

# **NEAR EAST UNIVERSITY**

# FACULTY OF ENGINEERING

# Department of Electrical and Electronic Engineering

# **ELECTRICAL INSTALLATION PROJECT**

# **Graduation Project**

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# ABSTRACT

The electrical installation is one of the most impotant subject of an electrical engineering. According to this, the thesis is about an electrical installation of a hospital.

The main objective of this thesis is to provide an electrical installation with AutoCAD. For this thesis AutoCAD is very important. Also, with the help of AutoCAD, you can easily draw the part of you installation project.

According to this thesis you can learn to use AutoCAD and also learn to make especially cost calculation and lighting calculation for electrical installation as well.

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#### **INTRODUCTION**

The thesis is about an electrical installation, The electrical installation is one of the **most** impotant subject of an electrical engineering. So I decided to choose this subject, **because** I believed, it will help me in my future carrier as well.

My thesis is about electrical installation of hospital. In this thesis firstly I research how I can design an electrical installation of the building .After I designed this thesis with an autocad. In this thesis I considered to many application for electrical installation. There are installation type(e.g ring for socets), earthing, protection, illumination, cables and conductors, weak current installation, generation and transmission, cost calculation , etc...

This thesis consist of introduction, 9 chapter and conclusion.

Chapter 1 is about history of electricity.

Chapter 2 is about generation and transmission in North Cyprus.

Chapter 3 is about weak current installation.

Chapter 4 is about conductors and cables.

Chapter 5 is about electrical safety, protection and earthing.

Chapter 6 is about illumination.

Chapter 7 is about circuit control devices.

Chapter 8 is about domestic installation.

Chapter 9 is about calculations (illumination calculations and cost calculations)

# **CHAPTER 1 : THE HISTORY OF ELECTRICITY**

Today's scientific question is: What in the world is electricity? And where does it go after it leaves the toaster?

Here is a simple experiment that will teach you an important electrical lesson: On a **cool**, dry day, scuff your feet along a carpet, then reach into a friend's mouth and touch one of **his** dental fillings. Did you notice how your friend twitched violently and cried out in pain? **This** teaches us that electricity can be a very powerful force, but we must never use it to hurt others unless we need to learn an important electrical lesson. It also teaches us how an electrical circuit works. When you scuffed your feet, you picked up small batches of "electrons," which are very small objects that carpet manufacturers weave into carpets so they will attract dirt. (That will cause the carpet to wear out faster so you will need to buy a **new** one sooner, but that's another story.) The electrons travel through your blood stream and collect in your finger, where they form a spark that leaps to your friend's filling, then travels down to his feet and back into the carpet, thus completing the circuit. Amazing Electronic Fact: If you scuffed your feet long enough without touching anything, you would build up so many electrons that your finger would explode! But this is nothing to worry about unless you have carpeting.

Although we modern persons tend to take our electric lights, radios, mixers, etc for granted, hundreds of years ago people did not have any of these things, which is just as well because there was no place to plug them in. Then came along the first Electrical Pioneer, Benjamin Franklin, who flew a kite in a lightning storm and electrical shock. This proved that lightning was powered by the same force as carpets, but it also damaged Franklin's brain so badly that he started speaking in maxims, such as "a penny saved is a penny earned." (Eventually he got so bad he had to be given a job running the post office, but that's another story.)

After Franklin came a herd of Electrical Pioneers whose names have become part of our electrical terminology: Myron Volt, Mary Louise Amp, James Watt, Bob Transformer, etc. These pioneers conducted many important electrical experiments. For example, in 1780 Luigi Galvani discovered this is the truth by the way) when he attached two different kinds of metal to the leg of a frog, an electrical current developed and the frog's leg kicked, even though it was no longer attached to the frog, which was dead anyway. Galvani's discovery led to enormous advances in the field of amphibian medicine. Today skilled veterinary surgeons can take a frog that has been seriously injured or killed, implant pieces of metal in its muscles,

and watch it hop back into the pond just like a normal frog, except for the fact that it sinks like a stone. But the greatest Electrical Pioneer of them all was Thomas Edison, who was a brilliant inventor despite the fact that he had little formal training and lived in New Jersey. Edison's first major invention in 1877, was the phonograph, which could be found in thousands of American homes, where it basically sat until 1923 when the record was invented. But Edison's greatest achievement came in 1879, when he invented the electric company. Edison's design was a brilliant adaptation of the simple electric circuit: The electric company sends electricity through a wire to a customer, then immediately gets the electricity back through another wire, then (this is the brilliant part) sends it right back to the customer again. This means the electric company can sell a customer the same batch of electricity thousands of times a day and never get caught, since very few customers take the time to examine their electricity closely. In fact the last year any new electricity was generated in the United States was 1937; the electric companies have merely been reselling it ever since, which is why they have so much free time to apply for rate increases. Today, thanks to men like Edison and Franklin, and frog's like Galvani's, we receive unlimited benefits from electricity. For example, in the past decade scientists developed the laser, an electronic appliance so powerful that it can vaporize a bulldozer 2,000 yards away, yet so precise that doctors can use it to perform delicate operations on the human eye, provided they remember to change the power setting from "Vaporize Bulldozer" to "Delicate."

# **CHAPTER 2 : GENERATION AND TRANSMISSION**

In north cyprus elecrical energy is generate by Teknecik Power plant and Kalecik power plant. The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn. Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

To transfer the generated voltage these steps will be done. Generated voltage (11KV) is applied to the step-up transformer to have 66KV. This voltage is carried up to a sub-station. In this sub-station the voltage will be stepped-down again to 11KV. At the end the voltage stepped-down to 415V that is used by costumers. As a result the value of the voltage has to be at definite value. These;

a-) line to line -415V

- **b**-) line to neutral -240V
- c-) line to earth -240V
- d-) earth to neutral -0V

# **CHAPTER 3: WEAK CURRENT INSTALLATION**

In generally, we call the weak current installation as an installation which has less than 65v. Voltage inside and outside of building. The values of voltage are 3v-5v-8v-12v-24v and 48v. The choosen voltage value within weak current subject to the capacity of installation and operating voltage of installation.

Most important one of the weak current installation is the notification installation which has produced for diverse and variant reason. Notification installation; it is the installation which has which has produced notify the any kind of news, event or danger through the faraway place by the sound notify tools or luminous notify tools. Especially installations which are necessary to have every time electricity such as fire alarm, burglar alarm and timing alarm. Such that reason it is necessary to have storage battery which must be continuously charge the battery to feed the installation.

Principal weak current installations which of them placed inside and outside of building are;

1- Bell Installation

2- Door Check (Door lock) Installation

3- Numerator Installation

4- Sound, Luminous Call installation

5- Burglar Notification Installation

6- Fire Notification Installation

7- Electricity clock Installation

8- Diaphone Installation

9- Telephone Installation

10- Radio Antenna Installation

11- Television Antenna Installation

12- Postsynching Installation

# 3.1 Bell Installation :

Bell notification installations are one of the most operating tools. Notification installations come about with such conducter as notification tools (bells), button and energy sources.

Bell as a structure separate into two groups which are mechanic and electronic. There is one or two electromagnet, flipper, beetle, bell and base plate at the mechanic bell. But there is not beetle and bell at the buzz bell which benefits from the mechanic sound in which come bell.

Electronic bells sound with the condenser, circuit in transistor and the other tools.

220 / 3-5-8v, 220 / 15v, 220 / 24v transformer can be used in the bells, if there is not electricity energy in the installation, we can benefit the battery with 4,5 and 9 volt as an electrotic current (AC). Neuter is directly given to bells.

# 3.2 Door Check :

Door check occur by lock bolt or a coil which moves the slide rod. Door check can be control with control with one or more button.

## **3.3 Numerator Installations:**

Such this installations produced to call one person from more than one place and notify the place of calling. Numerators sell in blocks with 3 and 5. we may combine the blocks whether make a call from more than one place and we may use transformer (220/8.12v) as aenergy source.

Numerator shows the calling place with its numbers and warns the caller person with buzz sounds.

# 3.4 Luminous, Sound, calling installation :

Luminous buzz installations uses to prevent distrupting bell sounds at such a place, hospital, hotel, official buildings... etc. and it uses to faciliate the determination of calling place. It uses 220/24 volt transformer as a energy source.

# **3.5 Burglar Notification Installation :**

On the cause of burglar has apportunity to enter inside the door and window so it is necessary to secure such a place with a strained back layer of conductor. By breaking conductor away, the power of relay circuit will cut so it may provide the notification by operation of bell or lumination of lamp.

The other kind of installation is that, the system which produced over the door-crate. It also used relay in this system the bell and lamp use a vehicle of notification.

# 3.6 Fire Notification Installation :

This installation produced to secure the buildings against fire. There are two method in this installation. First; fire notification button placed into rooms, corridors to notify the fire by the person who see the condition. When the button is pushed, the alarm circuit will get off and the alarm will begin to ring by passing energy across on the relay circuit.

The second kind of notification installation is that; Bimetal termic tools replaced to button. We may use the termic tools on the place in which there is possibility to have fire. The tools close the switch notify the fire automatically when the heat get high. To reach fire place in short time we do installation with numarator link.

# **3.7 Electric Clock Installations :**

Electric clock installation can be changeable according to company which produces electric clock.

### **3.8 Diaphone Installation :**

It is the kind of installations which provides mutual conversation. It used for communal announcement or mutual dialog with desired place from one center. There are mutual conversation buttons, amplification and laudspeakers.

# 3.9 Telephone installations :

It is the vehicle for mutual conversation. It connects the people in two different place place by telephone instrument and telephone installation. Telephone instrument has a pushing and turning switch to transform the sounds into electric current by a microphone and earphone which transform electric current into sound and ring bell.

# 3.10 Radio Antenna Installations :

Antenna is a conductive which receive the electromagnetic waves. In todays world, it is loosing its importance to use a roof antenna (permanent antenna) for radio receiver. In todays, the instrument include radio as an antenna mission. We use generally 1.5mm<sup>2</sup> - 2.5mm<sup>2</sup> copper conductor as an antenna conductor.

# 3.11 Television Antenna Installations :

It is a installation between antenna and television instrument, television antennas divides into two group according to its production properties such as cone antenna and yogi antennas. It has three section;

- 1- Dipsle
- 2- Reflector
- 3- Director

#### **3.12 Sounds Installations :**

Such installations produced to announce from certain place or to listen music.

## **4.1** Conductors

# **4.1.1 Definition of Conductors**

A conductor is a material which offers a low resistance to a flow of current. Conductors for everyday use must be;

(a) of low electrical resistance,

(b) mechanically strong and flexible,

(c) relatively cheap.

For example, silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are tin, lead, and iron.

#### **4.1.2 Conductor Identification:**

The wiring regulations require that all conductors have to be identified by some meaning to indicate their functions i.e. phase conductors of a 3 phase system are colored by red, yellow, blue with neutral colored by black, protective conductors are identified by green or yellow/green. In British Standard;

Red Phase Black Neutral

Green Earth

We have some methods to identify the conductors.

1. Colouring of the conductor insulation

2.Printed numbers on the conductor

3.Colorued adhesive cases at the termination of the conductor

4. Colored see levels types at the termination of the conductors

5.Numbered paint for bare conductors \*

6.Colored discs fixed to the termination of conductors' e.g. on a distribution board.

#### **4.1.3 Formation of Conductors**

Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired crosssectional area is obtained. The copper wire is then dipped into a tank containing molten tin. This is done for two reasons:

(a) to protect the copper if the wire is to be insulated with vulcanized rubber, as this contains sulphur which attacks the copper;

(b) to make the copper conductor easier to solder. Aluminium wire is also drawn from a solid block but is not tinned.

# 4.1.4 Comparision of alluminium and copper as conductor

#### **4.1.4.1** Alluminium

Smaller weight for similar resistance and current-carrying capacity

-Easier to machine

- Greater current density because larger heat-radiating surface .

-Resistivity 2.845 μΩ-cm

-Temperature coefficient practically similar  $(0.004\Omega/\Omega \text{ degC})$ 

#### 4.1.4.2 Copper

-Better electrical and thermal conductor, therefore lower C.S.A. required for same voltage drop.

-Greater mechanical strength

-Corrosion resistant

-High scrap value

-Much easier to joint

-Lower resistivity: 1.78 μΩ-cm

The determining factor in the use of one type of metal for conductors is usually that of cost. The future trend in costs will be for the price of aluminium to drop relative to that of copper, as the underdeveloped coun tries achieve the industrial capacity necessary to work their bauxite (aluminium ore) deposits.

Conductors were often stranded to make the completed cable JIlore flexible. A set number of strands are used in cables: 1, 3, 7, 19, 37, 61, 91, and 127. Each layer of strands is spiralled on to the cable in an opposite direction to the previous layer. This system increases the flexibility of the completed cable and also minimizes the danger of 'bird caging', or the opening-up of the strands under a bending or twisting force.

The size of a stranded conductor is given by the number of strands and the diameter of the individual strands. For example, a 7/0.85 mm cable consists of seven strands of wire, each strand having a diameter (not cross-sectional area) of 0.85 rom. Solid (nonstranded) conductors are now being used in new installations.

Bare Conductors. Copper and aluminium conductors are also formed into a variety of sections, for example, rectangular and circular sections, for bare conductor systems. Applications. Extra-low voltage electroplating and sub-station work.

The following precautions must be taken with open bus-bar systems (above extra-low

moltage). They must be:

- (a) inaccessible to unauthorized persons,
- (b) free to expand and contract,

(c) effectively insulated. Where bare conductors are used in extra-low voltage systems they must be protected against the risk of fire.

# 4.2 Cables

# **4.2.1 Definition of Cables**

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor **solid** or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors mayor may not be provided with an overall covering for mechanical protection." A cable consists of two basic parts: (a) the conductor; and (b) the insulator.

### 4.2.2 Types of Cables:

The range of types of cables used in electrical work is very wide; from heavy leadsheathed and annored paper-insulated cables to the domestic flexible cable used to connect a hair-drier to the supply. Lead, tough-rubber, PVC and other types of sheathed cables used for domestic and industrial wiring are generally placed under the heading of

power cables. There are, however, other insulated copper conductors (they are sometimes aluminum) which, though by definitions are termed cables, are not regarded as such. Into this category fall for these rubber and PVC insulated conductors drawn into a some form of conduit or trucking for domestic and factory wiring, and similar conductors employed for the wiring of electrical equipment. In addition, there are the various types of insulated flexible conductors including those used for portable appliances and pendant fittings.

The main group of cables is "flexible cables". So termed to indicate that they consist of or more cores, each containing a group of wires, the diameters of the wires and the construction of the cable being such that they afford flexibility.

#### Single core cable

Single-core: these are natural or tinned copper wires. The insulating materials include butyl-rubber, silicon-rubber and the more familiar PVC.

The synthetic rubbers are provided with braiding and are self-colored. The Lee regulations recognize these insulating materials for twin- and multi-core flexible cables rather than for use as single conductors in conduit or trunking wiring systems. But that are available from the cable manufacturers for specific insulation requirements. Sizes vary from 1 to 36

mm squared (PVC) and 50 mm squared (synthetic rubbers).

#### Two-core

Two-core or "twin" cables are flat or circular. The insulation and sheathing materials are those used for single-core cables. The circular cables require cotton filler threads to gain the circular shape. Flat cables have their two cores laid said by side.

#### Three-core

These cables are the same in all respects to single and two-core cables except, of course, they carry three cores.

#### **Composite cables**

Composite cables are those which, in an addition to carrying the currency-carrying circuit conductors, also contain a circuit-protective conductor.

To summarize, the following group of cable types and applications are to be found in electrical work, and the electrician, at one time or another during his career, may be asked to install them.

# **Power cables**

Heavy cables, generally lead sheathed and annored; control cables for electrical equipment. Both copper and aluminum conductors.

# Wiring cables

Switchboard wiring; domestic at workshop flexible cables and cords. Mainly copper conductors.

#### **Mining cables**

In this field cables are used for trailing cables to supply equipment; shot-firing cables; roadway lighting; lift-shaft wiring; signaling, telephone and control cables. Adequate protection and fireproofing are features of cables for this application field.

#### **Ship-wiring cables**

These cables are generally lead-sheathed and annored, and mineral-insulated, metalsheathed. Cables must comply with Lloyd's Rules and regulations and with Admiralty requirements.

#### **Overhead cables**

Bare, lightly insulated and insulated conductors of copper, copper vadmiuim and aluminum generally. Sometimes with steel core for added strength. For overhead distribution cables are PVC and in most cases comply with British Telecom requirements.

#### **COAXIEL CABLE (antenna cable)**

Antenna cables is a special cable which is used to transfer high frequancy. This cable a type of flexible cables. We use this cale for TV. We are using this type of cable between elevision sockets and from television to antenna.

# **TELEPHONE CABLE**

Telephone cable is special cable. We use telephone circuit in the buildings and also for intercom circuits. This cables are very slim. Telephone cables are not same as electric cables. There are a lot of size the telephone cables. Telephone cables are 0.5mm and everytime one cable is extra near this cables.

#### Welding cables:

These are flexible cables and heavy coeds with either copper or aluminum conductors.

#### **Electric-sign cables**

PVC and rubber insulated cables foe high voltage discharge lamps able to withstand the high voltages.

# **Equipment wires**

Special wires for use with instruments often insulated with special materials such as silicon, rubber and irradiated polythene.

# **Appliance wiring cables**

This group includes high temperature cables for electric radiators, cookers and so on. Insulated used includes nylon, asbestos and varnished cambric.

#### **Heating cables**

Cables for floor warming, road heating, soil warming, ceiling heating and similar applications.

### **Flexible cords**

A flexible cord is defined as a flexible cable in which the csa of each conductor does not exceed 4 mm squared. The most common types of flexible cords are used in domestic and light industrial work. The diameter of each strand or wire varies from 0.21 to 0.31 mm. flexible cord come in many sizes and types; for convenience they are groups as follows:

## a) Twin-twisted

These consist of one single insulated stranded conductors twisted together to form a core-cable. Insulation used is vulcanized rubber and PVC. Color identification in red and black is often provided. The rubber is protected by a braiding of cotton, glazed-cotton, and rayon barding and artificial silk. The PVC insulated conductors are not provided with additional protection.

# b) Three-core (twisted)

Generally as two twisted cords but with a third conductor colored green, for eating lighting fittings.

# c) Three-core (circular)

Generally as twin-core circular except that the third conductorcolored green and yellow for earthling purposes.

# d) Four-core (circular)

Generally as twin-core circular. Colors are brown and blue.

#### e) Parallel twin

These are two stranded conductors laid together in parallel and insulated to form a uniform cable with rubber or PVC.

## f) Twin-core (flat)

This consists of two stranded conductors insulated with rubber,

colored red and black. Lay side-by-side and braided with artificial silk.

# 2) High temperature lighting, flexible cord

With the increasing use of filament lamps which produce very high temperatures, the temperature at the terminals of a lamp holder can reach 71 centigrade or more. In most instances the usual flexible insulators (rubber and PVC) are quite unsuitable and special flexible cords for lighting are now available. Conductors are generally of nickel-plated copper wires, each conductor being provided with two lapping of glass fiber. The braiding is also varnished with silicon. Cord is made in the twisted form (two and three-core).

# h) Flexible cables

These cables are made with stranded conductors, the diameters being 0.3, 0.4, 0.5 and 0.6 mm. they are generally used for trailing cables and similar applications where heavy currents up to 630 A are to be carried, for instance, to welding plant.

# 4.2.3 Cable Sizes (Use of I.E.E. Tables)

The I.E.E. Regulations contain comprehensive information regarding the current-carrying capacity of cables under certain conditions.

These tables supply:

- (a) cross-sectional area, number, and diameter of conductors;
- (b) type of insulation;
- (c) length of run for I V drop;

# (d) current rating (a.c. and d.c.), single and bunched.

The following terms are used in the I.E.E. tables:

- (a) ambient temperature
- (b) rating factor

# **4.2.4 Ambient Temperature**

This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this. changed current-carrying capacity can be calculated by using the relevant rating factor.

#### 4.2.5 Rating Factor

This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change.

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease: a rating factor is therefore supplied for the bunching, or grouping, of cables.

