ELECTRICAL SAFETY IN HEALTHCARE FACITILIES

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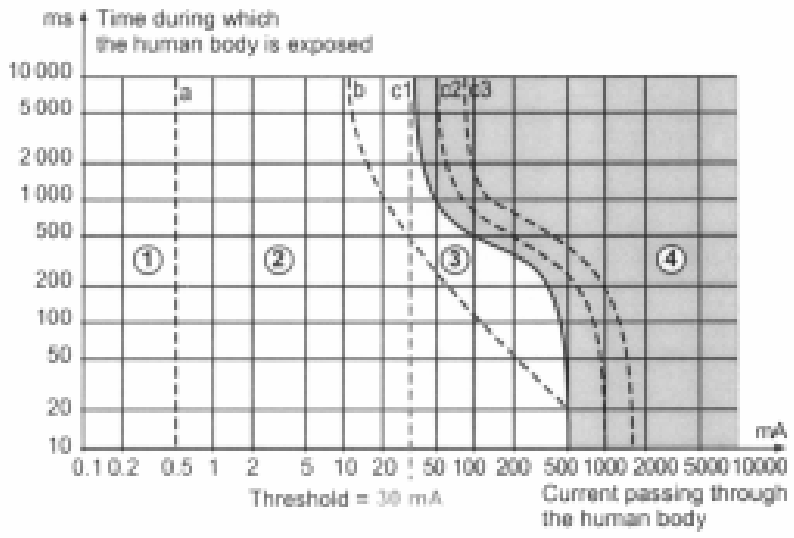
ABSTRACT

The increasing use of electrical diagnostic and treatment equipment in healthcare facilities has focused worldwide concerns upon electrical safety in healthcare facilities. This article gives an overview of the safety measures recommended by various national and international agencies through their standard specifications.

INTRODUCTION

The objective of this article is to highlight appropriate measures for a high level of electrical safety in healthcare facilities.

Most of the equipment used in healthcare facilities are electrically operated, such as; ECG machine, bedside monitor, anesthesia machine, ventilators, catheter machine, suction machine , laboratory equipment, radiology equipment (X-ray, C.T Scan, ultrasound, mammography etc) , incubators, infant warmer etc. As these equipments are often in contact with the staff or patient, the danger of



Zone 1: Perception
Zone 2: Considerable Discomfort
Zone 3: Muscular Contractions
Zone 4: Risk of Ventricular Fibrillation (cardiac arrest)
C2: Likelihood < 5%
C3:Likelihood ⩾ 50%

Figure 1: Time/Current Zones of AC Effects (15 Hz to 100 Hz) on Persons as in IEC 60479-1

electrical hazard always persists in such environment. According to the gravity of the Electric Shock and its duration, a person may experience:

- comfort
- muscular contraction
- a burn
- cardiac arrest (electrocution)

Time/Current relation with respect to human body is shown in Figure1.

The Current, in value and time, passing through the human body (particularly the heart) is the most dangerous aspect of electricity. In low voltage system, the impedance value of the body (an important aspect of which is skin resistance) changes according to environment i.e. dry and wet premises and damp premises.

Patients are particularly vulnerable when their natural protection is considerably reduced, especially when clinical procedures are in progress. With skin penetration giving a low resistance path or a low defense due to medication, or no defense due to anesthetic, the possibility of an electrical shock hazard under a fault condition is greatly enhanced.

In addition, during open heart surgery and when catheters are in use, great care has to be exercised to minimize leakage currents which may flow in a patient. Broken equipment earth connections offer greatest danger to the patient.

Various national and international standards address the requirements for electrical installations in healthcare premises, especially those in critical care areas. All with the objective to ensure the safe and reliable supply of power to patient connected medical equipment, especially life support equipment.

IMPORTANT MEASURES FOR ELECTRICAL SAFETY IN HEALTHCARE FACILITIES

SELECTION OF CORRECT POWER SUPPLY SYSTEM

It is important for patient safety, especially in operation theatres and ICU etc that a safe and secure source of power supply is available at all times. Essential power systems are designed to provide power, even in the event of mains failure. A secure local power system arrangement, which will not trip out even when a final sub-circuit supplying these areas suffers a first earth fault, is a further recommendation for these areas.

Type of power supply system used in a hospital is either TN-S (earthed) or IT (unearthed), based on the procedures carried out and/or medical equipment used in the area under consideration. These systems are briefly described as follows:

i) Use of TN-S System:

The TN-S system has separate neutral and protective conductors throughout the system and exposed conductive parts of the equipment are connected to the earthing conductor of the supply system. The TN-S system is shown in figure 2.

