosure must only be open by means of a key provided for this purpose, or after complete isolation of the live parts in the enclosure, or with the automatic interposition of another screen removable only with a key or a tool. The metal enclosure and all metal removable screen must be bonded to the protective earthing conductor of the installation.[9]

Another means of protection is by obstacles, or by placing out of arm's reach and this protection is reserved only to locations to which skilled persons only have access. Although protective measures are preventive, but several purposes they cannot be regarded as being reliable because of lack of correct maintenance, recklessness, sloppiness, deterioration of insulation; for example flexure and scrape of connecting leads, unintentional contact, submersion in water and so on that can lead to loss of insulation.

3.3 Protection by use of residual current devices (RCD)

In order to protect users in such circumstances, highly sensitive fast tripping devices, based on the detection of residual currents to earth are used to automatically disconnect the supply automatically, and with adequate speed to avert injury or even death by electrocution. These devices works on the theory of differential current magnitude, in which any change between the current entering a circuit and that leaving it is allowed to flow to earth. Residual current devices continually measure the difference between the value of the outgoing and incoming currents in the circuit they are protecting and if this difference is not equal to zero, that means there is a leakage current or a fault current. When this current's value reaches the residual current device's set threshold, it automatically cuts off the circuit's power supply An additional measure of protection against the hazards of direct contact is provided by the use of residual current operating device (RCD),

Protection against indirect contact hazards can be achieved by automatic disconnection of the supply if the exposed-conductive-parts of equipment are properly earthed and two levels of protective measures exist that includes the earthing of all exposed-conductive-parts of electrical equipment in the installation and the constitution of an equipotential bonding network and automatic disconnection of the supply of the section of the installation concerned, in such a way that the touch-voltage/time safety requirements are respected for any level of touch voltage and touch voltage is the voltage existing as the result of insulation failure between an exposed-conductive-part and any conductive element within reach which is at a different potential.

The greater the value of touch voltage, the greater the rapidity of supply disconnection required to provide protection and The highest value of touch voltage that can be tolerated indefinitely without danger to human beings is 50 V CA.

3.4 Protection by of circuit-breaker

While protecting with circuit-breaker, it is important to ensure that the fault current will always exceed the current-setting level of the instantaneous or short-time delay tripping unit.

The instantaneous trip unit of a circuit-breaker will remove short-circuit to earth in less than 0.1 second. In consequence, automatic disconnection within the maximum allowable time will always be assured, since all types of trip unit, magnetic or electronic, instantaneous or slightly retarded, are suitable: Ia = Im. The maximum tolerance authorised by the relevant standard, however, must always be taken into consideration. It is sufficient therefore that the fault current can be determined by calculation (or estimated on site) be greater than the instantaneous trip-setting current, or than the very short-time tripping threshold level, to be sure of tripping within the permitted time limit.

- **Protection by Safety Extra-Low Voltage (SELV)**

Safety by extra low voltage SELV is used in cases where the working of the electrical apparatus poses a grave danger like in swimming pools, amusement parks, etc. This protection depends on supplying power at extra-low voltage from the secondary windings of isolating transformers especially designed in compliance to international standard. The impulse withstands level of insulation between the primary and secondary winding is very high, an earthed metal shield is at times incorporated between the windings. The secondary voltage never exceeds 50 V rms. The conditions of its utilization that must be comply to in order to provide adequate protection against indirect contact are no live conductor at SELV must be connected to earth , exposed-conductive-parts of SELV supplied equipment must not be connected to earth, to other exposed conductive parts, or to extraneous-conductive-parts all live parts of SELV circuits and of other circuits of higher voltage must be separated by a distance at least equal to that between the primary and secondary windings of a safety isolating transformer.[11]

These require that SELV circuits must use conduits specially provided for them, unless cables which are insulated for the highest voltage of the other circuits are used for the SELV circuits and socket outlets for the SELV system must not have an earth-pin contact. The SELV circuit plugs and sockets must be special, so that unintentional connection to a different voltage level is not possible. In normal conditions, when the SELV voltage is less than 25 V, there is no need to provide protection against direct contact hazards.

- **Protection by Extra Low Voltage (PELV)**

This system is for common use where low voltage is required, or preferred for safety reasons, other than in the high-risk locations noted above. The idea is similar to that of the SELV system, but the secondary circuit is earthed at one point. Protection against direct contact risks is required, apart from when the equipment is in the zone of equipotential bonding, and the nominal voltage does not go above 25 V rms, and the equipment is used in places that are not wet only, and large-area contact with the body is not likely. In all other situations, 6 V rms is the maximum allowable voltage, where no direct contact protection is made available.

- **Protection by Functional Extra-Low Voltage (FELV) system**

Where, for functional reasons, a voltage of 50 V or less is used, but not all of the requirements relating to SELV or PELV are fulfilled, appropriate measures must be taken to ensure protection against both direct and indirect contact hazards, according to the location and use of these circuits[9]. Such situations can occur when the circuit contains equipment like a transformers, relays, remote-control switches, contactors that have been not sufficiently insulated with regard to circuits at higher voltages.