## 4.2.6 Permissible Voltage Drop in Cable

Voltage drop is another essential feature in the calculation of cable size, as it is useless installing a cable which is capable of supplying the required current if the voltage at the consumer's equipment is too low. Low voltage at the consumer's equipment leads to the inefficient operation of lighting, power equipment, and heating appliances. The maximum voltage drop allowed between the consumer's terminals and any point in the installation is 2.5 per cent of the voltage supplied by the Electricity Board, including motor circuits.

# 4.2.7 Voltage Drop and the I.E.E. Tables

The I.E.E. tables state the voltage drop across a section of cable when maximum current is flowing through it. If the current is halved, the voltage drop will also be halved. For example, a 4 mm2 twin-core cable has a current rating of 24 A and a voltage drop of 10m V per ampere per metre. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per metre.

#### 4.2.8New Voltage Bands

Extra-low voltage (Band I) now covers voltages not exceeding 50 V a.c. or 100 V d.c. (measured between conductors or to earth). The new low voltage range (Band II) is from extra-low voltage to 1000 V a.c. or 1500 V d.c., measured between conductors, or 600 V a.c. and 900 V d.c. between conductors and earth.

#### 4.2.9 Current Density and Cable Size

The current density of a conductor is the amount of current which the conductor can safely carry without undue heating per unit cross-sectional area. For example, if a copper conductor has a current density of 300 A/cm2 a copper conductor of cross-sectional area 0,5

cm2 will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area  $(cm^2)$ and current density (A/cm<sup>2</sup>):

Current-carrying capacity = current density x cross-sectional area

#### 4.2.10 Resistance of a Conductor

The resistance which a conductor offers to a flow of current is determined by three factors:

(a) the length of the conductor,

(b) its cross-st:ctional area,

(c) type of material used.

# **4.3 Insulators**

An insulator is a material which offers a very high resistance to a flow of current. An insulator should have certain electrical, mechanical, physical, and chemical properties.

#### **Electrical Properties**

It must have a high resistance.

#### **Mechanical Properties**

It must be capable of withstanding mechanical stresses, for example, compression.

#### **Physical Properties**

The perfect insulator would have the following physical properties:

(a) non-absorbent;

(b) capable of withstanding high temperatures.

# **Chemical Properties**

An insulator must be capable of withstanding the corrosive effects of chemicals. No insulator is perfect and each type is picked for a particular application. For example, porcelain and fireclay are relatively good insulators, but could not be used for covering conductors forming a cable because they are not flexible. P.V.C. is also a good insulator, but cannot be used in conditions where the temperature exceeds 45°C-for example, insulation for electric fires. Other examples of insulators are mica, wood, and paper.

# **CHAPTER 5: ELECTRICAL SAFETY-PROTECTION-EARTHING**

#### 5.1 Electrical safety:

The most common method used today for the protection of human beings against the task of electrical shock is either:

The use of insulation (screening live parts, and keeping live parts out of reach).

2) Ensuring, by means of earthling that any metal in electrical installation other than the conductor, is prevented from becoming electrically charged. Earthing basically provides a path of low resistance to earth for any current, which results from a fault between a live conductor and earthed metal.

The general mass of earth has always been regarded as a means of getting rid of inwanted currents, charges of electricity could be dissipated by conducting them to an electrode driven into the ground. A lighting discharge to earth illustrates this basic concept of earth as being a large drain for electricity. Thus every electrical installation, which has metal work, associated with it (the wiring system, accessories or the appliances used) is connected to earth. Basically this means if, say the framework of an electric fire becomes live. The resultant current will if the frame is earthed, flow through the frame, its associated circuit protective conductor, and then to the general mass of earth. Earthing metalwork by means of a bonding conductor means that all that metalwork will be at earth potential; or, no difference in potential can exist. And because a current will not flow unless there is a difference in potential, then that installation is said to be safe from the risk of electric shock.

Effective use of insulation is another method of ensuring that the amount of metalwork in an electrical installation, which could become live, is reduced to a minimum. The term double insulated means that not only are the live parts of an appliance insulated, but that the general construction is of some insulating material. A hairdryer and an electric shaver are two items, which fall into this category.

Though the shock risk in every electrical installation is something which every electrician must concern him, there is also the increase in the number of fires caused not only by faults in wiring, but also by defects in appliances. In order to start a fire there must be either be sustained heat or an electric spark of some kind. Sustained heating effects are often to be found in overloaded conductors, bed connections, and loosefining contacts and so on. If the contacts of a switch are really bad, then arching will occur which could start a fire in some nearby combustible material, such as blackboard, chipboard, sawdust and the like. The purpose of a fuse is to cut off the faulty circuit in the event of an excessive current flowing in

the circuit. But fuse-protection is not always a guarantee that the circuit is safe from the risk. The wrong six of fuse, for instance 15 A wires instead of 5 A wires, will render the circuit dangerous.

Fires can also be caused by an eat-leakage current causing arcing between live metalwork and, say, a gas pipe. Again, fuses are not always of use in the protection of a circuit against the occurrence of fire. Residual-current (RCD) are often used instead of fuses to detect small fault currents and to isolate the faulty circuit from the supply.

To ensure high degree of safety from shock-risk and fire risk, it is thus important that every electrical installation to be tested and inspected not only when it is new but at periodic intervals during its working life. Many electrical installations today are anything up to fifty years old. And often they have been extended and altered to such an extent that the original safety factors have been reduced to a point where amazement is expressed on why the place has not gone up in flames before this. Insulation used as it is preventing electricity from appearing where it is not wanted, often deteriorates with age. Old, hard and brittle insulation may, of course, give no trouble if left undisturbed and is in a dry situation. But the danger of shock and fire risk is ever present, for the cables may at the some time be moved by electricians, plumbers, gas fitters and builders.

It is a recommendation of the IEE regulations that every domestic installation be tasted at intervals of five years or less. The completion and inspection certificates in the IEE regulations show the details required in every inspection. And not only should the electrical installation be tested, but all current-using appliances and apparatus used by the consumer.

The following are some of the points, which the inspecting electrician should look for:

1) flexible cables not secure at plugs

2) frayed cables

3) cables without mechanical protection

4) use of unearthed metalwork

5) circuits over-fused

6) poor or broken earth connections, and especially sign of corrosion

7) Unguarded elements of the radiant fires.

8) Unauthorized additions to final circuits resulting in overloaded circuit cables.

9) Unprotected or unearthed socket-outlets.

10) Appliances with earthing requirements being supplied from two-pin BC adaptors.

11) Bell-wire used to carry mains voltages.

12) Use of portable heating appliances in bathrooms.

13) Broken connectors, such as plugs.

14) Signs of heating at socket-outlet contacts.

The following are the requirements for electrical safety:

1) Ensuring that all conductors are sufficient in csa for the design load current of circuits.

2) All equipment, wiring systems and accessories must be appropriate to the working conditions.

3) All circuits are protected against over current using devices, which have ratings appropriate to the current-carrying capacity of the conductors

4) All exposed conductive pans are connected together by means of CPCs.

5) All extraneous conductive parts are bonded together by means of main bonding conductors and supplementary bonding conductors are taken to the installation main earth terminal.

6) All control and over current protective devices are installed in the phase conductor.

7) All electrical equipment has the means for their control and isolation.

8)Alljoints and connections must be mechanically secure and electrically continuous and be accessible at all times.

9) No additions to existing installations should be made unless the existing

conductors are sufficient in size to carry the extra loading.

**10)** All electrical conductors have to be installed with adequate protection against physical damage and be suitably insulated for the circuit voltage at which they are to operate.

11) In situations where a fault current to earth is not sufficient to operate an over current device, an RCD must be installed.

**12)** All electrical equipment intended for use outside equipotent zone must be fed from socket-outlets incorporating an RCD.

13) The detailed inspection and testing of installation before they are connected to a mains supply, and at regular intervals there after.

#### 52 Earthing

An efficient earthing arrangement is an essential part of every electrical installation and system to guard against the effects of leakage currents, short-circuits, static charges and lightning discharges. The basic reason for earthing is to prevent or minimize the fisk of shock to human beings and livestock, and to reduce the risk of fire hazard. The earthing arrangement provides a low-resistance discharge path for currents, which would otherwise prove injurious or fatal to any person touching the metalwork associated with the faulty circuit. The prevention of electric shock risk in installations is a matter, which has been given close attention in these past few years, particularly since the rapid increase in the use of electricity for an ever-widening range of applications.

# **Electric shock**

An electric shock is dangerous only when the current through the body reaches a certain minimum value. The degree of danger is dependent not only on the current but also on the time for which it flows. A low current for a long time can easily prove just as dangerous as a high current for a relatively brief period. The applied voltage is in itself only important in producing this minimum current through the resistance of the body. In human beings, the resistance between band and hand, or between band and foot, can be as low as 500 ohms. If the body is immersed in a conducting liquid (e.g. as in a bath) the resistance may be as low as 200 ohms. In the case of a person with a body resistance of 500 ohms, with a 240 V supply the resulting current would be

480 mA, or 1.2 A in the more extreme case. However, much smaller currents are lethal, It has been estimated that about 3 mA is sufficient for a shock to be felt, with a tingling sensation. Between 10 mA and 15 mA, a tightening of the muscles is experienced and mere is difficulty in releasing any object being gripped. Acute discomfort is felt at this current level. Between 25 mA and 30mA the dangerous level is reached, with the extension of muscular tightening, particularly to the thoracic muscles. An over 50 mA result in fibrillation of the heart which is generally lethal if immediate specialist anention is not given. Fibrillation of the heart is due to irregular contraction of the heart muscles.

The object of earthing, as understood by the IEE Regulations, is, so far as is possible, to reduce the amount of current available for passage through the human body in the event of the occurrence of an earth-leakage current in an installation.

It has been proved that more than 25 per cent of alt electrical deaths are the result of a failure or lack of earthing.

# **Lightning protection**

Lightning discharges can generate large amounts of heat and release considerable mechanical forces, both due to the large currents involved. The recommendations for the protection of structures against lightning are contained in BS Code of Practice 6651 Protection of Structures Against Lightning). The object of such a protective system is to lead away the very high transient values of voltage and current into the earth where they are safely dissipated. Thus a protective system, to be effective, should be solid and permanent. Two main factors are considered in determining whether a structure should be given protection against lightning discharges:

1. Whether it is located in an area where lightning is prevalent and whether,

because of its height and/or its exposed position, it is most likely to be struck.

2. Whether it is one to which damage is likely to be serious by virtue of its use, contents, importance or interest (e.g. explosives factory, church monument, railway station, spire, radio mast, wire fence, etc.).

It is explained in BS Code of Practice 6651 that the 'zone of protection' of a single vertical conductor fixed to a structure is considered to be a cone with an apex at the highest point of the conductor and a base of radius equal to the height. This means that a conductor 30 meters high will protect that part of the structure which comes within a cone extending to 60 meters in diameter at ground level Care is therefore necessary in ensuring that the whole of a structure or building falls within the protective zone; if it does not, two down conductors must be run to provide two protective zones within which the whole structure is contained. All metallic objects and projections, such as metallic vent pipes and guttering, should be bonded to form part of the alrtermination network. All down conductors should be cross-bonded.

The use of multiple electrodes is common. Rule 5 of the Phoenix Fire Office Rules states:

Earth connections and number. The earth connection should be made either by means of a copper plate buried in damp earth, or by means of the tubular earth system, or by connection to the water mains (not nowadays recommended). The number of

connections should be in proportion to the ground area of the building, and there are few structures where less than two are necessary Church spires, high towers, factory chimneys having two down conductors should have two earths which may be interconnected.

All the component parts of a lightning-protective system should be either castings of leaded gunmetal, copper, naval brass or wrought phosphor bronze, or sheet copper or

stosphor bronze. Steel, suitably protected from corrosion, may be used in special cases where seesile or compressive strength is needed.

Air terminations constitute that part of dice system which distributes discharges into, collects discharges from, the atmosphere. Roof conductors are generally of soft annealed opper strip and interconnect the various air terminations. Down conductors, between earth and the air terminations are also of soft-annealed copper strip. Test points are joints in down conductors, bonds, earth leads, which allow resistance tests to be made. The earth terminations are those parts of the system designed to collect discharges from, or distribute tharges into, the general mass of earth. Down conductors are secured to the face of the structure by 'holdfasts' made from gunmetal The 'building in' type is used for new structures; a coulking type is used for existing structures.

With a lightning protection system, the resistance to earth need not be less than 10 chms. But in the case of important buildings, seven ohms is the maximum resistance. Because the effectiveness of a lightning conductor is dependent on its connection with moist earth, a poor earth connection may render the whole system useless The 'Hedges' patent tubular earth provides a permanent and efficient earth connection, which is inexpensive, simple in construction and easy to install These earths, when driven firmly into the soil, do not lose their efficiency by changes in the soil due to drainage; they have a constant resistance by reason of their being kept in contact with moist soil by watering arrangements provided at ground level. In addition, tubular or rod earths are easier to install than plate earths, because the latter require excavation.

Lightning conductors should have as few joints as possible. If these are necessary, other than at the testing-clamp or the earth-electrode clamping points, flat tape should be tinned, soldered and riveted; rod should be screw-jointed.

All lightning protective systems should he examined and tested by a competent engineer after completion, alteration and extension. A routine inspection and test should be made once a year and any defects remedied. In the case of a structure containing explosives or other inflammable materials, the inspection and test should be made every six months. The tests should include the resistance to earth and earth continuity. The methods of testing are similar to those described in the IEE Regulations, though tests for earth-resistance of earth electrodes require definite distances to be observed.

#### Anti-static earthing

'Static', which is a shortened term for 'static electric discharge' has been the subject of increasing concern in recent years partly due to the increasing use of highly insulating

materials (various plastics and textile fibbers).

#### **Earthing practice**

#### **1.Direct Earthing**

The term 'direct earthing' means connection to an earth electrode, of some recognized type, and reliance on the effectiveness of over current protective devices for protection against shock and fire hazards in the event of an earth fault. If non-currentcarrying metalwork is protected by direct earthing, under fault conditions a potential difference will exist between the metalwork and the general mass of earth to which the earth electrode is connected. This potential will persist until the protective device comes into operation. The value of this potential difference depends on the line voltage, the substation or supply transformer earth resistance, the line resistance, the fault resistance and finally, the earth resistance at the installation. Direct earth connections are made with electrodes in the soil at the consumer's premised A further method of effecting connection to earth is that which makes use of the metallic sheaths of underground cables. But such sheaths are more generally used to provide a direct metallic connection for the return of earth-fault current to the neutral of the supply system rather than as a means of direct connection to earth.

The earth electrode, the means by which a connection with the general mass of earth is made, can take a number of forms, and can appear either as a single connection or as a network of multiple electrodes. Each type of electrode has its own advantages and disadvantages.

The design of an earth electrode system takes into consideration its resistance to ensure that this is of such a value that sufficient current will pass to earth to operate the

protective system. It must also be designed to accommodate thermally the maximum fault current during the time it takes for the protective device to clear the fault. In designing for a specific ohmic resistance, the resistivity of the soil is perhaps the most important factor, although it is a variable one.

The current rating or fault-current capacity of earth electrodes must be adequate for the 'fault-currentftime-delay' characteristic of the system under the worst possible conditions. Undue heating of the electrode, which would dry out the adjacent soil and

increase the earth resistance, must be avoided. Calculated short-time ratings for earth electrodes of various types are available from electrode manufacturers. These ratings are based on the short-time current rating of the associated protective devices and a maximum temperature, which will not cause damage to the earth connections or to the equipment with which they may be in contact.

In general soils have a negative temperature coefficient of resistance. Sustained current loadings result in an initial decrease in electrode resistance and a consequent rise in the earth-fault current for a given applied voltage. However, as the moisture in the soil is current away from the soil/electrode interface, the resistance rises rapidly and will ultimately current infinity if the temperature rise is sufficient. This occurs in the region of 100°C and results in the complete failure of the electrode.

The current density of the electrode is found by:

Current density = I/A

where ;

I = short-circuit fault current; A = area (in cm2);

The formula assumes a temperature rise of 120°C, over an ambient temperature of 25°C, and the use of high-conductivity copper. The formula does pot allow for any dissipation of heat into the ground or into the air.

Under fault conditions, the earth electrode is raised to a potential with respect to the earth surrounding it. This can be calculated from the prospective fault current and the earth resistance of the electrode. It results in the existence of voltages in soil around the electrode, which may harm telephone and pilot cables (whose cores are substantially at earth potential) owing to the voltage to which the sheaths of such cables are raised. The voltage gradient at the surface of the ground may also constitute a danger to life, especially where cattle and livestock are concerned. In rural areas, for instance, it is not uncommon for the earth-path resistance to be such that faults are not cleared within a short period of time and animals which congregate near the areas in which current carrying electrodes are installed are liable to receive fatal shocks. The same trouble occurs on farms where earth electrodes are sometimes used for individual appliances.

The maximum voltage gradient over a span of 2 meters to a 25 mm diameter pipe electrode is reduced from 85 per cent of the total electrode potential when the top of the electrode is at ground level to 20 per cent and 5 per cent when the electrode is buried at 30 cm and 100 cm respectively. Thus, in areas where livestock are allowed to roam it is recommended that electrodes be buried with their tops well below the surface of the soil.

Corrosion of electrodes due to oxidation and direct chemical attack is sometimes a problem to be considered. Bare copper acquires a protective oxide film under normal stmospheric conditions which does not result in any progressive wasting away of the metal. It does; however, tend to increase the resistance of joints at contact surfaces. It is thus important to ensure that all contact surfaces in copper work, such as at test links, be carefully prepared so that good electrical connections are made. Test links should be bolted up tightly. Electrodes should not be installed in ground, which is contaminated by corrosive chemicals. If copper conductors must be run in an atmosphere containing hydrogen sulphide, or laid in cround liable to contamination by corrosive chemicals, iliey should be protected by a covering of PVC adhesive tape or a wrapping of some other suitable material, up to the point of connection with the earth electrode. Electrolytic corrosion will occur in addition to the other forms of attack if dissimilar metals are in contact and exposed to the action of moisture. Bolts and rivets used for making connections in copper work should be of either brass or copper. Uninsulated copper should not be run in direct contact with ferrous metals. Contact between bare copper and the lead sheath or armoring of cables should be avoided, especially underground. If it is impossible to avoid the connection of dissimilar metals, these should be crotected by painting with a moisture-resisting bituminous paint or compound, or by wrapping with PVC tape, to exclude all moisture.

The following are the types of electrodes used to make contact with the general mass of earth:

a) Plates. These are generally made from copper, zinc, steel or cast iron, and dlay be solid or the lattice type. Because of their mass, they tend to be costly. With the Steel or castiron types care must he taken to ensure that the termination of the earthing

Lead to the plate is water-proofed to prevent cathodic action taking place at the joint, If this happens, the conductor will eventually become detached from the plate and render ilie electrode practically useless. Plates are usually installed on edge in a hole in the ground about 2-3 meters deep, which is subsequently refilled with soil. Because one plate electrode is seldom sufficient to obtain a low-resistance earth connection, the cost of excavation associated with this type of electrode can be considerable. In addition, due to the plates being installed relatively near the surface of the ground, the resistance value is liable to fluctuate throughout the year due to the seasonal changes in the water content of the soil. To increase the area of contact between the plate and the surrounding ground, a layer of charcoal can be interposed. Coke, which is sometimes used as an alternative to charcoal, often has a high sulphur content, which can lead to serious corrosion and even complete destruction of the copper. The use of hygroscopic salts such as calcium chloride to keep the soil in a moist condition around the electrode can also lead to corrosion.

b) Rods In general rod electrodes have many advantages over other types of crectrode in that they are less costly to install. They do not require much space, are convenient test and do not create large voltage gradients because the earth-fault current is dissipated sertically. Deeply installed .electrodes is not subject to seasonal resistance changes. There are several types of rod electrodes. The solid copper rod gives e-xcellent conductivity and is highly resistant to corrosion. But it tends to be expensive and, being relatively soft, is not deally suited for driving deep into heavy soils because It is likely to bend if it comes up seainst a large rock. Rods made from galvanized steel a.re inexpensive and remain rigid when being installed. However, the life of galvanized steel in acidic soils is short. Another Esadvantage is that the copper earthing lead connection to the rod must be protected to prevent the ingress of moisture. Because the inductivity of steel is much less than that of copper, difficulties may arise, particularly under heavy fault current conditions when the temperature of the electrode wilt rise and therefore its inherent resistance. This will tend to in out the sunrounding soil, icreasing its resistivity value and resulting in a general increase in the earth resistance of the electrode. In fact, in very severe fault conditions, the resistance of the rod may rise so rapidly and to such an extent that protective equipment may fail to operate.