The use of the TN-S system (earthed system) in operating theatres is only considered acceptable for fixed equipment or non-critical equipment to patient life support or patient connected because first fault tripping of a protective device leads to an unannounced loss of power. Therefore, the TN-S system in combination with a Residual Current Device (RCD) must only be used for following devices:

- permanently installed or mobile x-ray equipment
- devices with a connected load > 5 KW
- room lighting (not theatre)
- operating theatre table

In addition, the use of a Residual Current Monitor (RCM) is also recommended. The RCM is able to detect small leakage currents before the RCD trips.

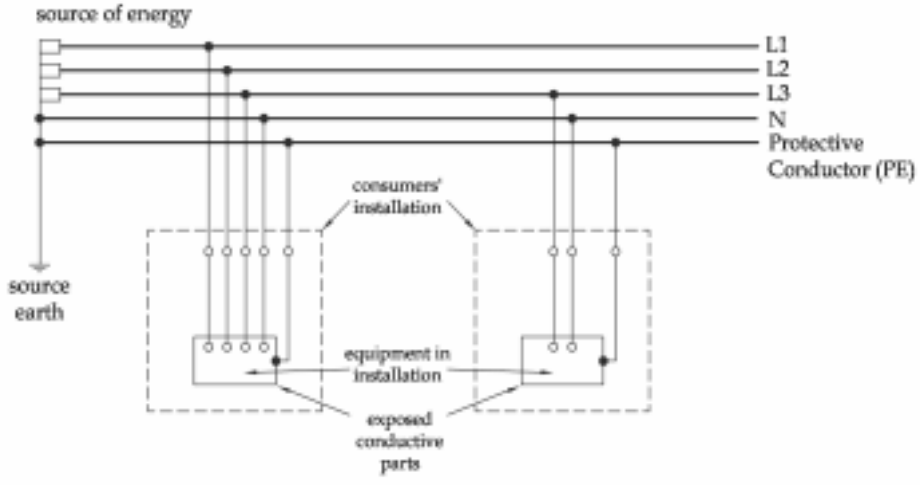


Figure 2: TN-S System: Separate Neutral and Protective Earthing Conductor Throughout

ii) Use of IT system:

IT system has no direct connection between live parts and earth and the exposed conductive parts of the equipment are earthed separately. In other words, the equipment is isolated from source earth. The IT system is shown in Figure 3.

The most common way to get an unearthed system from an earthed supply system is to use an Isolating Transformer with a ratio of primary winding to secondary winding as 1:1. As there is no direct connection between the primary coil of the transformer and the secondary coil of the transformer, the supply on the secondary side is completely isolated from the earthed system of the primary side. Since the current can not flow from either conductor of the isolated system to earth, there is no hazardous potential to ground in this system.

This system, being safer and more reliable, has been recommended by almost all internationally known standards for the critical areas such as Operating Theatres, Intensive Care Units (ICU),Coronary Care Units(CCU) and Emergency Room etc.

The use of ungrounded power supply system may be desirable for the following reasons:

- It improves the reliability of power supply in areas where power failure may cause safety hazards to patients and users.
- It reduces the leakage currents of devices to a low value, thus reducing the touch voltage of the protective conductor through which the leakage current may flow.

Internationally, the following three monitoring devices are used in an ungrounded system:

a. Monitoring of resistance with Insulation Monitoring Device (IMD)
b. Monitoring of impedance through Line Isolation Monitor (LIM)
c. Monitoring of load and temperature

The monitoring devices are briefly described as follows:

Resistance Monitoring With IMD

The IMD continuously monitors the insulation resistance between the active phase conductors and earth and reports a certain drop below a set value of the IT system. The IMD is able to sense a developing insulation fault at an early stage and to provide an alarm at an adjustable set-point, thus providing an improved level of safety. The alarm is raised visually and via a mutable audible alarm at the patient location.

Impedance Monitoring Through LIM

The LIM monitors the impedance of the conductors to earth. It is designed in such a way that a green LED alarm lights up when the system has reached sufficient impedance to earth. The red LED alarm lights up and sounds an audible warning signal as soon as the prospective fault current (consisting of resistive and capacitive leakage currents) of an ungrounded power supply system reaches the threshold of 5 mA (2 mA in Canada). Means are provided for re-setting the audible warning signal while leaving the red alarm LED activated. When the fault is eliminated and the green LED alarm lights up again, the audible alarm is automatically reset.

Load and Temperature Monitoring

To avoid overloading the isolating transformer a respective installation must be designated in order to protect the transformer and supply conductors between primary and secondary terminals and the distribution bus from overloading or overheating. When rated current or temperature is over ranged, an acoustic or optical alarm is released.