3.6 Protection by electrical separation of circuits

The electrical separation of circuits is suitable for relatively short cable lengths and high levels of insulation resistance. It is preferably used for a separate device. The theory of the electrical separation of circuits for safety rationales is based on the following underlying principle. The two conductors from the unearthed single-phase secondary winding of a separation transformer are insulated from earth. If a direct contact is made with one conductor, a very small current only will flow into the person making contact, through the earth and back to the other conductor, via the inherent capacitance of that conductor with respect to earth. Since the conductor capacitance to earth is very small, the current is generally below the level of perception. As the length of circuit cable increases, the direct contact current will gradually rise to a point where a hazardous electric shock will be felt.[9] Even if a short length of cable prevents any danger from capacitive current, a low value of insulation resistance with respect to earth can result in danger, since the current path is then through the person making contact, via the earth and back to the other conductor through the low conductor-to-earth insulation resistance, this is why comparatively little lengths of well insulated cables are used in separation systems. Transformers are specially made for this function, with a high degree of insulation between primary and secondary windings, or with equivalent protection, such as an earthed metal screen between the windings. Construction of the transformer is to class II insulation standards. As stated earlier, effective use of the principle require that no conductor or uncovered conductive part of the secondary circuit must be connected to earth, The length of secondary cabling must be regulated to avoid large capacitance values and most importantly a high insulation-resistance value must be maintained for the cabling and appliances.

These specifications normally limit the use of this safety procedure to an individual device. In the situation where several devices are supplied from a separation transformer, it is necessary to note the following conditions that the exposed conductive parts of all devices must be joined together by an insulated protective conductor, but not connected to earth, the socket outlets must be provided with an earth-pin connection. The earth-pin connection is applied in this situation only to ensure that the interconnection or bonding of all exposed conductive parts [9]. It is suggested that the product of the nominal voltage of the circuit in volts and length in metres of the wiring system should not exceed 100,000, and that the length of the wiring system should not exceed 500 m.

- **Protection by Class II equipment**

These appliances are also referred to as having "double insulation" since in class II appliances a supplementary insulation is added to the basic insulation. No conductive parts of a class II appliance must be connected to a protective conductor and some equipment are designed to have double insulation. It is vital to take special caution in the use of class II equipment and to check frequently that the class II standard is maintained. Electronic appliances have safety standards equivalent to class II, but are not strictly class II devices

- **Out-of-arm's reach or interposition of obstacles**

When this method of protection is applied, the chance of having contact with a live exposed-conductive-part, while at the same time touching an unconnected -conductive-part at earth potential, is very small. Safety by placing simultaneously-accessible conductive parts out-of- arm's each, or by inserting obstacles, requires also a non-conducting floor, and so is not an easy practical method. This method can only be practically used in area that is not wet, and is applied in line with the following stipulations that the floor and the wall of the chamber must be non-conducting, that is the resistance to earth at any point must be greater than50 kΩ for installation voltage of less than or equal to 500 V and for resistance greater than 100 kΩ for installation voltage between 500V and 1000V. The placing of equipment and obstacles must be such that simultaneous contact with two exposed-conductive-parts or with an exposed conductive-part and an extraneous-conductive-part by an individual person is not possible.[11]

No exposed protective conductor must be introduced into the chamber concerned and entrances to the chamber must be arranged so that persons entering are not at danger, e.g. a person standing on a conducting floor outside the chamber must not be able to reach through the doorway to touch an exposed-conductive-part

- **Protection with Earth-free equipotential chambers**

Earth-free equipotential chambers are associated with specific installations like laboratories, etc. and In this system, all uncovered -conductive-parts, including the floor are bonded by suitably large conductors, such that no substantial difference of potential can be between any two points. A failure of insulation between a live conductor and the metal envelope of a device will result in the whole “cage” being raised to phase-to-earth voltage, but no fault current will flow. In such cases, a person entering the chamber would be at danger since he would be stepping on to a live floor. Appropriate preventive measure must be chosen to safeguard people from this risk for example the provision of non-conducting floor at entrances. Special protective apparatuses are also important to identify insulation breakdown, in the absence of substantial fault current.

4.0 Conclusion

Complete protection is never possible and the best safety approach entails finding reasonable and well thought-out compromises in which precedence is given to safeguarding persons. The protection of people in relation to the risks identified must be a priority consideration at every step of any project.

Electrical safety audit is an effective tool in identifying and perusing a comprehensive safety management program. A properly designed, planned and executed safety audit can bring out many hazards that could save life and property of the organization. An auditor is expected to help the auditee to identify the potential electrical hazards, to make the auditee understand the consequences and also to help them through the process of implementation of electrical safety recommendations.

This study could be significantly useful for an industry for minimizing essential energy cost and also raps several other benefits like improved production, better quality, higher profit and most important satisfaction of heading towards developing electrical hazards. The improving quality of equipment, changes to standards and regulations, and the expertise of specialists have all made electricity the safest type of energy. However, it is still essential to take account of the risks in all projects. Of course, expertise, common sense, organisation and behaviour will always be the mainstays of safety, but the areas of knowledge required have become so specific and so numerous that the assistance of specialists is often needed.

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