The bimetallic rod has a steel core and a copper exterior and offers the best alternative to either the copper or steel rod. The steel core gives the necessary rigidity while the copper exterior offers good conductivity and resistance to corrosion. In the extensible type of steelcored rod, and rods made from bard-drawn copper, steel driving caps are used to avoid splaying the rod end as it is being driven into the soil. The first rod is also provided with a pointed steel tip. The extensible rods are fitted with bronze screwed couplings. Rods should be installed by means of a power driven hammer fitted with a special head. Although rods should be driven vertically into the ground, an angle not exceeding 600 to the vertical is recommended in order to avoid rock or other buried obstruction.

c) Strip. Copper strip is used where the soil is shallow and overlies rock. It should be buried in a trench to a depth of not less than 50 cm and should not be used where there is a possibility of the ground being disturbed (e.g. on farmland). The strip electrode is most effective if buried in ditches under hedgerows where the bacteriological action arising from the decay of vegetation maintains a low soil resistivity.

d) Earths mat. These consist of copper wire buried in trenches up to one meter deep. The mat can be laid out either linearly or in 'star' form and terminated at the down lead from transformer or other items of equipment to be earthed. The total length of conductor used often exceed 100 meters. The cost of trenching alone can be expensive. Often scrap werhead line conductor was used but because of the increasing amount of aluminum now being used, scrap copper conductor is scarce. The most common areas where this system is till used are where rock is present near the surface of the soil, making deep excavation impracticable. As with plate electrodes, this method of earthing is subject to seasonal changes resistance. Also, there is the danger of voltage gradients being created by earth faults along the lengths of buried conductor, causing a risk to livestock.

e) Cable sheaths. These form a metallic return path and are provided by the

supply undertaking. They are particularly useful where an extensive underground cable system is available; the combination of sheath and armoring forms a most effective earth electrode. In most cases the resistance to earth of such a system is less than one ohm. Cable sheaths are, however, more used to provide a direct metallic connection for

the return of fault current to the neutral of a supply system rather than as a means of direct connection with earth this ,even though such cables are served with the gradual

deterioration of the final jute or Hessian serving.

In rural areas with overhead distribution, there is a problem, for any direct metallic return path must consist of an additional conductor. This, when provided, is known as a continuous earth wire. The disadvantage, apart from the cost of the extra conductor and its installation, is that an open-circuited earth wire could remam undetected for a long time. The earth wire is connected at the source of supply to the neutral and to the low-voltage distribution earth electrode.

# 2.Protective multiple earthing

This form of earthing is popularly known by the abbreviation PME. It is an extremely reliable system and is being used increasingly in this country. Basically the system uses the neutral of the incoming supply as the earth point. In this way all circuit protective conductors connect all the protected metalwork in an installation to this common point: the main earthing terminal. Allline-to-earth faults are convened to lineto-neutral faults, the intention being to ensure that sufficient current flows under the fault conditions to bring over current protective devices into operation.

There are two main hazards associated with PME. The first is that owing to the increased earth-fault currents, which are encouraged to flow, there is an enhanced fire risk during the time it takes for the protective device to operate. Also, with this method of earthing it is essential to ensure that the neutral conductor cannot rise to a dangerous potential relative

to earth. This is because the interconnection of neutral and protected metalwork would automatically extend the resultant shock risk to all the protected metalwork on every installation connected to this particular supply distribution network. As a result of these hazards, stringent requirements are laid down to cover the use of PME on any particular distribution system. In accordance with the new system of carting arrangements identified by the IEE Regulations, PME is officially known as TNC-S. Three points of interest might be mentioned here. First, the neutral conductor must be earthed at a number of points on the system, and the maximum resistance from neutral to earth must not exceed 10 ohms. In addition, an earth electrode at each consumer's installation is recommended, Secondly, so fir as the consumer is concerned, there must be no fusible cutout, single-pole switch, removable link or automatic circuitbreaker in any neutral conductor in the installation. Thirdly, the neutral conductor at any point must be made of the same material and be at least of equal cross-sectional area as the phase conductor at that point.

PME can be applied to a consumer's installation only if the supply authority's feeder is multiple earthed. This restricts PME to new distribution networks, though conversions from old systems can be made at a certain cost, which varies according to the type of consumer. The supply authority has to obtain permission in accordance with

the provisions laid down by the Minister of Energy and Secretary of State for Scotland British Telecom approval must also be obtained for each and every PME installation, and is required since it was once thought that the flow of currents from PME neutrals to the general mass of earth could cause interference with and/or corrosion of their equipment. In practice, however, no such problems have occurred although the board still retains its right to approve or otherwise a proposed PME installation.

Should a break occur in a neutral conductor of a PME system, the conductor will become live with respect to earth on both sides of the break, the actual voltage distribution depending on the relative values of the load and the earth electrode resistances of the two sections of the neutral distributor. All earthed metalwork on every installation supplied from this particular distribution system would become live. Highresistance joints on the neutral can also have a similar effect, the degree of danger in all cases being governed by the values of the connected load and the various earth electrode resistances. Trouble on a neutral conductor may go undetected for some considerable time, some of the only symptoms being reduced voltages on appliances, lights, etc. and slight to severe shocks from earthed metalwork. Overhead-line distribution systems are, of course, particularly prone so far as broken or discontinuous neutral conductors are concerned.

The aspect of earthed concentric wiring is important in the context of PME. For PME systems, the conventional four-core (three phases and neutral) armored cable can be replaced by a three-core metallic sheathed and armored cable where the sheath and armor are used for the earthed neutral. For consumer wiring, the sheath-return concentric cable, in which the sheath acts as both the neutral and earth conductor, is a logical extension of the PME principle and is covered by IEE Regulations Section 546. The main advantage of sheathreturn wiring is that a separate epe is not required. This is because the chances of a complete disconnection of the earth neutral conductor

without breaking the included phase conductors are remote.

Sheath return usually means that mineral-insulated cable is used. While the cost of MI cable is slightly higher than other types of cable (including any necessary conduit) this is offset considerably by the saving in labor resulting from ease of handling, the small diameter, and the reduced amount of chasing work required. Sheathreturn wiring can result in savings in installed cost of about 30 per cent compared with a conventional direct-earthed system using plastic insulated cable in black-enameled screwed conduit. For single-phase supplies, single-core MI sheath-return cables are used. Twincore cables are used for two-way switching. Multi-core cables are used from multiswitch points and rising mains to junction boxes where a number of separate outlets are situated close together. Since the outer sheath of the MI cable is used for neutral and earth connections, care has to be taken at terminations which are made with pot-type seals and glands into switchgear and terminal boxes at which sockets, ceiling roses, etc., are fined. Duplicate bonding is used to ensure that the contact remains good at all tines. A special seal, with an earth-bonding lead, is used.

#### 3. Circuit-protective conductors

The circuit-protective conductor (CPC) is defined as, 'a protective conductor connecting exposed conductive pans of equipment to the main earthing terminal' The IEE Regulations go into some considerable detail to identity the specific requirements which CPCs must satisfy, if they are to perform their function in the context of ensuring that should an earth fault occur, the resulting current is carried for the time it takes for the associated circuit over current protective device to operate.

IEE Regulations Section 543, and specifically Regulation 543-02-02, indicates the following types of circuit protective conductor, which are generally recognized. All these types of conductor are regarded as being normally dormant (that is, they do not carry current) until a fault to earth occurs.

a) Conductor contained in a sheathed cable, known as a composite cable. In this cable, the sheath can be of metal, rubber, or PVC; the conductors are the circuit conductors and the CPC (e.g. 2.5 mm2 twins with CPC). The conductor is either singlestrand or multi-stranded, depending on the size of the circuit conductors. And it is uninsulated. If the sheath is of metal, the conductor is always single-stranded. Inspection of samples of cables will reveal that the cross-sectional area of CPCs in metal-sheathed cables is less than their counterparts in insulated-sheathed cables; this is because the metal sheath and conductor are in parallel and together constitute a conducting path of very low resistance.

Where these CPCs are made off at, say, a switch position or ceiling rose, they should be insulated with a green-colored sleeve.

b) Conductor in a flexible cable or flexible cord. The requirement is that the CPC should have a cross-sectional area equal to that of the largest associated circuit conductor in the cable or cord. The color of the CPC, which is insulated in this case, is green and yellow.

c) The separate Cpc. The requirement in this case is that the CPC should have a crosssectional area not less than the appropriate value. The minimum size is 2.5 mm2, but in practice the size depends on the size of the associated circuit conductors. The reason for this is that if the circuit conductors are rated to carry I amperes, then the CPC should be able to carry a similar current, in the event of an earth fault, for sufficient time to allow a fuse to blow or a circuit-breaker to open. The resistance of a CPC of a material other than copper should not exceed that of the associated copper conductor.

Additional requirements for the separate CPC are that it. shall be insulated and colored green.

d) Metal sheath of MICS CABLE. Where the sheath of MICS cable is used as a CPC, the effective cross-sectional area of the sheath should be not less than one-half of the largest current-carrying conductors, subject to a minimum of 2.5 mm2  $\sim$  requirement is not applicable to MICS cables used in earthed concentric wiring systems.

e) Conduits, ducting, trunking, Wiring systems, which comprise metalwork, such as conduit, trunking, and ducting, are used as the CPC of an installation. The requirement here is that the resistance of the CPC should not he more than twice that of the largest current-carrying conductor of the circuit. All joints must be mechanically sound and be electrically continuous.

# **4.Additional Requirements**

a) Extraneous Metalwork. The IEE Regulation recommends that extraneous fixed Metalwork be bonded and earthed. This is particularly important where exposed metalwork of all apparatus, which is required by the Regulations to be earthed, might come into contact with extraneous fixed metalwork. Two solutions are offered: the bonding of such metalwork, or its segregation. The latter course is often very difficult to achieve and appreciable voltage differences may arise between points of contact. The extraneous fixed metalwork includes baths and exposed metal pipes, radiators, sinks and tanks. where there are no metal-to-metal joints of negligible resistance; structural steelwork; and the framework of mobile equipment on which electrical apparatus is mounted, such as cranes and lifts.

**b) Bathrooms**. Additional precautions are required to be taken to prevent risk of shock in bathrooms; these places are usually associated with dampness and condensation from steam. A bathroom is regarded as any room containing a fixed bath

or shower. First, all parts of a lamp holder likely to be touched by a person replacing a lamp shall be constructed 01 or shrouded in, insulating material and, for BC lamp holders, should be fined with a protective shield of insulating material. The Regulations strongly recommend that lighting fittings should be of a totally enclosed type. Switches or other means of control should be located so that they cannot be touched by a person using a fixed bath or shower. This means location of the control switch either outside the room itself or be ceiling-mounted with an insulating cord for its operation. No stationary appliances are allowed in the room, unless the heating elements cannot he touched. There should be no provision for socketoutlets, except to supply an electric

shaver from a unit complying with BS 3052.

c) Bell and similar circuits. Where a bell or similar circuit is energized from a

public supply by means of a double-wound transformer, the secondary circuit, the core of the transformers, and the metal casing if any, should be connected to earth.

d) **Portable appliances**. To reduce the risk of electric shock when portable appliances are used, the appliance is often supplied with a reduced voltage. A double wound transformer reduces the mains voltage to a suitable level. The secondary winding has one point earthed so that should a fault to earth occur on the appliance the shock received will be virtually harmless. Another method of protecting the user of a portable appliance from electric shock is to provide the appliance with automatic protection. In the event of an earth-fault the supply is automatically disconnected from the appliance.

# **Protective methods**

## Insulation

Measures to prevent dangerous voltages occurring on exposed

metalwork of electrical equipment are divided into three classes: earthed equipment; protective insulation extra-low voltage (less than 50 V to earth). The second class (protective insulation) is sub-divided into all-insulated equipment and double-insulated equipment All-insulated equipment is recognized by the majority of Regulations and Specifications as an alternative to earthing. The principles of design of all-insulated equipment are simple and therefore difficult to abuse. It is the only protective measure that will meet all the requirements of safety. The advent in recent years of modem reinforced plastics has met all the practical requirements of strength, stability and incombustibility.

The Factories Act Memorandum on the Electricity Regulations, Regulation 21, covers the precautions to be taken either by earthing or other suitable means to prevent

any metal other than a conductor from becoming electrically charged. The memorandum recognizes the possibility of providing apparatus with covers and handles of insulating material, which should also be incombustible and mechanically strong, as an alternative to earting. The recent advances in plastics technology have made available reinforced incombustible plastics and polycarbonate material which will withstand mechanical damage better than many of the average metal enclosures

supplied for equipment today.

A British Standards Memorandum sates.

If the outside of the protective case is made entirely of insulating material, to a satisfactory standard, no further protection is necessary.

In general, it is accepted, despite the TEE Regulations' emphasis on the earthing of metalwork, that insulation is a better and more effective method than earthing for medium voltage installations.

The insulation necessary for the proper functioning of electrical equipment and for basic protection against electric shock is known as 'functional' insulation. 'Protective' insulation is provided externally to the functional insulation. With 'double' insulation, accessible metal parts are separated from live pans by both functional and protective insulation. With 'all-insulated' equipment, all conductive pans are safely and permanently covered with a substantially continuous cover of insulating material. A good example of 'allinsulation' is a PVC-sheathed cable. The basic principles of all "totally-insulated' equipment are that the protective insulation must not be penetrated by conducting parts, however small,
which could assist a voltage path to the outside of the enclosure in the event of a fault. In addition, it must be impossible for inactive conductive parts inside the totally insulated component or enclosure to be connected to an earth conductor.

Double-insulated equipment is marked with the internationally recognized symbol for Class II equipment: two concentric squares. An additional label is also affixed, approved by the H.M. Senior Electrical Factory Inspector, to draw attention to the characteristics of the equipment. It states:

The metal mounting plate and other con current carrying metal parts are not connected to earth, and therefore earthing terminals are not provided. Fuses are recognized by the 16th Edition of the IEE Wiring Regulations as having a pan to play in the disconnection of circuits on which an earth fault occurs. Of necessity, fault currents in excess of the fusing factors of the fuses are required before the device will operate and this requirement itself presents problems, not least the rise in voltage on protected metalwork, which occurs while the fuse operated. A number of Tables in the IEE Regulations are specifically concerned with the maximum values of earth fault loop impedance for circuits supplying (a) socket outlets and (b) fixed equipment. In each of these cases, the disconnection times are, respectively, 0.4 second and 5 seconds. Recognizing that the fusing characteristics of different types of fuses vary, even among devices of the same rating, the Regulations offer detailed information regarding the maximum values of earth loop impedance which are not to be exceeded if the disconnection of the faulty circuit is to be achieved in less than the stated times for disconnection.

Fuses, however, do not provide a wholly satisfactory answer to the problem of increasing the safety factor in respect of electric shock from earth-leakage currents. For example, take a 40 A metal sub distribution hoard protected by 40 A HRC fuses with a fusing factor of 1.5. The metal case is caroled by a steel-wire4rnoured cable direct to the consumer's earthing lead. The earth loop test at 3 times the rated current of the circuit gives an impedance of 2 ohms and the circuit protective conductor is satisfactory at one ohm. If an earth-fault of negligible impedance occurs (at 240 V) then a current of 120 A flows. This current through the I-ohm CPC impedance will raise the potential of the steel enclosure of the board to 120 V above the consumer's main earth potential for the time taken for the fuse to blow, about 20 seconds.

Any increase in the earth leakage impedance due to a partial earth fault or arcing causes a lower current to flow for a longer time. If the total earth-loop impedance the impedance of the partial earth fault, is 3 ohms, the fault current will be 80 And the board metal enclosure will rise to 80 V above earth for more than four minutes while the fuse melts. During this time a person could receive a dangerous or fatal shock on touching the board metalwork.

Fuses do not provide sensitive protection, whether or not they are of the semi-enclosed type of cartridge fuses with fusing factors which exceed [5. The rapid cut-off of earth fault current, which is desirable for protection against serious electric shock, can be achieved only with earth-fault loops of much lower impedances now called for by the IEE Regulations. Indeed, lower impedance values are advised for industrial premises, in which the maximum earth-fault loop impedance should be equal to:

# (phase-to-neutral voltage / Minimum fusing current x 2) ohms

Fuses are insensitive devices because they must operate above the full-load current of the protected circuit, and also have an appreciable time lag even on higher currents.

# **Circuit-breakers**

Over current circuit-breakers, like fuses, do not altogether provide a satisfactory protection against earth-leakage currents, The IEE Regulations, however, recognize that these protective devices offer some degree of protection; and in view of the low tripping factors of these devices they are in many ways better than fuses. it is generally accepted that protection can be provided by over current circuitbreakers in situations where the level of earth fault current available to operate the device exceeds 1.5 times the tripping current of the device.

### **E.L.V** supplies

Equipment in which extra-low voltage supplies are used have the disadvantage that, to achieve modem power requirements, impracticably high currents are involved and applications are restricted to control circuits, small portable tools, lighting circuits and the like. Virtually complete safety from shock to earth, however, can be provided by limiting the voltage to earth to a non-lethal value. A large nunber of supplies at 55 V or less to earth have been proved to be almost free from electrical accidents. E.L. V. systems should be used wherever practicable for socket outlets and in dangerous situations. The cost involved in purchasing low-voltage appliances, and the problems raised by increased loading, limit the use of F. L.V. voltages to a small proportion of the instances in which protection is required.

# Earth-monitoring devices and portable equipment

For applications such as the protection of portable equipment where (due to the use of flexible or trailing leads) the reliability of the circuit protective conductor may by suspect, direct methods of protection are required. The use of E.L. V. supplies is not always practicable. If an earth fault occurs whilst an appliance is being handled, neither a fuse nor an over current circuit-breaker may operate quickly enough to protect the user. If the actual fault current is only of the order of three times the fuse retiring (a good rule of thumb limit) the fuse can easily take a matter often seconds or so to blow - a time delay which may welt have fatal consequences. Again, if the circuit of an appliance becomes completely opencircuited, an earth fault on an appliance may leave its casing alive at a voltage to earth which is almost equal to the phase-to-neutral voltage of the supply. This condition is by no means uncommon with portable and transportable equipment where the earthing conductor of the flexible cable may break or come adrift from its terminal. Special risks arise when the appliance is held in the hand.

Earth-monitoring devices are designed to ensure that earth connections to particular pans of an installation exist during the time it is energized. A small current is made to flow round a circuit consisting of the earth, and pilot conductors and the trip coil of a circuitbreaker. The trip is prevented from operating while the coil is energized. But as soon as the monitoring circuit is opened, the circuit-breaker is tripped. Earth monitoring requires an additional conductor and special socket-outlets; installation costs are thereby increased. The system is insensitive to appreciable impedances in the monitoring circuits and completely so to resistance or open-circuit in the earth path before the monitored circuit.

The use of the 'Butcher' system of protection for portable appliances involves a centretapped isolating transformer and a voltage operated earth-leakage circuit-breaker. Socket outlets are supplied at 240 V. The advantage of this method of protection is that if an earth fault occurs (even if it is only due to someone touching a live conductor) the earth-leakage current must return to the transformer via the trip coil of the circuitbreaker. Hence, provided that the operating current of the trip coil is below the lethal limit of body current, it is theoretically impossible to receive a lethal shock from any of the socket outlets supplied from the isolating transformer.

### Earth-leakage circuit-breakers

Earth-leakage and earth-fault protection are systems of protection arranged to disconnect the supply automatically from an installation or circuit when the earth-leakage or earth-fault current exceed predetermined values. Similarly, protection is offered when the voltage between non current-carrying metalwork of the installation and earth rises above a predetermined value. Such a system may be made to operate more rapidly and at lower values of leakage or fault current than one depending on over current protective devices such as fuses, thermal trips etc. Automatic protection is therefore used where the impedance of the earth-fault loop limits the current flowing in it to a value less than three times the current rating of the fuse of 1.5 times the over current setting of the circuit-breaker.