SAFETY THROUGH REDUNDANT POWER LINES

The system is supplied by two cables; in the event of the failure of first cable, the system automatically switches over to the other redundant source. The second cable

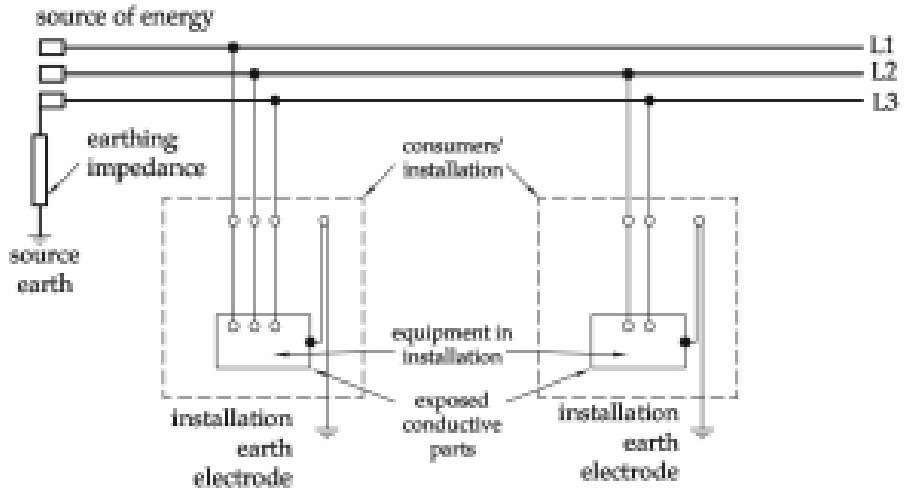


Figure 3: IT System: The Source is either Connected to Earth Through a Deliberately Introduced Earthing Impedance or Isolated from Earth. All Exposed Conductive Parts are Connected to Earth Electrode

derives the power from a safety power source backed up by batteries of Uninterruptible Power Supply (UPS). That ensures the supply of life-supporting devices, independently from the utility network and the emergency generator.

SAFETY OF ELECTRICAL DEVICES

An electrically safe environment requires also that the electrical devices are safe. A defective device may expose the personnel operating the device as well as the patient connected to the device to danger. It is, therefore, imperative to test all electrical and medical electrical equipment at regular intervals.

SAFETY MEASURES FOR MEDICAL ELECTRICAL DEVICES ACCORDING TO IEC 60601-1

Regular testing of medical electrical devices is an essential aspect of the safety concept in hospitals.

Today, the International Electrotechnical Commission Standard IEC 60601: 1998 and European Standard EN 60601-1:1990 are widely used for periodic tests. According to these standards the following tests are required to be conducted:

- resistance of protective conductor
- earth leakage current
- enclosure leakage current
- patient leakage current and
- patient auxiliary current

IEC 60601 is a standard for type tests and production tests for electrical medical equipment but it is also used for periodic tests since dedicated standards for periodic tests are not available in many countries.

SAFETY AGAINST STATIC ELECTRICITY IN ANESTHETISING AREAS

In addition to the safety measures for the electrical power supply and safe electrical devices, measures shall be taken to avoid electrostatic sparking hazard in rooms where flammable anesthetics are likely to be regularly administered by means of anesthetic apparatus having a closed or partially closed breathing circuit. The most effective means of eliminating the electrostatic ignition hazard is to exclude highly electrostatic materials and to provide an anti-static environment. This will be achieved by providing flooring having suitable anti-static properties. The electrical resistance of anti-static floors, however, should not be too low because it will then have the effect of increasing the electric shock hazard associated with equipment connected with electricity mains. The anti-static floors will normally be used only where flammable anesthetics are administered by means of apparatus having a closed or partially closed breathing circuit, such as operating theatres, anesthetic rooms and maternity units of abnormal deliveries. Anti-static floors are not recommended for recovery rooms, intensive care rooms, plaster rooms, x-ray rooms , patient rooms and rooms used for normal deliveries.

RECOMMENDED LIMITS OF ELECTRICAL RESISTANCE OF ANTI-STATIC FLOORS

The recommended limits of electrical resistance of anti-static floor, as recommended by Health Technical Memorandum No. 2 of U.K (HTM 2) are:

- **Upper limit:** The average value shall not exceed 2 mega ohms between two separate electrodes spaced 600 mm apart, with no individual reading exceeding 5 mega ohms.

- **Lower Limit:** The average value shall not be less than 50,000 ohms measured between two separate electrodes spaced 600 mm apart with no individual reading less than 20,000 ohms.

Sufficient tests should be made for the results to be representative of the resistivity of the whole floor. As a general indication, one test should be made for each two square meters of a new floor and at not less than five locations for routine tests on floors in service.

CONCLUSION

The highest degree of safety for the patients, doctors and their assistants in hospitals can only be achieved when installations are sufficiently safe according to the regulations and devices are maintained by trained responsible operators.

*** *Date: 1st July 2003*

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