Earth-leakage or earth-fault protection is generally effected by means of a device known as an earth-leakage circuit-breaker (ELCB). There are two types; (i) the fault-voltage and (ii) the residual-current.

i) Fault-voltage operated ELCBs are units designed to be directly responsive to fault voltages appearing on protected metalwork. Their primary function is to give protection against earth-leakage shock risk. If the only connection to earth is through the ELCB, leakage currents of as low as 50 mA will produce immediate circuit isolation. The fault-voltage ELCB depends for its operation on a voltage which, existing between the apparatus to be protected and the general mass of earth, is itself dependent not only on the circuit-breaker, but also on earth-electrode resistance. Depending on design, the units trip at 24 V to earth with a 200-ohm earth electrode, or 40 V with a SOO-ohm earth electrode. The ELCBs are instantaneous in operation. The nonnal operating time is less than one cycle.

The unit consists of an operating or trip coil, which is connected between a reference earth-electrode and the protected metalwork of the installation. Any fault current, which appears in the metalwork, will flow through the coil to energize it and trip the circuit-breaker to isolate the faulty circuit from the supply. In present-day practice, there are two conditions in which the fault-voltage ELCB may function:

1. The trip coil is connected between an earth-electrode and the metal to be protected, which are not otherwise connected with earth.

2. The trip coil is connected in earth-electrode with the metal to be protected, which is in addition unavoidably connected directly with earth, e.g. a metallic waterpipe system.

In making the earth connection, care is taken to ensure that the earth electrode of the ELCB is at least 2 meters away from any buried metalwork, or the consumer's earth electrode, if one is installed. As far as possible, the operating coil of the unit should carry any fault current, which occurs, and not by-pass it by means of another path. The effect of 'parallel' earth connection is to deprive the operating coil of the necessary current which is required to trip the circuit-breaker.

Units are generally provided with a test switch. The primary purpose of this switch is to prove the existence of an adequate earth path. Failure of the unit to trip indicates potentially dangerous conditions in the installation such as excessive earth-electrode resistance or a broken earth lead. The test switch also checks that the sensitivity of the tripping mechanism is correct. The switch, generally a push-button, connects a highohmic value resistance in series with the live conductor and the operating coil to allow

sufficient current to flow to operate the circuit-breaker.

The fault voltage ELCB is susceptible to nuisance trapping, because it is not selective in operation and will trip out if the installation metalwork becomes live, irrespective of the source of the leakage current. This gives rise to several problems. It is virtually impossible to sub-divide large installations, because of the difficulty in isolating sections of installation metalwork associated with individual earth-leakage circuit-breakers. This difficulty applies with equal force to the parallel condition of a number of installations in the same building, such as is encountered with flats. Even when the dwellings are quite separate, trouble has been encountered with a common water pipe transmitting faults from one house to another. This particular disadvantage may lead to another difficulty if the installation on which a fault occurs does not have adequate earth-fault protection. The leakage current from the first dwelling may then flow to earth through the trip coil of the fault-voltage ELCB in the second dwelling. One effect of this fault condition is a bum-out of the trip coil.

The protection offered by the fault-voltage ELCB is ideally suited to the small countrycottage installation: relatively remote from other dwellings, with poor earthing facilities and without a piped water supply. The most awkward problem associated with these units is finding a suitable location for the reference earth electrode. It must be located outside the resistance area of any metallic pipes or gas pipes or any other metalwork associated with the installation. This problem has recently become particularly acute in recent years with the cross bonding of water pipes to the electrical earth-continuity system, which automatically results from the installation of immersion heaters in household hot-water tanks.

ii) A residual-current ELCE is a device consisting of a transformer having opposed windings, which carry the incoming and outgoing current of the load. In a healthy circuit, where the values of current in the windings are equal, their magnetic effects cancel out in the

magnetic flux in the core which links with the turns of a secondary winding and induces an emf in it. The secondary winding is permanently connected to the trip coil of the circuit breaker. When the circulating current reaches a pre-determined value, it pulls out the release latch to open the main contacts which are normally held closed against strong springs.

In contrast to the fault-voltage ELCB, this type can he used to provide discriminative protection for individual circuits. In practice, the normal order of sensitivity ranges from about one ampere out-of-balance, for a 15 A unit, up to about 3 A out-of-balance for a 60 A unit.

These units are also known as 'low-sensitivity units' to distinguish them from the 'highsensitivity units'. The latter units operate within 1125 of a heart cycle and can detect a fault current of 30 mA to earth or less. The operating time is in the region of 30 milliseconds. Certain units are available which do not require an earth connection; they rely for their operation on the actual fault current to earth through a person's body. The rapid time of operation, however, ensures that no electrical accident occurs.

One fault found with these high-sensitivity units is that they are also susceptible to what is called nuisance tripping. This occurs because the units can detect very low currents of the order of 25-30 mA, which are often found as normal leakage current from, say, cooker boiling plates and immersion elements.

Regulation 4 13-02-16 indicates that a residual current device shall be used only where the product of its operating current in amperes and the earth-loop impedance in ohms does not exceed 50. Where such a unit is used, the consumer's earthing terminal shall be connected to a suitable earth electrode. It is recommended that the operating current of a residual-current device should not exceed 2 per cent of the normal rates current of the circuit. Operating currents less than 500 mA is not regarded as necessary unless the value of earth-loop impedance is such that a lower operating current is essential.

However, residual-current devices of 30 mA sensitivity are coming into general use because of their reliability, the simplicity of their installation, and their low cost. They are generally recommended because they are considered effective in providing more positive protection. They are also suitable for earthing installations having loop impedances of 80 ohms or less, and are regarded as being effective in reducing fire risks.

Devices of below 500 mA sensitivity fail into two broad groups: those requiring electrical amplification, and those using a combination of permanent and electromagnetic fields. The latter are independent of the electrical supply for their operation. The electrically

amplified types have a wide range of loadings and interruption ratings. Primary windings are not necessary: the load cables are simply taken through an aperture in the core of the ransfonner. The magnetically assisted types depend on delicate tripping mechanisms and are berefore subject to the effects of vibration and shock. They require primary windings, which rends to limit their load capacity and makes them vulnerable to thennal and magnetic stresses when they are subjected to high fault currents. They are satisfactory where conditions are not unduly dangerous.

Response tunes of 30 to 50 ma are common to most sensitive relays and the maximum shock severity that can be experienced on metalwork protected by these units is well within the limits of safety prescribed by the International Labor Office (500 mA sec at SO mA, to 50 mA-sec at 600 mA).

High-sensitivity units are particularly recommended for protection in laundries, boiler

houses and for electrically heated food-trolleys as used in hospitals. They are also ideal for preventing the ignition of concentrations of explosive vapors by sparking along earth-fault paths and at the same time avoid the sudden interruption of the supply to an operating theatre while an operation is in progress. Circuits to operating theatres are fed from an isolating transfonner with a 40-ohm resistor, having its mid-point earthed, connected across the output terminals. This limits the maximum earth-fault current and energy to small values. And the supply need not be interrupted until it can be manually discontinued, without danger or inconvenience to the patient and operating staff, to enable the fault to be removed. Healthy and dangerous conditions are indicated by the use of indicating lamps (colored green and red respectively).

# Earth testing

IEE Regulations requires that tests he made on every installation to ensure that the earthing arrangement provided for that installation is effective and offers the users of the installation a satisfactory degree of protection against earth-leakage currents. The following are the individual tests prescribed by the Regulations.

#### **Circuit-protective conductors**

Regulation 7 13-02-01 requires that every circuit-protective conductor (CPC) be tested to verify that it is electrically sound and correctly connected. The IEE Regulations Guidance Notes on inspection and testing give details on the recognized means used to test the CPC. For each final circuit, the CPC fonns part of the earth-loop impedance path, its purpose being to connect all exposed conductive parts in the circuit to the main earth tenninal The CPC can take a number of fonns. If metallic conduit or trunking is used, the usual figure for ohmic resistance of one meter length is 5 milliohms/m.

Generally if the total earth-loop impedance (Zn) for a particular final circuit is within the maximum Zs limits, the CPC is then regarded as being satisfactory.

However, some testing specifications for large installations do require a separate test of each CPC to be carried out. The following descriptions of such tests refer to a.c.

a) Reduced a.c. test. In certain circumstances, the testing equipment in the a.c. test described above is not always available and it is often necessary to use hand-testers, which deliver a low value of test current at the frequency of the mains supply. After allowing for the resistance of the test lead, a value for impedance of 0.5 ohm maximum should be obtained where the CPC, or part of it, is made from steel conduit. If the CPC is in whole or in part made of copper, copper-alloy or aluminum, the maximum value is one ohm.

b) Direct current. Where it is not convenient to use a.c. for the test, d.c. may be used estead. Before the d.c. is applied, an inspection must be made to ensure that no inductor is ecorporated in the length of the CPC. Subject to the requirements of the total earth loop medance, the maximum values for impedance for the CPC should be 0.5 ohm (if of steel) or cohm (if of copper, copper-alloy or aluminum).

The resistance of an earth-continuity conductor, which contains imperfect joints, varies with the test current. It is therefore recommended that a d.c. resistance test for quality be made, first at low current, secondly with high current, and finally with low current. The lowcurrent tests should be made with an instrument delivering not more than 200 mA into one ohm; the high-current test should be made at IOA or such higher current as is practicable. The open-circuit voltage of the test set should be less than 30 V. Any substantial variations in the readings (say 25 per cent) will indicate faulty joints in the conductor; these should be rectified. If the values obtained are within the variation limit, no further test of the CPC is recessary.

# **Residual current devices**

IEE Regulation 713-12-01 requires that where an RCD provides protection against

indirect contact, the unit must have its effectiveness tested by the simulation of a fault condition. This test is independent of the unit's own test facility. The latter is designed for use by the consumer who is advised to ensure that the RCD trips when a test current, provided by an internal resistor, is applied to the trip-coil of the unit. Thus, on pressing the 'Test' button the unit should trip immediately. If it does not it may indicate that a fault exists and the unit should not be used with its associated socket-outlet, particularly if the outlet is to be used for exceeding 40 ms at a test current of 150 mA. RCD testers are commercially available, exceeding 40 ms at a test current of 150 mA. RCD testers are commercially available, which allow a range of tripping currents to be applied to the unit, from 10 mA upwards. In exceeding the lower the tripping current the longer will be the time of disconnection. It should be that a double pole RCD is required for caravans and caravan sites and for agricultural horticultural installations where socket-outlets are designed for equipment to be used that 'that essential to the welfare of livestock.

# Earth-electrode resistance area

The general mass of earth is used in electrical work to maintain the potential of any pert of a system at a definite value with respect to earth (usually taken as zero volts). It also mows a current to flow in the event of a fault to earth, so that protective gear will operate to solate the faulty circuit. One particular aspect of the earth electrode resistance area is that its resistance is by no means constant. It varies with the amount of moisture in the soil and is merefore subject to seasonal and other changes. As the general mass of earth forms part of the earth-fault loop path, it is essential at times to know its actual value of resistance, and merticularly of that area within the vicinity of the earth electrode. The effective resistance area an earth electrode extends for some distance around the actual electrode; but the surface soltage dies away very rapidly as the distance from the electrode increases. The basic method measuring the earthelectrode resistance is to pass current into the soil via the electrode and measure the voltage needed to produce this current. The type of soil largely determines its resistivity. The ability of the soil to conduct currents is essentially electrolytic in nature, and is therefore affected by moisture in the soil and by the chemical composition and concentration of salts dissolved in the contained water. Grain size and distribution, and closeness of packing are also contributory factors, since these control the manner in which moisture is held in the soil. Many of these factors vary locally. The following table shows some typical values of soil resistivity.

Table of soil-resistivity values

Type of soil Marshy grund Loam and clay Chalk Sand Peat Sandy gravel rock Approximate value in ohm-em 200 to 350 400 to 15, 000 6000 to 40,000 9000 to 800,000 5000 to 50,000 100,000 upwards When the site of an earth electrode is to be considered, the following types of soil recommended, in order of preference:

1. Wet marshy ground, which is not too well drained.

2. Clay, loamy soil, Arabic land, clayey soil, and clayey soil mixed with small coantities of sand.

3. Clay and loam mixed with varying proportions of sand, gravel, and stones.

- Damp and wet sand, peat.

Dry sand, gravel, chalk, limestone, whinstone, granite and any very stony ground **could** be avoided, as should all locations where virgin rock is very close to the surface.

Chemical treatment of the soil is sometimes used to improve its conductivity Common set is very suitable for this purpose. Calcium chloride, sodium carbonate and other substances are also beneficial, but before any chemical treatment is applied it should be verified that no corrosive actions would be set up, particularly on the earth electrode. Either a hand-operated tester or a mains-energized double-wound transformer can be used, the latter requiring an immeter and a high-resistance voltmeter. The former method gives a direct reading in ohms the instrument scale; the latter method requires a calculation in the form:

Resistance = Voltage / Current

The procedure is the same in each case. An auxiliary electrode is driven into the ground at a stance of about 30 meters away from the electrode under test (the consumers electrode). A mind electrode is driven midway between them. To ensure that the resistance area of the first electrodes do not overlap, the third electrode is moved 6 meters farther from, and nearer the electrode under test. The three tests should give similar results, the average value being electrode.

One disadvantage of using the simple method of earth electrode resistance measurement is that the effects of emfs (owing to electrolytic action in the soil) have to

be taken into account when testing, also there is the possibility of stray earth currents being leakages from local distribution systems. Because of this it is usual to use a commercial instrument, the Megger earth tester being a typical example.

#### Earth-fault loop impedance

Regulation 113-11-01 stipulates that where earth-leakage relies on the operation of current devices, an earth-loop impedance test should be carried out to prove the entiveness of the installation's earthing arrangement. Although the supply authority makes own earth-loop impedance tests, the electrical contractor is still required to carry out his tests. The tests carried out by a supply authority will not absolve the contractor from his responsibilities for the safe and effective operation of protection equipment which he install as part of a wiring installation. This applies both to new installations and ensions to existing installations. Earth-loop impedance tests must be carried out on all ension work of major importance to ensure that the earth-continuity path right back to the sumer's earthing terminal is effective and will enable the protective equipment to operate and fault conditions.

Phase-earth loop test. This test closely simulates the condition which would arise could an earth- fault occurs. The instruments used for the test create an artificial fault to earth between the 'me and earth conductors, and the fault current, which is limited by a resistor or one other means, is allowed to flow for a very short period. During this time, there is a cleage drop across the limiting device, the magnitude of which depends on the value of the earth loop. The voltage drop is used to operate an instrument movement, with an associated cale calibrated in ohms. The contribution of the consumer's earthing conductor should be not more than one ohm. This is to ensure that the voltage drop across any two Points on the conductor is kept to a low value and, under fault conditions there will be no danger to any person touching it at the time of the test.

The testers, which are commercially available, include both digital readouts and analogue scales, and incorporate indications of the circuit condition (correct polarity and a proven earth connection). The readings are in ohms and represent the earth-loop impedance (Zs).

Once a reading is obtained, reference must be made to IEE Regulations Tables 4IBI to +1D, which give the maximum values of Zs which refer to:

(a) the type of over current device used to protect the circuit and

(b) the rating of the device. Reference should also be made to any previous test reading to see whether any increase in Zs has occurred in the meantime. Any increase may indicate a deteriorating condition in the CPC or earthing lead and should be investigated immediately. The values of Zs indicated in the Tables are maximum values which must not be exceeded if the relevant circuits are to be disconnected within the disconnection times stated.

Before a test is made, the instrument should be 'proved' by using a calibration unit, which will ensure that it reads correctly during the test. It is also recommended that the serial number and type or model used for the test should be recorded, so that future tests made by the same tester will produce readings which are correlated.

# **5.3 Protection**

In electrical work the term protection is applied to precautions to prevent damage

to wiring systems and equipment, but also takes in more specific precautions against the occurrence of fire due to over currents flowing in circuits, and electric shock risks to human beings as a result, usually, of earth-leakage currents appearing in metalwork not directly associated with an electrical installation, such as hot and cold water pipes.

The initial design of any installation must take into account the potential effects on wiring system and equipment of environmental and working conditions. BS 5490 is a British Standard concerned with protection against mechanical, or physical, damage and gives full details of the Index of Protection Code to which all electrical equipment must conform. The Code is based on a numbering system with each number indicating the degree of protection offered.

The first characteristic numeral indicates the protection level offered to persons against contact with live or moving parts inside an enclosure and also the protection of the enclosure itself against the ingress of solid bodies, such as dust particles. The numbers range from 0 (no protection of equipment against the ingress of solid bodies and no protection against contact with live or moving parts) to 6 (complete protection).

The second characteristic numeral indicates the degree of protection of equipment against the ingress of liquid and ranges from 0 to 8. Thus an equipment with IP44 means that there is protection against objects of a thickness greater than 1.0 mm and against liquid splashed from any direction.

# Mechanical damage

This tenn includes damage done to wiring systems, accessories and equipment by Impact, vibration and collision, and damage due to corrosion. Typical examples of prevention include single-core conductors in conduit and trunking, the use of steel enclosures in industrial situations, the proper supporting of cables, the minimum bending radius for cables, the use of annored cables when they are installed underground, and the supports required for conductors in a vertical run of conduit and trunking.

Some types of installation present greater risks of damage to equipment and cables than others, for example on a building or construction site and in a busy workshop. In general, the working conditions should be assessed at the design stage of an installation and, if they have not been foreseen, perhaps due to a change of activity in a particular area, further work may be needed to meet the new working conditions.

Electrical fires are caused by (a) a fault, defect or omission in the wiring, (b) faults or defects in appliances and (c) mal-operation or abuse of the electrical circuit (e.g. overloading). The electrical proportion of fire causation today is around the 20 per cent mark. The majority of installation fires are the result of insulation damage, that is, electrical faults accounting for nearly three-quarters of cables and flex fires. Another aspect of protection against the risk of fire is that many installations must be fireproof or flameproof~ The definition of a flameproof unit is a device with an enclosure so designed and constructed that it will withstand an internal explosion of the particular gas for which it is certified, and also prevent any spark or flame from that explosion leaking out of the enclosure and igniting the surrounding atmosphere. In general, this protection is effected by wide-machined flanges, which damp or otherwise quench the flame in its passage across the metal, but at the same time allows the pressure generated by the explosion to be dissipated.

One important requirement in installations is the need to make good holes in floors, walls and ceilings for the passage of cables, conduit, trunking and ducts by using incombustible materials to prevent the spread of fire. In particular, the uses of fire barriers are required in trunking.

It was not until some years after the First World War that it was realized there was a growing need for special measures where electrical energy was used in inflammable situations. Precautions were usually limited to the use of well-glass lighting fittings.

Though equipment for use in mines was certified as flameproof, it was not common to find industrial gear designed specially to work with inflammable gases, vapors, solvents and dusts. With progress, based on the results of research and experience, a class of industrial flameproof gear eventually made its appearance and is now accepted for use in all hazardous areas.

There are two types of flameproof apparatus: (a) mining gear, which is used solely with armored cable or special flexible; and (b) industrial gear, which may be used with soliddrawn steel conduit, MIMS cables, aluminum-sheathed cables or armored cables. Mining gear **Exposent as** 'Group I' gear and comes into contact with only one fire hazard: firedamp or methane. Industrial gear, on the other hand, may well be installed in situations where a wide of explosive gases and liquids are present. Three types of industrial hazards are to be found: explosive gases and vapors inflammable liquids - and explosive dusts. The first two two seards are covered by what is called 'Group II' and 'Group III' apparatus. Explosive dusts may be of either metallic or organic origin. Of the former, magnesium, aluminum, silicon, and ferromanganese are hazards, which can be minimized by the installation of the former of apparatus; the flanges of which are well greased before assembly. The appropriate Standard Code of Practice is BS 5345 Electrical Apparatus and Associated Equipment for Use in Explosive Atmospheres of Gas or Vapor, other than Mining Applications.

All equipment certified as 'flameproof carries a small outline of a crown with the letters inside it. The equipment consists of two or more compartments. Each is separated from the ther by integral barriers, which have insulated studs mounted therein to accommodate the ectrical connection. Where weight is of importance, aluminum alloy is permitted. All is of the toughened variety to provide additional strength. The glass is fitted to the paratus with special cement. Certain types of gear, such as distribution boards, are provided with their own integral isolating switches, so that the replacement of fuses, maintenance, and so on, cannot be carried out while a circuit is live.

All conduit installations for hazardous areas must be carried out in solid-drawn 'Class B', with certified draw-boxes, and accessories. Couplers are to be of the flameproof type with a minimum thread length of 50 mm. All screwed joints, whether entering into switchgear, junction boxes or couplers, must be secured with a standard heavy locknut. This is done to ensure a tight and vibration-proof joint, which will not

slacken during the life of the installation, and thus impair both continuity and flameproof ness. The length of the thread on the conduit must be the same as the fitting plus sufficient for the locknut. Because of the exposed threads, running couplers are not recommended. Specially designed unions are manufactured which are flameproof and are designed to connect two conduits together or for securing conduit to an internally threaded entry.

Conduits of 20 and 25 mm can enter directly into a flameproof enclosure. Where exposed tenninals are fitted, conduits above 25 mm must be sealed at the point of entry with compound. Where a conduit installation is subject to condensation, say, where it passes from an atmosphere containing one type of vapor to another, the system must be sectionalized to prevent the propagation of either condensated moisture or gas. Conduit stopper boxes, with two, three or four entries, must be used. They have a splayed, plugged filling spout in the

cover so that the interior can be completely filled with compound.

When flexible, metal-sheathed or annored cables are installed, certified cable glands must be used. Where paper-insulated cables are used, or in a situation where sealing is necessary, a cable-sealing box must be used, which has to be filled completely with compound.

The following are among the important installation points to be observed when Installing flameproof systems and equipment. Flanges should be greased to prevent rusting. Special care is needed with aluminum-alloy flanges as the metal is ductile and easily bent out of shape. All external bolts are made from special steel and have shrouded heads to prevent unauthorized interference; bolts of another type should not be fined as replacements. Though toughened glass is comparatively strong, it will not stand up to very rough treatment; a faulty glass will disintegrate easily when broken. Protective guards must always be in place. Conduit joints should always be painted over with a suitable paint to prevent rusting. Because earthing is of prime importance in a flameproof installation, it is essential to ensure that the resistance of the joints in a conduit installation, or in cable sheaths, is such as to prevent heating or a rise in voltage from the passage of a fault-current. Remember that standard flameproof gear is not necessarily weather proof; and should be shielded in some way from rain or other excessive moisture.

Being essentially a closed installation, a flameproof conduit system may suffer condensation. Stopper boxes prevent the passage of moisture from one section to Draining of condensate from an installation should be carried out only by an person. Alterations or modifications must never be made to certified gear. Because flexible metallic tubing is not recognized as flameproof, to movable motors (e.g. on slide-rails) should be of the armored flexible cable with suitable cable-sealing boxes fitted at both ends. It is necessary to ensure that, as far as possible, contact between flameproof

apparatus, conduit, or cables, and pipe work carrying inflammable liquids should be avoided. If separation is not possible, the two should be effectively bonded together. When maintaining equipment in hazardous areas, care should be taken to ensure that circuits are dead before removing covers to gain access to terminals. Because flexible cables are a potential source of danger, they should he inspected frequently. All the equipment should be inspected and examined for mechanical [units, cracked glasses, deterioration of well-glass cement, slackened conduit joints and corrosion. Electrical tests should be carried out at regular intervals.

#### Corrosion

Wherever metal is used, there is often the attendant problem of corrosion and its prevention. There are two necessary conditions for corrosion:

(a) A susceptible metal and (b) a corrosive environment. Nearly all of the common metals corrode under most natural conditions. Little or no specific approach was made to the study of corrosion until the early years of the nineteenth century. Then it was discovered that corrosion was a natural electrochemical process or reaction by which a metal reverts in the presence of moisture to a more stable form usually of the type in which it is found in nature. It was Humphry Davy who suggested that protection against corrosion could result if the electrical condition of a metal and its surroundings were changed.

Corrosion is normally caused by the flow of direct electrical currents, which may be selfgenerated or imposed from an external source (e.g. an earth-leakage fault-current). Where direct current flows from a buried or submerged metal structure into the surrounding electrolyte (the sea or soil), no corrosion takes place. It is an interesting fact to record that where a pipe is buried in the soil there is a 'natural' potential of from O.3V to -0.6 V between the pipe and the soil. In electrical installations, precautions against the occurrence of corrosion include:

a) The prevention of contact between two dissimilar metals(e.g. copper and aluminum).

**b**) The prohibition of soldering fluxes, which remain acidic or Corrosive at the completion of a soldering operation (e.g. cable joint).

c) The protection of cables, wiring systems and equipment against the corrosive action of water, oil and dampness, unless they are suitably designed to withstand these conditions.

d) The protection of metal sheaths of cables and metal conduit linings where they come into contact with lime, cement and plaster and certain hard woods (e.g. oak and beech).

e) The use of bituminized paints and PVC over heating on metallic surfaces liable to corrosion in service.

Dampness can affect conduit Systems both on the inside and externally. With enamel finishes, it is important that the enamel is preserved as intact as possible, particularly at the thread entry to fittings. Also, the breaking of the galvanizing finishing

on galvanized conduit presents a great risk of rusting simply because this type of conduit was specified to cope with damp or wet working conditions. Thus any breaks in the finish must be repaired with the use of a suitable paint to prevent rusting

Internal corrosion can occur in situations where the ambient temperature tends to fluctuate. Condensation thus occurs, even in what would otherwise be dry situations, and if

the resulting condensate is not allowed to drain away out of the conduit run a build-up can occur. To deal with this problem, the drainage points are recommended in the form of conduit boxes either with holes drilled to allow condensate to drip out or else, say, using a tee box with the T-outlet plugged with a plug which can be removed at intervals.

Special care is needed in the choice of materials for clips and other fittings for bare aluminum-sheathed cables, and for aluminum conduit, because aluminum is not particularly stable in damp situations and especially when in contact with other metals. For instance, fixing an aluminum bulkhead luminary with brass screws to an external wall can set up an electrolytic action between the fitting and the screws. Chromiumplated screws would be better in this situation.

While copper is fairly resistant to corrosion, there are situations in which the material will corrode. This is why MI copper-sheathed cables are provided with PVC

sheaths and clips are also covered with PVC.

### **Under-voltage**

This is an electrical protection required by Regulation 552-4, and is a provision in the circuit of an electric motor to prevent automatic restarting after a stoppage of the motor due either to an excessive drop in the supply voltage, or a complete failure of the supply, where unexpected restarting of the motor might cause injury to an operator. These devices are found in dc motor starters (No-volt releases). In ac contactor starters failure of the supply stops the motor.

# **Over currents**

Over current protection is one of the requirements of Statutory and the IEE Regulations. LEE Regulation 130-03-01 states: 'Where necessary to prevent danger, every installation and every circuit thereof shall be protected against over current by devices which (i) will operate automatically at values of current which are suitably related to the safe current ratings of the circuit, and (ii) are of adequate breaking capacity and, where appropriate, making capacity. Transient over currents are due mainly to motor-starting currents and the inrush currents associated with such apparatus as capacitors, transformers and fluorescent lamp and other discharge lighting circuits. Sustained over currents are the result of indiscriminate additions to an existing circuit. Generally termed 'overloading', the additions cause current to flow, which is in excess of the current rating of the cables. Some transient currents can become sustained. Accidental single-phasing on three phase induction motors means the loss of one phase

caused by a fuse blowing in one of the lines; faulty operation of a contactor; or an open-circuit in one of the motor windings. Contactor faults and fuse blowing are frequent. When single phasing occurs, the motor, in order to produce its designed performance characteristics, finds that it mist draw more current from the supply. With normal motor designs, a 5 per cent imbalance in supply voltage can lead to a 15-20 per cent increase in the current in one phase on full load. This fault condition is very dangerous and can cause damage to the and inconvenience to the user (unless, of course, the motor circuit has been provided with adequate protection which disconnects it from the supply). The main problem associated with single-phasing is that because in practice the majority of small and medium-phasing induction motors operate on no more than 50-80 per cent full load, they will continue to run in a singlephased condition. Single-phasing stator damage is characterized by signs of uneven overheating. If an attempt is made to start the motor with a single-phase condition, damage will occur to the squirrel-cage rotor in the form -of localized overheating caused by high induced rotor-bar currents in positions corresponding to the number of poles in the stator winding.

#### Short-circuit currents

A short-circuit occurs for any of the following reasons

- 1. Incorrect connection during the initial installation or after a modification.
- 2. Failure of the insulation of cables or equipment.
- 3. Excessive arcing leading to a phase-to-phase or phase-to-earth short.
- 4. Disconnection of a cable or wire leading to a phase-to-phase or phase-to-earth short.

The energy of the s40rt-circuit, which can be taken as a link between points of differing potentials of negligible resistance or impedance, is fed from the point of supply, usually via the h.v. /Lv. transformer. This energy is dissipated in the complete distribution system as IR losses. The sub-division of this energy is in proportion to the resistance and reactance of the various items in the system or circuit, e.g., h.v. reactance, transformer reactance, and busbar and cable resistance and reactance. The value of the maximum short-circuits at any point in the installation can be calculated, provided the following data are known:

- 1. The high-voltage MV A rating.
- 2. The transformer rating and its percentage impedance.

3. The total resistance and reactance of the busbar and cables up to the point of the installation where the value of the theoretical fault current is required.

The items which have the greatest influence on the value of the fault are:

1. The percentage impedance and current rating of the transformer and the secondary circuit ohmic resistance.

2. The remaining items affect the fault current by usually less than 20 per cent. These can be taken into account or omitted at discretion.

For example, a 415 V. three-phase transformer of 750 kV A and a 4.75 per cent impedance (this value is standard for the majority of transformers conforming to the electricity Boards T.L. Specification) will have a full-load current of 1050 A at unity power factor. The 4.75 per cent impedance means that if the secondary terminals of the transformer ere bolted together and the primary voltage was reduced to 4.75 per cent of its rated voltage, then the rated secondary full-load current of the transformer would flow in the short-circuited connection. Thus, when full voltage is applied, the short circuit will be:

Rated current x 100/4.75

which in the above transformer will be

1050 x 21 =22 kA (r.m.s.).

If a cable resistance of 0.01 ohm per phase is added, the fault current will be reduced to about -14 kA.

This value of the fault current is the symmetrical fault level in amperes (r.m.s.) and causes the thermal damage to equipment. The asymmetrical fault current depends on the inductance of the circuit and the point on the sine wave at which the fault occurs. This peak current, under the worst conditions can reach twice the symmetrical fault current peak value or  $2 \times 1.414 = 2.828 \times r.m.s.$  symmetrical value. In the example given above the worst asymmetrical current would be 62 kA (peak).

The asymmetrical short-circuit current is responsible for the mechanical damage which results from the high oscillating mechanical forces (proportional to 12) set up between two conductors which are adjacent and parallel to each other. For example, if

The initial peak current 31 MVA system is about 110 kA, this would mean a force in kg per mm run of bus bars, assuming a 76 mm spacing between conductors, of about 100 kgf, which is either repealing or attracting depending upon the direction of the currents at the instant of short circuit.

In summary, when a short-circuit fault occurs, for any given supply voltage, two main factors will be seen to control the severity of the fault. These are the magnitude

and the power factor of the fault current. In this connection, two terms are worthy of note: prospective and actual values of fault current.

The 'prospective' level of fault current is the r.m.s. symmetrical current that would flow in a circuit due to the nominal applied voltage when a short-circuiting link of negligible impedance replaces the designed circuitry. In other words, it corresponds to a circuit condition of zero fault impedance. In a similar manner, the prospective value of power factor is assumed to obtain with zero fault-impedance.

The actual current, however, can never exceed the prospective value and usually it is considerably less. Almost any fault has some impedance, to which must be added the impedances and resistances, which exist in the circuit. These additional elements usually combine to limit the actual fault current to about 30 per cent or less the full prospective value; they also raise the actual short-circuit power factor to a value which approaches unity. The effect of a low power factor can be serious, because in such a circuit condition, there will be a considerable amount of stored energy to be dissipated during the time taken to clear the fault.

#### **Protection by fuses**

The fuse offers a means of protection against over currents. In its basic form, the first consists of a short length of suitable material, often in the form of a wire, which has a very small cross-sectional area compared with that of its associated circuit conductors. When a current flows which is greater than the current rating of the wire, the wire will get hot and, eventually, melt. This occurs because its resistance per 'unit length is much greater than that of its associated circuit conductors (so giving greater power loss and heat), and because this increased beat is concentrated in the smaller volume of the material.

### **Fuse terminology**

The following terms are used in connection with fuses:

**Current rating**. This is a current, less than the minimum fusing current, stated by the manufacturer as the current that the first will carry continuously without deterioration. The current rating is chosen in consideration of the temperature rise while the fuse element carries the specified current Because a fuse is a thermal device, the ambient temperature m which it operates is very important. Where fuses are used in high-temperature situations, a derating of the assigned current rating may be necessary for ambient temperatures of 35°C and above.

**Applied voltage**. It is important that the applied voltage of a circuit does not exceed the voltage rating of any fuse used for its protection. This is because a fuse is particularly voltage-sensitive immediately before and after it operates to break the circuit current. The rated voltage is that assigned to the fuse by the manufacturer to indicate the nominal system voltage with which the fuse may normally be associated. It is important to note that the voltage rating of a fuse may not apply equally to both a.c. and d.c. circuits.

Breaking capacity rating. This is a prospective current stated by the manufacturer as the greatest prospective current that may be associated with the fuse under prescribed conditions

of voltage and power factor or time constant. Fuses of different breaking-capacity ratings are available according to the several categories listed in British Standards. The category of duty assigned to a fuse should take into account the prospective current and the transient behavior of the circuit during shortcircuits conditions (for instance, the degree of asymmetry in the a.c circuits).

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**Rated minimum fusing current**. This is the current, which will cause the fuse to operate in a specified time under prescri 1 ed conditions.

**Fusing factor**. This is the ratio, greater than unity, of the rating minimum fusing current to the current rating.

A fuse, which carries its rated current, does not suffer any deterioration. However, if the current carried approaches the rated minimum fusing current, it will eventually reach a temperature at which its fuse element will begin to melt. A fuse is not intended to be run at currents between the values given for prolonged periods; if this does happen the characteristics of the fuse will change.

Let-through energy. This is the specific energy to which a protected circuit is subjected during the pre-arcing time.

# **Rewirable fuses**

The rewirable fuse is a simple device. It consists of a short length of wire, generally of tinned copper. The current at which the wire will melt depends on the length of the wire and its cross-sectional area. If it is very short, the beat generated (12R watts) will be conducted away from the wire by the contacts or securing screws. Also, if the wire is open to the atmosphere, it will cool much more quickly than if it was surrounded by a thermal insulator such as an asbestos sleeve. In view of these and other factors, the rewirable fuse is a device with a number of variables, which affect its performance; anyone, or all, of these can differ between similar fuses. Though the rewirable fuse is cheap, involving only the replacement of the fuse-element, it has a number of disadvantages and limitations:

1. The fuse element is always at a fairly high temperature when in use. This leads to oxidization of the element material, which is a form of corrosion, and results in a reduction in the cross-sectional area of the element, so that it fuses at a current lower than its rating. Fuses, which carry their rated current for long periods generally, require replacement at two-yearly periods, otherwise nuisance blowing will be experienced on the circuit.

2. It is very easy for an inexperienced person to replace a blown fuse element with a wire of incorrect size or type.

3. When a fault occurs on a circuit, the time for the fuse to blow may be as long as

several seconds, during which time considerable electrical and physical damage may occur to the circuit conductors and the equipment being protected.

4. The calibration of a rewirable fuse can never be accurate, which fact renders this type of fuse unsuitable for circuits, which require discriminative protection.

5. Lack of discrimination means that it is possible in certain circuit conditions for a 15 A-rated fuse-clement to melt before a 10 A-rated element. Also, the type is not capable of discriminating between a transient high current (e.g., motor starting current) and a continuous fault current.

6. Owing to the fact that intense heat must be generated in the fuse-element before it can perform its protective action, there is an associated fire risk. Also in this context, should the fault current be particularly high, though the wire fteaks, an arc may still be maintained by the circuit voltage and flow through the air and metallic vapor. The rewirable fuse has thus a low rupturing capacity, which is the product of the maximum current, which the fuse will interrupt, and the supply voltage. The capacity is measured in kV A. Generally a limit of 5000 kV A is placed on rewirable fuses.

Semi-enclosed or rewirable fuses are not regarded as devices, which will offer closely, controlled protection, particularly where important circuits are concerned. As seen ftom the above, they cannot be guaranteed as to their performance, which is why their use is penalized in the IEE Wiring Regulations.

# **Cartridge fuses**

The cartridge fuse was developed to overcome the disadvantages of the rewirable type of fuse, particularly because with the increasing use of electricity, the energy flowing in circuits was growing larger. The main trouble with the rewirable fuse was oxidation and premature failure even when carrying normal load currents, causing interruptions in supply and loss of production in factories. Thus the fully enclosed or cartridge fuse came into existence. Non-deterioration of the fuse-element was, and stilt is, one of the most valuable features of this type of fuse. The advantage also of the cartridge fuse is that its rating is accurately known. However, it is also more expensive to replace than the rewirable type and it is also unsuitable for really high values of fault current.

It finds common application for domestic and small industrial loads. As houseservice cutout fuse links (BS 88), they are used by Supply Authorities as services fuses. Ferrule-cap fuse links (BS 1361) are used in domestic 250 V consumer control units, switch fuses and switch splitters. The domestic cartridge fuse links (BS 1361) were designed for use specifically in 13 A fused rectangular-pin plugs. Domestic cartridge fuse links (BS 646) are

for use specifically in 15 A, round-pin plugs where the load taken from a 15 A socket-outlet is small (e.g. radio, TV or table lamp), in relation to the

15 A fuse which protects the circuit at the distribution board. In addition, there are other cartridge fuses for particular applications (e.g. in fluorescent fittings). All these cartridge fuses are so designed that they cannot be interchanged except within their own group.

Essentially the cartridge fuse is a ceramic barrel containing the fuse element. The barrel is filled with non-fusible sand, which helps to quench the resultant arc produced when the element melts.

The short-time characteristics of the HRC fuse enable it to take care of shortcircuits conditions when used to protect motor circuits. Tests have shown that HRC fuses have a short-circuit fusing time as low as 0.0013 second. On large ratings they will open circuit in less than 0.02 second. HRC fuses are discriminating, which means that they are able to distinguish between a high starting current taken by a motor (which lasts only a matter of seconds) and a high fault or overload current (which lasts longer).

## **Selection of fuses**

The selection of a particular fuse for circuit-protection duty should never be a casual matter. The important factors to be considered are:

1. The Voltage Rating of the fuse which should be not less than the highest voltage obtainable between the conductors of the circuit.

**2**. Ampere Rating of the fuse should be suitable for the circuit and the type of apparatus to be protected

**3.** The Service Condition& These fall into two categories. First, the ambient temperature that will affect the operational characteristics of the fuse. In high ambient temperatures the current-ratings of fuses should be reduced to ensure that the total temperature does not exceed the permitted values calculated for materials and insulation. The total temperature varies with fuse size and application and it is thus advisable for advice to be sought from manufacturers regarding the derating factors to be used. Secondly, an altitude of 1000 meters will result in the derating of a fuse.

# **Protection by circuit-breakers**

There are few industrial power switching requirements which cannot be dealt with by standard circuit-breakers. And for the smaller-rated loads such as commercial and domestic installations, the molded-case and miniature circuit-breakers are finding an increasing role to play for both the control and protection of circuits. Essentially, switchgear links the various elements of an electrical system together to provide normal operational facilities and permit

be immediate disconnection of faulty apparatus and circuits. To do this it must be able to perform some or all of the following duties without damage to itself or other equipment and without danger to personnel:

I. Carry full-load currents continuously.

1. Withstand normal and possible abnormal system voltages.

3. Open and close the circuit on no-load.

4. Make and break on normal operating currents.

5. Make short-circuit currents.

6. Break short-circuit currents.

Of the different switching devices available, all must perform (1) and (2); the isolating switch is normally designed to perform (3) although certain types can perform (4); the circuit-breaker must perform (3), (4), (5) and (6).

The actual making or breaking of the circuit takes place at the contacts; these must be able to carry continuously the full-load current of the circuit without excessive temperature rise, i.e. they must have a very low contact resistance; they must also be able to pass, in a fraction of a second, from the state in which they carry a short-circuit current with a negligible volt drop to the state in which they can withstand full system voltage across them. This rapid change can only be effected as a result of the arc that takes place when current-carrying contacts are separated. The main problem in switch, circuit-breaker or fuse design is the proper control of this arc. But other important associated problems are the provision of adequate insulation, the countering of the high mechanical forces due to short-circuit currents, and the devising of suitable operating mechanisms for rapidly closing and opening the contacts. The most arduous duty is the interrupting of short-circuit currents.

In the medium voltage range (up to 660 V) oil-and air-break circuit-breakers are For applications at 3.3 kV, 6.6 kV and 11 kV, oil-break, air-break and (for special applications at 11 kV) air-blast circuit-breakers are also available. The several factors which affect the selection of the right circuit-breaker for a particular application include: service voltage and load current; the type of duty; environment of installation; ancillaries and other features required. BS 116 and BS 936 contain appendices, which gives guidance on the selection of circuit-breakers. They contain details of methods, which should be used to determine the symmetrical current; BS 116 also gives guidance on the calculation of asymmetrical fault current. BS 162 Electrical Power Switch gear and Associated Apparatus coordinates requirements of circuit breakers and those of associated apparatus and provides information on general matters appertaining to switchgear.

Circuit-breakers must not he allowed to carry current in excess of their rated current as they normally have little, if any, overload capacity. An approximate of symmetrical fault currents to be anticipated on systems supplied through can be made by neglecting the impedance on the supply side of the transformers. The formula used

is:

Fault MV A = (Transformer rated kV A) / (% impedance of the transformer x 10)

Allowance has also to be made for the fault contribution of rotating machinery. It desirable to take advantage of the reduction in fault current, which can occur on medium voltage Systems due to the impedance of all connections.

Various types of operating mechanisms are used in circuit-breakers. Manual mechanisms are not recommended for use in 11 kV and 6.6 kV installations are the fault levels exceed 150 MV A. Where manual mechanisms are required, it is necessary to ensure that the design incorporates features such as instantaneous trip and trip-free features, which can add greatly to the safety with which circuit-breakers can with their fault-making duty. For a manual spring-operated arrangement, a handle is provided whereby a spring is charged and released in one stroke. A charged spring closes the circuit-breaker, the energy of the spring having been checked on short-circuit tests, thus ensuring safe closing of the circuit-breaker during fault conditions. The band-charged spring arrangement is similar, except that the charging of the spring is carried out manually and the closing of the circuit-breaker is carried out by a separate action to release the charged spring. In the spring motor-wound arrangement, manual charging is dispensed with.

Amongst the service conditions which must be taken into account when considering the choice of suitable equipment are the temperatures and climatic circumstances under which it is intended to operate. For instance, when circuit-breakers are installed in places subject to abnormally low temperatures, a suitable low-freeze oil should be selected not only for the breaker itself but also for the over current dashpots. To prevent the oil from freezing, heaters are sometimes built into the circuit-breaker tanks. Special low-temperature greases may be required to maintain the correct functioning of mechanical parts. On the other hand, where the maximum temperature exceeds 40°C, or the average ambient over a 24-hour period exceeds 35°C, derating of the standard circuit-breaker may be necessary.

Where excessive dust exists, as in steel Millis, cement works and boiler houses, special precautions may be necessary and the breaker may be required to be enclosed in a recognized enclosure. In general, oil circuit-breakers, because they tend to be totally enclosed, are more tolerant of dusty and dirty locations. Than are their air-break counterparts. Application outdoors involves equipment specifically designed for outdoor use or, alternatively, the application of indoor equipment within weatherproof enclosures.

#### **Moulded case circuit-breakers**

The molded case circuit-breaker is designed to provide circuit protection for medium-voltage distribution systems. It is defined as an air-break circuit-breaker, designed to have no provision for maintenance, having a supporting and enclosing housing of molded insulating material forming an integral part of the unit. It is capable of making, carrying and breaking currents under specified abnormal circuit conditions such as those of short-circuit. The usual current ratings are fromIO-1200 A up to 600 V in single-, double-, or triple-pole units with a breaking capacity of up to 50kA (r.m.s.) at power factors of 0.25 to 0.4.

The breakers were developed because of the advantages they had over ordinary switches and fuses in the control and protection of circuits and apparatus They have a repeatable non-destructive performance, safety in operation under fault conditions, and, in the case of the triple-pole circuit-breaker, simultaneous opening of all three phases, even under a single-phase fault to earth. All breakers have, as a standard feature, the ability to disconnect automatically under overload conditions, usually up to 8-10 times the rated current via bimetal over current trips in each pole. An essential feature of all mounded-case circuitbreakers is the quick-make-and-break operation of the contacts, independent of operating personnel, and a high contact pressure; both these features are essential ifhigh fault currents are to be switched safely.

The function of the breaker trip elements is to trip the operating mechanism in the event of a prolonged overload or short circuit. To accomplish this, a thermal-magnetic

trip action is normally provided. The thermal trip action is achieved through the use of a bimetal heated by the load current. On a sustained overload, the bimetal will deflect, causing the operating mechanism to trip. Because bimetals are responsive to the heat generated by the current flow, they allow a long time delay on light overloads and have a faster response on heavier overloads. Magnetic trip action is achieved through the use of a simple electromagnet m series with the load current and thermal device. This provides instantaneous tripping when the current reaches too high a value for the thermal trip element to provide sufficiently rapid tripping.

# **Miniature circuit-breakers**

These devices are in many ways similar to the molded-case breakers. The dividing line between the two types of breaker is drawn on a basis of current rating and shortcircuits capacity. The m.c.b. has found an increasing role for final circuit protection in domestic and commercial installations. It offers these circuits better protection, and a better fire risk protection, particularly when overload conditions are being considered, than the fuse alternative.

## Discrimination

The term discrimination is applied to a circuit condition, under the circumstances of an excess-current flow, where, for example, one fuse blows before another. If the blown fuse is the 'minor' fuse in the circuit, then the other, the 'major' device has discriminated with the minor unit. In practice, if two fuses appear to have discriminated with each other, the criterion of discrimination is, however, not merely that one is opencircuited and the other is not. It is essential for the unblown fuse to continue to give satisfactory service after the fault has been removed and the minor fuse replaced.

Discrimination may be defined as 'the ability of fuses and circuit-breakers to interrupt the supply to a faulty circuit without interfering with the source of supply to the remaining healthy circuits in the system'. This requires that a larger fuse nearer to the source of supply will remain unaffected by fault currents, which would cause a smaller fuse, further from the source of supply, to operate.

In practice, fairly good discrimination, as required by Regulation 533-01-06 can be achieved between different fuse ratings when the prospective current of the circuit is small and the fuse operates in more than approximately 0.02 second. If, however, the prospective current is large, resulting in operating times of less than 0.1 second, discrimination will be more difficult and a ratio of not less than 2: 1 between major and

minor fuses may become necessary. Reference to standard time/current curves will enable a fairly close approximation of discrimination to be made for operating times of not less than 0.02 second.

In practice, too, it is often the case that a system of circuits contains protection offered by HRC fuses, semi-enclosed fuses, and circuit-breakers; circuits are also protected by one type only or two or more m combination. In these circumstances the advice of fuse manufacturers should be sought. Where circuit-breakers and HRC fuses are used, either as one means of protection or in combination, it is a relatively simple matter to choose ratings to achieve discrimination by referring to standard curves issued by the manufacturers.

#### Relays

The over current protective relay has been a common means of protection against

excess currents for large and small systems for many years and is now finding new applications. With the ever-growing size of electrical power systems and the increasing use of interconnection, it is often difficult to secure the really accurate and discriminative disconnection of the supply when circuit conditions become unhealthy. Relays are used in association with circuit-breakers which are tripped by a series connected, direct acting, over current trip oil. This device is electromagnetic in operation and consists of either an electromagnet and armature, or a solenoid with a central plunger. The coil of the electromagnet (or the solenoid) consists of a few turns of conductor connected in series with the main circuit. The armature (or plunger) is arranged to operate the circuit-breaker trip mechanism. The operating current of such a device is usually adjustable by means of variation of either the magnetic gap or a restraining spring.

Some items of electrical equipment, such as transformers, can carry an overload for a short time without damage; this time will decrease with heavier overloads. The overload trip coil, in consequence, is required to impose a time delay between the incidence of an overload and the tripping of the circuit-breaker, this time delay being arranged to decrease with increasing current, Le., an inverse-time characteristic. One method of obtaining this characteristic is by means of an oil dashpot.

The disadvantage of the direct-acting overload trip-coil is that it has to carry the main circuit current and it must also be capable of carrying, without damage, shortcircuit currents. Instead, the direct-acting overload device can be arranged to operate via a current-transfonner. This method has advantages where it is necessary to insulate the trip device from the main circuit. In addition, since a current-transfonner will saturate on heavy over-current, it is possible to obtain overload settings which are lower than those obtainable with a series connected coil; this is because the saturation of the current-transfonner relieves the coil of the overload trip device from the stresses due to short-circuit currents. When current-transfonner operation is used, it is possible to obtain a time lag on overloads by means of a time-limit fuse. This fuse is connected across the trip coil, and consequently the overload trip device is prevented from operating until the fuse melts due to a current in excess of its rating. The thennal characteristic of the fuse provides a satisfactory time lag for overload currents.

Perhaps the most familiar relay is the induction-type over current relay It consists of an operating coil which is tapped, the tapings being brought out to a plug bridge; the tapings correspond to different current settings. A closed secondary winding is wound on upper and

lower magnets. The fluxes produced by the primary (operating coil) and secondary windings are separated in phase and space and produce a torque, as in the shaded-pole induction disc motor. The disc experiences a torque, which depends on the current, and will move against a restraining spring provided the current, is large enough. The time of travel is adjustable by means of a stop, which adjusts the distance of disc travel to contacts connected to the trip coil of the associated circuit-breaker.

The thennal relay is suitable for the protection against serious overload of such items of equipment as motors and transformers. The relay has a relatively slow action, due to the thennal lag. But this can be an advantage where a time lag is needed in the circuit. The relay will therefore not operate on momentary overloads such as occur during motor starting. An advantage is that the overload is integrated over a period of time, since the heating action is continuous due to the fact that the relay does not reset immediately load is removed, but only recovers gradually as the bimetal cools down.

The thennal relay action is not suitable for coping with short-circuit currents, which must be interrupted as quickly as possible. Some types of relay incorporate an instantaneous high-set element which operates immediately a predetennined value of current is exceeded, as represented by short-circuit conditions.

The use of relays for the protection of motors is becoming common place. Overload protection is arranged to carry the starting current for the starting period without tripping. In the case of direct-on-line starting, the initial starting current may be

as high as 8 x F.L., and the starting period as long as 25 seconds. Under these conditions the protection is usually by means of thermal relays. Instantaneous high-set over-current devices are recommended for short-circuit currents.

# **Protection for cables**

Cables require protection against excess currents, from small overloads to the highest values of short-circuit currents. The introduction of plastics in recent years has resulted in cables insulated and sheathed with such materials being more sensitive to over current conditions than rubber-compounds, paper and mineral insulation. The HRC fuse can provide short-circuit protection up to the highest values of fault currents and, in addition, limit the fault energy so as to keep the fault damage to a minimum. The zone in which protection is probably most difficult to provide is at the low overload/long-time region. Investigations have proved that PVC-insulated cables are able to withstand currents not exceeding 150 percent of their rating for 4 hours when installed in air. Most other forms of cable in common use have a higher withstand value than this; the

implication in this is that an over current protective device which will protect PVC and similar cables will, within reason, be satisfactory for other types.

# **Protection for apparatus**

When a capacitor is switched into a circuit, a heavy inrush of current results and to ensure that fuses do not blow unnecessarily in these circumstances higher rated fuses are required in the circuit. In general, if the fuses fitted are rated at 125-150 per cent of

the capacitor rating, nuisance blowing of the fuses will be avoided. Transformer and fluorescent lighting circuits may also require higher rated fuse links to deal with the inrush currents associated with this class of gear. Fuse links with a rating about 50 per cent greater than the normal current of the apparatus to be protected are usually found to be satisfactory.

The use of semi-conductor devices for rectification and for system control purposes has increased rapidly in recent years, with specific problems in their protection. The result has been the introduction of specialized ranges of fuses. The semi-conductor device has a low thermal withstand compared with its rating and is, therefore, capable only of accepting a comparatively small input of fault energy. Protection must be capable of rapid operation and provide a high degree of energy limitation. The special HRC fuse is the only protective device at present capable of being matched to a semi-conductor. When such a fuse does blow, it is extremely important that it is replaced with a fuse link of exactly the same make and type. Published data are available which discuss the various types of basic circuitry at present in use.

# **CHAPTER 6: ILLUMINATION INSTALLATION**

# **6.1 ILLUMINATION**

It is the most using illumination system of electric energy in todays. Such that reason it is necessary to produce the light installation to respond the diverse demands inside and outside of building.

Illumination installation works with alternative current exept spuralreason. Its linked directly into long by neuter switch illumination installation.

Lamps can be controlled by switch at light installation.

The distinction between terms used in illumination often presents difficulties. The following table shows units and definitions.

Term	Definition	Symbol	Unit	
Luminous intensity	Light source	Ι	Candela	
Luminous flux	Light emitted from a source	Φ	Lumen	
Illumination	Density of luminous flux falling on a working plane	E	Lumen/m2 or Lux(lx)	

# **Inverse Square Law**

The illumination falling on a working plane varies inversely as the square of the distance of that surface from the light source.

The illumination (in lumens per square metre) at a point below a light source on a horizontal work plane (Fig. 16.2) is calculated as follows:

$$E = I/d^2$$

Where;

E = illumination in lumens per square metre,

I = luminous intensity in candelas,

d = distance from light source in metres.

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# **Cosine Law**

The illumination at a point on a horizontal working plane which is at an angle to the light source is calculated as follows:

 $E=(I/d^2).\cos\theta$ 

### **Other Factors in Illumination**

### **Maintenance Factor**

This factor (a number without units) takes into consideration losses in light output due

to;

(a) ageing of lamps and

(b) dirt collecting on lamps and fittings.

The maintenance factor taken between 1.25-1.75.

# **Coefficient of Utilization**

The level of illumination in a factory or office is affected by

(a) light output of lamp (lumens),

(b) the type of reflector used,

(c) height and spacing of fittings,

(d) the colouring of the walls, ceiling, and floor.

These factors are taken into consideration in the coefficient of utilization (a number without units)

Coefficient of Utilization= (Light received on working plane)/(light output of lamps)

Average lighting calculations

```
k = (a.b) / (h(a+b))

\Phi_T = (E.A.d)/\eta

n = \Phi_T / \Phi_L
```

Where,

n = total lamp

 $\Phi_{\rm T}$  = the total luminance flux

A = the area of working place

 $\Phi_L$  = luminance flux of one lamp

k = room index

a = the length of the working place

b = the width of the working place

h = the height of the working place

E = illumination

d = maintenance factor

 $\eta$  = utilization factor

### 6.2 Lamps

# Incandescent Lamp

Principle of Operation . Light energy is produced by passing a current through a conductor (usually tungsten) enclosed in an evacuated glass bulb. The operating temperature is over 2000°C. The efficiency of the lamp is further increased by the following methods:

1. Filling the bulb with an inert gas, usually argon. The gas allows an increased operating temperature (about 2500°C) giving increased light, as it minimizes the losses from the filament due to evaporation. The life of the lamp is also increased (minimum 1000 hours).

2. Double-coiling the filament (the coiled-coil lamp). This reduces the heat losses due to convection currents in the gas. The filament is operated at the same temperature.

The efficiency of the lamp is approximately 121m/W.

NOTE. The efficiency of a lamp is detpendent on

(a) the rating of the lamp (efficiency increases with lamp size);

(b) the age of the lamp;

(c) the operating voltage

Efficiency is decreased when run at values less than rated voltage.

#### **Discharge Lamp**

Principle of Operation. When an electrical pressure is applied across a glass tube containing a certain gas (e.g., neon) an electrical discharge takes place and energy in the form of light is given off. The gas under these conditions is said to be ionized. The electrical connections inside the tube are called electrodes.

Ionization is caused by the movement of electrons in the gas. These electrons 'bombard' the atoms of gas and free other electrons. Light is given off during this' bombardment'.

The flow of current through the tube increases with ionization as a 'chain reaction' takes place:

1. Increased ionization.

2. Decreased resistance of the discharge path.

3. Increased current.

4. The cycle is repeated.

This process of ionization is started off by

(a) a high voltage being applied across the tube; or

(b) the use of heated filaments in the lamp.

The filaments are heated at the moment of starting and are coated with a special oxide which emits electrons. This type of lamp is termed a hot cathode lamp.

A current-limiting device (e.g., a choke) must be fitted in the lamp circuit or the tube will disintegrate

# **The Flourescent Lamp**

It's the lamp which operates between 4-120 watt according to the principles of decharge tube. It's the more preferable than the other lamps due to have more light receiver, regular light distribution and become long life but there is only one drawback, you need subsidiary vehicles.

It can operate when we bind 2x20 watt fluorescent lamps on the ballast with 40 watt as a series. But this bindings don't preferable because of line voltage doesn't less than 220V and in the case of any out of order on the switch or the lamp, It can not use as a system.

The flourescent lamps are fed by three phased systems especially we may usually come across to this system at the workshops.

If the lamps are fed by one phase which is called stroboskobic event, that may cause work-accidients because this event shows us as objectsves are not moving whether moves or it seems to turning adverse direction. To prevent this kind of accident we must do system which is that three phased distribution illuminations at workshop in where works with machinery.

# The Lamps With Mercury Steam :

It is the decharge lamps with high-pressure. Decharge comes out and illuminates when mercury steams as a result of fire the mercury inside the decharge. Illuminations value is so high as a watt/lumen we use it on the streer illuminating. In addition of Fleman, the kind selffired without ballasts of system advanced further.

## 3.4 The Sodium Steamed Lamps :

It is the decharge lamps when it uses at normal voltage. Volfram Flemans are covered by barium oxide. When it get warm under low pressure, sodium turns to steam inside the lamp and it illuminates. For instance, we may come across them at traffic avenues and the high places in where we need to see capability.

#### 3.5 Arc Lamps :

It is the source of light which emits most powerfull light on certain point. It operates about 65 volt direct current (DC) and alternative current (AC). Firstly each one contacts each other and send current. Two coal electrot light come out after arc maker calls.

It is connecting parallel and differential, series to fix the intermediates among coals. Positive electrots are thick because of more eroded in the direct current. But in the alternative current both electrode has thickness.

# 3.6 Light Pipes :

It is the decharge lamp which has basic gases with low-pressured operating in high voltage to use for advertising. It is related the lengths of operating high voltage value.

sorrely restinive load or resultor used at a farmy filanarity or bester elements

country could into This many that the switch of other side

# **CHAPTER 7: CIRCUIT CONTROL DEVICES**

### 7.1 Circuit Conditions Contacts

All electrical circuits are required to have some means whereby they can be energized and disconnected from their supply source. This is done by switches, of

which there is a very wide variety of types available. A 'switch' is defined as a mechanical device capable of making, carrying and breaking current under normal circuit conditions, which may include specified overload conditions. Switches in domestic installations are familiar devices used to control the supply to lighting, cooker and water-heating circuits. Socket-outlets may have switches incorporated. In a consumer unit, the main switch isolates the whole installation from the supply.

Certain types of circuit controls do not qualify as switches. These include thermostats for water-heaters and heating equipment, and touch switches, or electronic switches. Some switches are used as isolators, which are designed to disconnect a circuit usually when the circuit has no current flowing in it.

Some switches are operated by an electromagnet; these include contactors used for switching heating loads, large lighting loads and are also incorporated in motor starters. A more specialized type of electromagnet-operated device is the relay.

Although circuit-breakers tend to be regarded as devices used for protection of circuits against over current (overload and short-circuit), they also perform a duty as switches.

#### **Circuit conditions**

Electrical circuit has its own characteristics, which means that it will show some peculiar electrical property depending on the type of load connected to it. For instance, a circuit which has a purely resistive load (a resistor used as a lamp filament, or heater element) will show a current, which rises when the circuit is first switched on and then falls as the element reaches its normal operating condition. This means that the switch or other circuit-control device must at least be able to break the full-load current taken by the resistor. This applies particularly if the circuit has a de supply. 11 however, the supply is ac, when the switch contacts separate there may be a small arc drawn out between the contacts. This characteristic is even more noticeable when the resistor is in the form of a coil (e.g. in a fire bar element). This effect is caused by the electrical property, which a coil has in an ac circuit. It is called the 'inductive effect'.

If, instead of a resistive conductor wound in the form of a coil, a low-resistance
conductor is wound round a soft-iron core, the item is then known as a 'choke' or inductor, and the circuit is said to have 'inductive characteristics', which lead to switching problems. A fluorescent circuit is an inductive circuit, as is a motor circuit.

If the circuit has a capacitor included in it, it will also show certain characteristics, which may be shown as arcing between switch contacts as they separate. The most pronounced effects of the inclusion of an inductor or a capacitor in a circuit is seen when an ac supply is used. However, small capacitors are often used connected across switch contacts to absorb the sparking caused by contact separation. Used in this way they are sometimes called 'radio-interference suppressors' (e.g. in fluorescent lamp switch starters)

Thus, before a circuit-control device is chosen the circuit to be controlled must be studied so that the device can handle, without damage to itself or the associated circuit wiring, the conditions in the circuit when it is connected or disconnected from its supply. The sections in this chapter, which follow, indicate the type of control for a circuit which various devices offer.

#### Contacts

There is in existence an extremely wide range of electrical-contact types used to control the flow of an electric current in a circuit. The action of any pair or pairs of contacts is (a) to 'make', to allow the current to flow, and (b) to 'break', to prevent the current flow. When this action is contained in a specially designed wiring accessory or apparatus it becomes one of the many forms of devices used to control circuits: switches, contactors, circuit-breakers and the like.

The basic requirements of any pair of contacts are (a) low resistance of the contact material and (b) low resistance between the two contact surfaces when they meet to make the circuit.

When these requirements are satisfied, the two main factors, which lead to switch troubles, are very much reduced. Though one can choose a low-resistance contact material (e.g. copper), one cannot always control the amount of pressure required to keep the two contact surfaces closed sufficiently to reduce what is called 'contact resistance'. A switch, for instance, which is operated many times, will eventually reach a state when its springs become weakened, with the result that pressure of the contacts is lost to such an extent that heat is generated and a breakdown of the switch follows.

The higher the resistance of contact material the more heat (12R walls) there will be when a current passes along it. The second factor involved in the design of switch contacts is the amount of pressure needed to keep the two contact surfaces together. All circuit-control devices, which meet the relevant specifications of the BSI, are tested very rigorously to ensure that they stand up to more wear and tear than they would meet with in normal use. Even so, most contact troubles met with in practice involving the use of circuit-control devices can be traced to insufficient contact pressures.

The material most often used for contacts is copper; this is because it is available in commercial quantities and it has a very low resistance. The terminals associated with the contacts, to which cables and wires are attached, are most often made from brass or phosphor bronze. These two metals are much harder than copper and so can withstand a certain amount of rough handling with screwdrivers when wiring is being carried out.

The insulating materials used in circuit-control devices include vitrified ceramic (for the bases of switches), bakelite (for switch covers and cases), nylon and mica (for carrying the moving contacts of switches), and insulating oil (used in oil-break circuitbreakers)

In many circuit-control devices silver is used, either as a contact facing, or as the contact itself the material has a resistance lower than that of copper; it also has high heatdissipation characteristics and is, for this application, economical to use. Motorcontrol switches sometimes have contacts of silver-cadmium oxide to reduce thetendency to weld together with heat.

Liquid mercury is also used in special switches called mercury switches. This material has a low contact resistance and a high load-Carrying capacity, and can be used in situations with ambient temperatures from about - 17 to 204 DC.

Because the contacts are the bean of the circuit-control device; it follows that their surfaces must be kept clean at all times. Cleaning fluids are available for this purpose. Other maintenance points are the periodic tightening up of conductor terminals and connections, and ensuring that springs have not weakened through use, or that cam surfaces have not become worn.

There are two classes of duty for circuit-control devices: (a) light current and (b) heavy current. Into the first class fall generally lighting switches, relays and bell pushes; the second class includes contactors and circuit-breakers.

#### 7.2 Circuit-breakers

The circuit-breakers can be regarded as a switch, which can be opened automatically by means of a 'tripping' device. It is, however, more than this

Whereas a switch is capable of making and breaking a current not greatly in excess of its rated normal current, the circuit-breaker can make and break a circuit, particularly in abnormal conditions such as the occasion of a short-circuit in an installation. It thus disconnects automatically a faulty circuit.

A circuit-breaker is selected for a particular duty, taking into consideration the following. (a) The normal current it will have to carry and (b) the amount of current which the supply will feed into the circuit fault, which current the circuit-breaker will have to interrupt without damage to itself.

The circuit-breaker generally has a mechanism which, when in the closed position, holds the contacts together. The 'contacts are separated when the release mechanism of the circuit-breaker is operated by hand or automatically by magnetic means. The circuitbreaker with magnetic 'tripping' (the term used to indicate the opening of the device) employs a solenoid, which is an air cooled coil. In the hollow of the coil is located an iron cylinder attached to a trip mechanism consisting of a series of pivoted links. When the circuit-breaker is closed, the main current passes through the solenoid. When the circuit rises above a certain value (due to an overload or a fault), the cylinder moves within the solenoid to cause the attached linkage to collapse and, in turn, separate the circuit-breaker contacts.

Circuit-breakers are used in many installations in place of fuses because of a number of definite advantages. First, in the event of an overload or fault all poles of the circuit are positively disconnected. The devices are also capable of remote control by push buttons, by under-voltage release coils, or by earth-leakage trip coils. The overcurrent setting of the circuit-breakers can be adjusted to suit the load conditions of the circuit to be controlled. Time-lag devices can also be introduced so that the time taken for tripping can be delayed because, in some instances, a fault can clear itself and so avoid the need for a circuit-breaker to disconnect not only the faulty circuit, but other healthy circuits which may be associated with it. The time-lag facility is also useful in motor circuits, to allow the circuit-breaker to stay closed while the motor takes the high initial starting current during the run-up to attain its normal speed. After they have tripped, circuit-breakers can be closed immediately without loss oftime. Circuit-breaker contacts separate either in air or in insulating oil.

In certain circumstances, circuit-breakers must be used with 'back-up' protection, which involves the provision of HBC (high breaking capacity) fuses in the main circuitbreaker circuit. In this instance, an extremely heavy over current, such as is caused by a short circuit, is handled by the fuses, to leave the circuit-breaker to deal with the over currents caused by overloads

In increasing use for modem electrical installations is the miniature circuitbreaker (MCB). It is used as an alternative to the fuse, and has certain advantages: it can be reset or reclosed easily; it gives a close degree of small over current protection (the tripping factor is

1.1); it will trip on a small sustained over current, but not on a harmless transient over current such as a switching surge. For all applications the MCB tends to give much better overall protection against both fire and shock risks than can be obtained with the use of normal IIBC or rewirable fuses. Miniature circuit-breakers are available in distribution-board units for final circuit protection.

One main disadvantage of the MCB is the initial cost, although it has the longterm advantage. There is also tendency for the tripping mechanism to stick or become sluggish in operation after long periods of inaction it is recommended that the MCB be tripped at frequent intervals to 'ease the springs' and so ensure that it performs its prescribed duty with no damage either to itself or to the circuit it protects.

#### Contactor

When a switching device has one or more switches in the form of pivoted contact arms, which are actuated automatically by an electromagnet, the device is known as a contactor. The coil of the electromagnet is energized by a small current, which is just sufficient to hold the pivoted contact arm against the magnet core, and in turn so hold the contacts (fixed and moving) together. Contactors are used in an extremely wide range of applications.

They fall into two general types: (a) 'maintained' and (b) 'latched-in'. In the first type, the contact arm is maintained in position by the electromagnet. In the latched-in type, the contact arm is retained in the closed position by mechanical means.

Contact design and material depend on the size, rating and application of the contactor. Contactors with double-break contacts usually have silver cadmium-oxide contacts to provide low contact-resistance, improve arc interruption and anti- welding characteristics. Large contactors with single-break contacts use copper contacts for economy. Usually single-break contacts are designed with a wiping action to remove the copper-oxide film which readily forms on the copper tips. Since copper oxide is not a good conductor, it must be eliminated in this way for good continuity.

When the contacts open, an arc is drawn between them. The longer the arc remains, the more the contact material is consumed, and so the shorter is the contact lift-. The arc can be extinguished by two means: long contact travel, or by use of arc interrupters.

The typical arc interrupter is called a 'blow-out' coil. This uses magnetic means to force the arc and its products away from the surfaces of the contacts, thus lengthening and weakening the arc so that it is eventually extinguished.

Contactors are used to control heating loads, and are often used in conjunction with time switches and thermostats, which close or open the electromagnet current as required. With the contactor, a small current (for the electromagnet) can be used to control a relatively large current in another circuit.

### Thermostat

The thermostat is used to control an electric heating appliance or apparatus so that a definite temperature is maintained. it is, therefore, a switch, which operates with a change in temperature and is used in the temperature control of rooms, water-heaters, irons, cooker ovens and toasters. It maintains a temperature within defined limits by switching off the appliance when a higher temperature is attained, and switching it on again when a lower temperature has been reached.

The methods used to operate the switch contacts of a thermostat include the expansion of a metal rod, expansion of a liquid or a gas or the bending of a bimetallic strip. Applications ofthese methods are, respectively, water-heaters, ovens and irons.

The illustrations show the basic elements of each type of thermostat.

The speed of response of a thermostat to a change in temperature depends to a large extent on the material used to convey the heat, called the controller. A thermostat whose thermally sensitive elements are directly opposed to the heat transfer medium will respond faster than one whose elements are shielded by a housing. Liquid-filled systems respond more quickly than gas-filled systems.

## 7.3 Switches and switch fuses

A switch is a device for controlling a circuit or pan of a circuit. The control function consists of energizing an electrical circuit, or in isolating it from the supply.

The type of switch generally indicates the form, which this control takes. For instance, a single-pole switch (usually called 'one-way') controls the Jive pole of a supply. A double pole switch controls two poles.

A common type of switch in use today is the micro-gap with a rating of 5 A, to control lighting circuits. Switches with a 15 A rating are also used to control circuits, which carry heavier currents on both power (socket-outlet) and lighting arrangements.

Switches are designed for use on de and/or ac. In a de circuit, when the switch contacts separate, an arc tends to be drawn out between the separating surfaces. This arc is extinguished only when the contacts are for enough apart and when the breaking movement is quick.

Investigation of a de switch will indicate the length of the gap required when the switch

is open. Compare this gap with the gap length on an ac-only switch it will be found that the latter is very much smaller. The reason for this is that ac tends to be what is called 'selfextinguishing. In an ac circuit, during the time taken for the contacts to open, the voltage, which is alternating, varies between zero and a maximum. It is at the zero position of the alternating voltage that the arc drawn between the parting contacts of an ac only switch is extinguished - and it does not establish itself again in normal circuit conditions. Thus, a switch designed for use only on an ac system need have only a small gap and, furthermore, the con-tact movement does not require to he operated so rapidly as is the case with do switches.

Quick-make-and-break switches are used for de circuits. Quick-make, slow-break switches are recommended for ac circuits, particularly where the load is an inductive one, for instance where fluorescent lamps are being used.

The most common lighting circuits are controlled by using one-way and two-way switches, double-pole switches and intermediate switches.

The single-pole, one-way switch provides the ON and OFF control of a circuit from one position only. When the switch is closed, the lamp is on; when the switch is open, the lamp is off One-way switches are mounted with the word TOP', which appears on the back of the switch plate, at the top. This is to ensure that when the switch rocker is in the up position, the circuit is disconnected from the supply. The switch is, of course, connected in connected in the phase conductor only. The double-pole switch is used in any situation where the voltage of the neutral conductor of a supply system is likely to rise an appreciable amount above earth potential: use of the double-pole switch means that a two-wire circuit can be completely isolated from the supply. The usual application is for the main control of sub-circuits and for the local control of cookers, water-heaters, wall-mounted radiators, and other fixed current using apparatus. The double-pole switch is often used for the 'master' control of circuits, the switch being operated by a 'secret key' attachment, and in consumer units for the complete isolation of an electrical installation from the supply.

The two-way switch is basically a single-pole changeover switch offering two alternative routes for the passage of the circuit current. These switches are sometimes known as 'landing' switches from the days when their application in the electrical installation was virtually limited to 'one in the hail, and one on the landing upstairs'

Though the two-way switch is still used extensively for stair lighting, it is also to be found wherever it is necessary to have one or more lights controlled from anyone of two positions. They are nowadays to be found in bedrooms (door and bedside), long hails (at each and particularly in any room with two entry doors (one at each door). In design, the ch has four terminals, two of which are permanently connected together inside the switch small copper bar on what is called the 'bar' side. One of the bar terminals is blanked off orm a non-separable contact. The switch feed is taken to the other open terminal on the side. The two other terminals are connected to the 'strapping wires'. Two-way switches are in pairs, interconnected so that the switch wire of the light circuit is taken from the open tinal on the bar side of the second switch.

The intermediate switch offers control of a circuit from anyone of three positions, the two positions being at the two two-way switches with which the intermediate switch is often used. The intermediate wiring circuit is basically a two-way circuit in which the ping wires are cross connected by the two ON positions of the intermediate switch. There wo different kinds of intermediate switch, one of which is in common use. It is thus sable to check the type with an ohmmeter, or bell-andbattery set, because the method of ecting up differs. Shows the two common forms of connection made within each type of ch.

The application of the intermediate switch in electrical installations has so far been limited. But there is no reason why it should not be used more extensively. Long balls, idors and passageways with many doors are stilt wired up for two-way control. For mable convenience the light or lights should be controlled from every door and entrance. s, the user of this type of circuit can make his way through a house, switching on lights re him, and switching off behind him without have to grope about in the dark. Two or e intermediate switches can be inter-connected into the basic two-way circuit to offer rol from an almost unlimited number of positions.

1

The switch fuse is often found as the 'main switch', near the supply-intake position. It unit in which the main switch (for installation control) and the main fuses (for the ction of the installation) are combined. In all instances, the switch of the switch fuse of be operated when the cover is open, nor can the cover be removed or opened while the ch fuse is closed. The switch fuse, which usually controls a separate distribution board, is e double or triple-pole type, depending on the supply system.

able and triple-pole switches are found in metal-clad units called isolators. An example is ireman's emergency switch, painted red and found beside high-voltage gas-discharge s such as neon. Isolators are also used to isolate the supply from motors, and heating and *portable appliances.* 

consumer control unit is the most common means used to isolate a complete

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domestic installation from the supply. It incorporates a double-pole switch and a 'live' busbar to which the fmal circuits' protection are connected, and either semi-closed fuses, cartridge fuses, or miniature circuit-breakers the latter becomeing increasingly popular because of their definite action in the event of overloading and circuit faults, coupled with safety in their operation. Allthough originally intended for domestic installations, these units are being used in commercial and industrial installations where small lighting and power loads are involved.

The extremely wide range of switchgear types available today can be found in makers' trade literature, study of which is advised so as to become familiar with what is offered for use in electrical installations. All circuit-control devices, whether switches or other types, must conform to the relevant BS specifications, which thus ensure a minimum guarantee of quality and suitability for use.

### 7.4 Special switches

With the extensive use of electricity today, it is not surprising to find that there is a great variety of switches and other circuit-control devices with special applications. It is possible to indicate here only some of the most common types.

#### Three-heat switch

This type of switch is most often associated with the grill-plate of an electric cooker, though it is also used for the heat control of boiling plates The circuit controlled by the switch consists of two elements of equal resistance. The three-heat switch then offers low, medium and high heat values by its three positions.

The three-heat switch is essentially a rotary or turn switch. The positions are OFF, LOW, MEDIUM, HIGH. The switches are available as a single-pole type (four terminals) or a double-pole type (five terminals).

#### Time switch

As indicated by its definition, the time switch introduces a time element' into an electrical circuit, so that automatic control of the circuit is available at predetermined times. Time switches fall into two general groups: spring-driven and motor-driven. The former uses a mechanism similar to that found in clocks The latter group uses as the driving unit a small electric (synchronous) motor whose speed is constant and varies only with the 50 Hz frequency of the mains supply. Similar motors are used in electric clocks.

There are many applications for time switches: shop-window lighting, driveway lighting, street lighting, staircase lighting in multi-tenanted buildings and heating loads, the latter being switched on during 'off-peak' periods when a cheaper tariff is available.

The time-switch control of lighting circuits is often found in such particular applications

as poultry houses, where banks of switches control the lighting to simulate summer-daylight conditions and so introduce a 'longer-day'. The same technique is also used in horticulture, to hasten the growth of seedlings and plants, particularly during off-season periods of the year.

For normal work, the contacts (either single- or double-pole) are silvered copper, or entirely silver. For heavy currents, mercury-contact time switches are used.

## **Mercury** switch

This is basically a sealed glass tube with a small amount of liquid mercury inside it The leads are fused into the glass. When the tube is tilted, mercury flows over a second tenninal (the first being in pennanent contact with the mercury). Thus, contact is made to make the circuit. Mercury switches are made in a very wide variety of types, each type being designed with a particular duty and application in mind.

Switches of this type have many advantages: low force required to operate them, low contact-resistance, high load-carrying capacity, low cost, and a long life because of the -no wear' characteristic of the contacts. it is also relatively insensitive to ambient temperature conditions; a range from \_4°C to over 204°C has been specified for some switches. Because the glass is hennetically sealed, the mercury switch is effectively immune to dust, oil and condensation, and can be used where corrosive fumes are present.

Contact connections to the switch are made through flexible leads, or 'pigtails', attached to the embedded electrodes or contacts. Some switches are filled with a reducing gas to keep the surface of the mercury pool free from tarnish.

Because glass is used as the switch container, the contacts are always visible for inspection; and mercury tends to resist heat and arc effects. The materials used for the contacts include tungsten, iron or iron alloys (e.g. nickel-iron) and Mercury pools.

Mercury switches are operated by a tilting motion; the method of mounting a switch depends on its application, shape of the actuating member, and the motion produced by it. In the case of a single-throw switch, the glass tube is tilted from the horizontal. Mountings include bimetallic strips, cams and rotating levers. A time-lag element can be introduced by restricting the flow of mercury from one position to another; this is done by a wall placed inside the tube. The wall contains a hole, the diameter of which detennines the amount of rime-delay.

#### **Rotary switch**

The rotary or turn switch offers the facility of controlling a large number of circuits from a local position by using one switch. The three-heat switch is one of the most common examples of the rotary switch. Others include the switches used on switchboards in

conjunction with ammeters and voltmeters on three-phase systems to indicate phase-to-phase currents and voltages.

Many banks of contacts can be fitted to a rotary switch so that complete control of circuits is available. Generally the currents are not large: 15 A is the usual limit.

### **Micro-gap switch**

This switch derives its type name from the fact that when its contacts (usuaUy silver) are open they are separated by an extremely smaU gap: anything up \0 3 rom. A.s indicated earlier in the section on contacts, such switches can be used only on ac circuits. They have many applications apart from 'ac only' lighting circuits.

Thermostats using a 'snap-acting' bimetallic element are in effect micro-gap switches and are to be found in the temperature control of irons, toasters, and cooker heating elements. One industrial application is where a motor overheats and a bimetallic, snap-acting device will switch off the energizing current to stop the motor and so protect its winding.

The snap action is always positive in these switches, no matter how rapidly or how gently the force is applied to the operating button. The button can be moved by a plunger, a leaf spring, or a roller and a lever.

## Starter switch

Starter switches are used for starting fluorescent lamps. The glow-type starter

switch consists of two separated bimetallic contact strips contained in a glass bulb filled with helium gas. The contacts are connected to the fluorescent lamp filaments. When the circuitcontrol switch is closed, the mains voltage appears across the two contact strips. This voltage is sufficient to cause a small gas discharge. The heat generated by the discharge affects the bimetallic contact strips, which bend forward to meet each other. When they make contact, the current flows through the fluorescent lamp filaments to heat them. The gas-discharge glow in the starter switch now disappears. After a few seconds the bimetallic contact strips cool down and separate. This sudden interruption of the circuit causes a high-voltage surge to appear across the ends of the main lamp electrodes to start the gas discharge.

The voltage which now appears across the contact strips in the starter switch is, during running conditions, insufficient to cause further discharge in the helium gas, and so the contacts remain open while the main lamp is burning.

#### Two-way-and-off switch

This is a single-pole changeover switch with an OFF position. It is to be found in hotels, ships and hospitals where it is required to have two lamps in circuit while so arranging their control that both cannot be used at the same tune. The two-way-and-off switch can be used as a dimmer control, when in one ON position of the switch only one lamp is lit; in the other ON position, two lamps are connected in series to give a 'dim' light. Other lamp-control arrangements are available when this type of switch is used with other types such as the two-way.

#### Series-parallel switch

This is a three-position switch with an OFF position when the switch knob or dolly is central the switch is used to control two points, or two groups of points. In one ON position, the lamp or lamps are connected in series (dim). In the other ON position, the lamp or lamps are connected in parallel (bright). These switches are to be found in hotel corridors, hospital wards and in railway carriages.

### Low-voltage contacts

The most common type of low-voltage contact is the bell push, which is operated by the direct pressure of a finger on a push-button: the contacts are copper or brass. One is fixed to the base of the bell push, the other is fixed at one tenninal end, its other free end being raised. Pressure on the push-button depresses the contact's free end to complete the circuit. The contacts are usually natural copper, though they are sometimes given a coating of non-oxidisable metal. Other low-voltage contacts use steel springs and phosphor-bronze springs, and are associated with various alarm circuits: burglar, fire, frost, water-level and smoke-density.

#### Relay

The most common relay is a switch operated by an electromagnet. It consists of an ironcored coil and a pivoted armature. When the coil is energized, one end of the armature is attracted to the electromagnet and the other end presses two or more contacts together contacts may also be opened by this movement of the armature.

Relays are either nonnally closed (NC) or nonnally open (NO). In the first type, when the coil is energized the contacts are open; the contacts close when the coil is reenergized. In the NO relay, the contacts are closed when the coil is energized, and open when it is deenergized. In effect, the relay is an automatic switch. Relays are nonnally designed to operate when a very small current flows in the coil. Thus, a small current can be made to switch a larger current on or off just as a contactor functions from a distant point (remote control). They are also used in bell and telephone systems, and have a wide application in industry.

Other types of relays use a solenoid for their operation. In this instance a plunger is attracted when a predetennined value of current flows in the coil. A time-lag element can be introduced by the addition of an oil- or air-dashpot to delay the movement of the plunger.

Induction and impedance relays operate by the movement of a pivoted disc in the field of an electromagnet; the protective device (usually a circuit-breaker) with which these types are associated is operated by small contacts on the moving disc which, when they close, trip the circuit-breaker. They are used in the protective systems for supply systems, motors, generators and transformers.

The thermal rel~y consists of a bimetallic strip, which heats up when the operating or circuit current flows through it or through an adjacent heating coil. The bending of the strip causes the contacts to either make or break.

#### **Fireman's switch**

This switch is used to isolate high-voltage lighting circuits usually found on the exterior walls of buildings, such as neon signs. The switch, which is painted red, is mounted on the outside of the building adjacent to the sign lamps. A label Fireman's switch' is required to be mounted close to the switch. The OFF position of the switch is at the top and there must be a catch (spring-loaded) to prevent its inadvertent return to the ON position. The mounting height should be not more than 2.75 m from ground level.

#### **Emergency switching**

This is a requirement of the Wiring Regulations. The switches take the form of large mushroom-head buttons, which can be knocked in the event of an emergency, say, in a workshop. The switch then disconnects the circuit or machine.

#### **General requirements**

Directly operated switches are not allowed in bathrooms or shower rooms where switches are within reach of a person in contact with the bath or shower. Pull-cord switches are recommended in these situations.

When time switches are being connected up, it is essential to ensure that a CPC is also connected to the earth terminal provided. From time to time the consumer may need to make adjustments to the switch settings, thus coming into contact with metal parts such as the switch-operating levers. Correct use of the earthing terminal will prevent shock risks.

All lighting switches must be connected m the phase conductor only and the correct color coding of the connecting wires is required by the Wiring Regulations. Any exposed metalwork (such as a metal switch plate) must be earthed. The switch must be of an adequate current rating. If they are used for inductive loads such as fluorescent circuits, they must be filly rated for the value of inductive current taken. If they are not, then they must not carry any more than half their rating, e.g. 2.5 A in the case of a 5 Arated switch. Where switches are used as isolators for motor circuits, they should be located close to the motor position. If this

is not possible, the switch handle should be able to be padlocked in the OFF position so that work can be carried out without fear of the circuit becoming live.

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### **CHAPTER 8 : DOMESTIC INSTALLATION**

Domestic installation are usually supplied from a 16mm<sup>2</sup> twin armoured cable.

1- The Supply Authority's sealing chamber for the termination of the armoured cable.

2- The supply Authority's fuse and neutral block.

3-The Supply Authority's energy meter (kWh meter)

4-Consumer's control unit.

The Supply Authority's fuses need not be dublicated if the permission of the Authority is obtained.

#### 8.1 Domestic Consumer's Control Unit:

This type of unit is usually made up of the following:

a-Main switch (60A) which isolates both the phase and the neutral conductors.

b-One 30A fuse for the cooker circiuti

c-One 30A fuse for the 13Aring circiut (capable of taking two 7/0.85 in cables)

d-One or two 5 A fuses for lighting circuits.

### 8.2 Loading of Final Sub-circuits :

The assumed current demand from points is as follows

15 A socket outlet	15 A
5 A socket outlet	5 A
2A socket outlet	at least ½A
Lighting outlet	minimum 100 W

1- Only one phase of a supply should preferably be brought in to a multigang switch box. Where more than one phase is used there must be a rigid screen or barrier separating the phases, and a clearly visible notice warning of the maximum voltage present. This notice must be placed outside the switch.

2- All final sub-circuits must be electrically separate (i.e. there must be no 'bunching' of neutral conductors). All neutral conductors must be connected at the distribution board in the same order as the line conductors.

#### 8.3 Domestic Ring Circuit :

Regulations as 'a final sub-circuit in which the current-carry-ing and earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution fuse board or its equivalent. A spur of a ring circuit shall be a branch cable having conductors of a cross-sectional area not smaller than that of the conductors forming the ring'.

1- Cable size: minimum twin 2.5 mm<sup>2</sup> and earth p.v.c or t.r.s.

2- Maximum number of socket outlets allowed: unlimited number in floor area under 100m<sup>2</sup>, but spurs may not number more than half the socket outlets on the ring circuit, including stationary appliances.

**3-** Fused 13 A plugs to be used at socket outlets supplying portable appliances.

4- Fixed appliances must be protected by a local fuse, for example, a fused spur box.

5- A 30 A fuse should be used to protect the ring circuit.

6- All socket outlets in any one room must be connected to the same phase.

7- Apparatus permanently connected to the ring circuit without a fused plug or socket outlet must be protected by a local fuse or circuit-breaker with a rating not exceeding 15 A. The apparatus must have anjacent controlling switch.

The purpose of the ring circuit is:

a- To minimize trailing flexes.

b- To take advantage of the fact that all outlets in a domestic installation.

## 8.4 Domestic Lighting:

Domestic lighting circuits are usually wired in 1 mm<sup>2</sup> twin t.r.s. or p.v.c.(twin 1.5 mm may also be used). The protecting fuse is generally 5 A (20 mm tinned copper wire or cartridge fuse with white body). Conductors in a lighting final sub-circuit (or any final sub-circuit) should never be interconnected with other final sub-circuits. For example, a final sub-circuit neutral should never be used to feed more than one final sub-circuit. Each neutral conductor should be connected to its individual terminal at the neutral block: 'bunching' is not permitted. An earthing terminal must be provided at every lighting point. The earth continuity conductor of the final sub-circuit must be connected to this terminal. Nonmetallic switches must also be supplied with and earthing terminal is not required where earthed metal boxes are used which have a fixing for the metal switch plate giving reliable electrcial contact between the plate and the metal box.

Light switches are usually of the 5A (A.C.) quick-make-slow-break (Q.M.S.B.) type, flush mounting. Switches used in fluorescent lamp circuits must be capable of carrying twice the normal circuit current in order to withstand the inductive effect of the choke.

## 8.5 Water Heaters:

Domestic water heaters are generally rated at 3kW and are usually supplied from the ring circuit. Asbestos-covered cable should be used to terminate the conductors at the immersion heater since p.v.c and tir.s cables are normally expected to be used where the surrounding

temperature (the ambient temperature) does not exceed 30°C. The temperature range of water heaters is between 43°C and 82°C.

The thermostat, in common withall other switching devices, musts always be fitted in the phase conductor.

## 8.6 Bathroom:

All lampholders must be of the Home Office (skirted) type and lamps should be totally enclosed. Only circular flexible cable should be used where necessary and the switch must be of the pull-cord type. No portable appliances should be fitted or used in the bathroom and fixed appliances, for example, wall fires, must be placed out of reach of persons in the bath.

#### 8.7 Garages :

Socket outlets in garages must be placed at a safe distance from floor level. All portable appliances, particularly handlamps, must be earthed and handlamps should be fitted with an earthed shiled.

## 8.8 Cooker Control Unit :

This generally consists of a double-pole switch feeding the cooker and an independent 13A socket outlet. It is essential that the earth continuity conductor supplying the unit should be effectively connected.

The cooker control unit is generally supplied from a separate way in the consumer's control unit and wired with 10mm<sup>2</sup> twin and earth p.v.c or t.r.s cable. It is fused at 30A which is sufficient to protect a maximum of 9kW (3-plate cooker). The current demand from a stationary cooking appliance is calculated as follows: 10A+30 per cent of the total remaining full load current. Every stationary cooking appliance in domestic premises must have an adjacent control switch fitted within 2 m of the appliance.

## **CHAPTER 9: ILLUMINATION AND COST CALCULATIONS**

## 9.1 Illumination calculation

## Bodrum Katı

## 1. Labaratuvar

a= 3.6m	b=4.5m	h=3m	A=16.2m <sup>2</sup>	d= 1.25
Ceiling= 0.80	en constituine	Wall= 0.50		Graund= 0.10
E=300 lux	Armat	ure Type=4x18	8w floresent	$\Phi_L$ =4200 lm
Room index				
k=(axb)/[hx(axb)/[h	a+b)] = (3.6x4)	.5)/[3x(3.6+4.5	5)] = 0.67	
effeciency of	illumination			
k=0.60	η=0.23			
k=0.80	η=0.29			
interpolation				
△k=0.20	∆η=0	.06		
0.07	X=?			
X=0.021				
$\eta = 0.23 + 0.022$	l = 0.251 = 0.25			
$\Phi_T = (ExAxd)/$	$\eta = (300 \times 16.2)$	x1.25)/0.25=24	4300	
$n = \Phi_T / \Phi_L = 2$	24300/4200=5.	785		

we can use 6 Armature

2. Diş Klini	ği			
a= 4.8m	b=7.85m	h=3m	A=31.92m <sup>2</sup>	d= 1.25
Ceiling= 0.8	0	Wall= 0.50		Graund= 0.10
E=250 lux	Arm	ature Type=4x	18w floresent	$\Phi_L$ =4200 lm
Room index				
k= (axb)/[hx	(a+b)] = (4.82)	x7.85)/[3x(4.8+	7.85)] = 0.99	
effeciency of	fillumination			
k=0.80	η=0.29			
k=1.00	η=0.33			
interpolation				
△k=0.20	$\Delta \eta =$	-0.04		
0.09	X=?			
X=0.018				
$\eta = 0.29 + 0.01$	8= 0.308= 0.3	31		
$\Phi_{T} = (ExAxd)/$	$\eta = (250 \times 31.)$	92x1.25)/0.31=	= 32177	
$n = \Phi_T / \Phi_L =$	32177/4200="	7.66		
we can use 8	Armature			
3. Tomografi	i Bölümü			
a= 9.00m	b=7.7m	h=3m	$A = 48.35 m^2$	d= 1.25
Ceiling= 0.80	0.88	Wall= 0.50		Graund= 0.10
E=250 lux	Arma	ature Type=4x1	8w floresent	$\Phi_L$ =4200 lm
Room index				
k=(axb)/[hx(axb)/[h	(9x7.	7)/[3x(9+7.7)]	= 1.38	
effeciency of	illumination			
k=1.25	η=0.38			
k=1.50	η=0.41			-
interpolation				
△k=0.25	$\Delta \eta =$	0.03		
0.13	X=?			
X=0.0156				
$\eta = 0.38 + 0.013$	56= 0.3956= (	0.40		
$\Phi_T = (ExAxd)/$	$\eta = (250 \times 48.2)$	35x1.25)/0.40=	37773	
$\mathbf{n} = \Phi_{\mathrm{T}} / \Phi_{\mathrm{L}} = 3$	37773/4200=8	3.99		
we can use 9 A	Armature			

# 4. Tanı Bölümü

a= 6.1m	b=6.00m	h=3m	$A = 31.95 m^2$	d= 1.25
Ceiling= 0.80		Wall= 0.50		Graund= 0.10
E=250 lux	Arma	ture Type=4x1	8w floresent	$\Phi_L$ =4200 lm
Room index				
k=(axb)/[hx(axb)/[h	(a+b)] = (6.1x)	6)/[3x(6.1+6)]	= 1.00	
η= 0.33				
$\Phi_T = (ExAxd)/$	$\eta = (250 \times 31.9)$	95x1.25)/0.33=	= 30256	
$n = \Phi_T / \Phi_L = 2$	30256/4200=7	2.20		
we can use 7	Armature			
Zemin Kat				
1. Hasta Mua	yene Odası			
a= 6.70m	b=4.7m	h=3m	$A = 31.5 m^2$	d= 1.25
Ceiling= 0.80		Wall= 0.50		Graund= 0.10
E=250 lux	Arma	ture Type=4x1	8w floresent	$\Phi_L$ =4200 lm
Room index				
k=(axb)/[hx(axb)/[h	$(a+b)] = (6.7x^4)$	4.7)/[3x(6.7+4	.7)] = 0.92	
effeciency of	illumination			
k=0.80	η=0.29			
k=1.00	η=0.33			
interpolation				
△k=0.20	$\Delta \eta = 0$	0.04		
0.12	X=?		_	
X=0.024				
$\eta = 0.29 + 0.024$	4= 0.314= 0.3	1x1.25y0.30-		
$\Phi_T = (ExAxd)/$	$\eta = (250 \times 31.3)$	5x1.25)/0.31=	31754	
$n = \Phi_T / \Phi_L = 3$	31754/4200=7	.56		
we can use 8	Armature			

# 2. Hasta Muayene Odası

a= 4.95m	b=8.00m	h=3m	$A = 39.6m^2$	d= 1.25
Ceiling= 0.8	0	Wall= 0.50		Graund= 0.10
E=250 lux	Arma	ature Type=4x	18w floresent	$\Phi_L$ =4200 lm
Room index				
k= (axb)/[hx	(a+b)] = (4.95)	x8)/[3x(4.95+	8)] = 1.00	
η= 0.33				
$\Phi_{T} = (ExAxd)$	$/\eta = (250 \mathrm{x} 39.$	6x1.25)/0.33=	37500	
$n = \Phi_T / \Phi_L =$	37500/4200=8	8.928		
we can use 9	Armature			
3. Hasta Mu	ayene Odası			
a= 6.20m	b=4.3m	h=3m	$A = 26.7 m^2$	d= 1.25
Ceiling= 0.80		Wall= 0.50		Graund= 0.10
E=250 lux	Arma	ture Type=4x1	8w floresent	$\Phi_L$ =4200 lm
Room index				
k=(axb)/[hx(axb)/[h	$(6.2x^2)$	4.3)/[3x(6.2+4.	.3)] = 0.85	
effeciency of	illumination			
k=0.80	η=0.29			
k=1.00	η=0.33			
interpolation				
△k=0.20	$\Delta \eta = 0$	.04		
0.05	X=?			
X=0.01				
η= 0.29+0.01=	= 0.30			
$\Phi_T = (ExAxd)/$	$\eta = (250 \times 26.7)$	x1.25)/0.30=2	27812.5	
$n = \Phi_{\rm T} / \Phi_{\rm L} = 2$	7812.5/4200=	6.622		
we can use 6 A	rmature			

# Kat

# İç Hol

11.1m b=3.5	$0m h=3m A=40.1m^2$	d= 1 25
iling= 0.80	Wall = 0.50	Graund=0.10
150 lux	Armature Type=2x18w floresent	$\Phi_{\rm I} = 2100  \rm{lm}$
om index		- L 2100 mi
(axb)/[hx(a+b)] =	(11.1x3.50)/[3x(11.1+3.50)] = 0.85	
eciency of illumination	ation	
0.80 η=0.29	)	
.00 η=0.33		
rpolation		
=0.20	$\Delta \eta = 0.04$	
•	<u>X=?</u>	
.018		
.29+0.018= 0.308	8=0.31	
$(ExAxd)/\eta = (150)$	0x40.1x1.25)/0.31 = 24254	
$\Phi_{\rm T} / \Phi_{\rm L} = 24254/21$	00=115495	

an use 12 Armature

# 2. Hasta Muayene Odası

a= 6.7m	b=4.8m	h=3m	$A = 28.8 m^2$	d= 1.25
Ceiling= 0.80		Wall= 0.5	0	Graund= 0.10
E=150 lux	Arma	ature Type=2	x18w floresent	$\Phi_{\rm L}$ =2100 lm
Room index				
k=(axb)/[hx(axb)/[h	(a+b)] = (6.7x)	4.8)/[3x(6.7-	(+4.8)] = 0.93	
effeciency of i	illumination			
k=0.80	η=0.29			
k=1.00	η=0.33			
interpolation				
△k=0.20	$\Delta \eta =$	0.04		
0.13	X=?	0.5-0		
X=0.026				
$\eta = 0.29 + 0.026$	= 0.316=0.3	2		
$\Phi_T = (ExAxd)/r$	$\eta = (150 \mathrm{x} 28.8$	8 x1.25)/0.32	= 16875	
$n = \Phi_T / \Phi_L = 1$	6875/2100=8	.0357		
we can use 8 A	rmature			
3. Hasta Muay	yene Odası			
a= 6.2m	b=4.3m	h=3m	$A=24m^2$	d= 1.25
Ceiling= 0.80		Wall= 0.50		Graund= 0.10
E=150 lux	Arma	ture Type=2>	18w floresent	$\Phi_L=2100 \text{ lm}$
Room index				
k=(axb)/[hx(a-	(6.2x4)	.3)/[3x(6.2+	4.3)] = 0.85	
effeciency of il	lumination			
k=0.80 1	η=0.29			
k=1.00 1	η=0.33			
interpolation			-	
△k=0.20	∆η=0	.04		
0.05	X=?			
X=0.01				
$\eta = 0.29 + 0.01 =$	0.30			
$\Phi_{\rm T}=({\rm ExAxd})/\eta$	=(150x24 x)	1.25)/0.30=1	15000	
$n = \Phi_T / \Phi_L = 15$	5000/2100=7.	1428		
we can use 7 A	rmature			

2. Kat	
1. İç Hol	
$a=11.1m$ $b=3.50m$ $h=3m$ $A=40.1m^2$	d= 1.25
Ceiling= 0.80 Wall= 0.50	Graund= 0.10
E=150 lux Armature Type=2x18w floresent	$\Phi_L=2100 \text{ lm}$
Room index	
k = (axb)/[hx(a+b)] = (11.1x3.50)/[3x(11.1+3.50)] = 0.85	
effeciency of illumination	
k=0.80 η=0.29	
k=1.00 η=0.33	
interpolation	
$\Delta k=0.20$ $\Delta \eta=0.04$	
<u>0.09 X=?</u>	
X=0.018	
$\eta = 0.29 + 0.018 = 0.308 = 0.31$	
$\Phi_{\rm T}$ =(ExAxd)/ $\eta$ = (150x40.1x1.25)/0.31= 24254	

 $n = \Phi_T / \Phi_L = 24254/2100 = 115495$ 

we can use 12 Armature

# 2. Hasta Muayene Odası

a= 6.7m b=4.8r	n h=3m	$A = 28.8 m^2$	d= 1.25
Ceiling= 0.80	Wall= 0.50		Graund= 0.10
E=150 lux	Armature Type=2x1	8w floresent	$\Phi_L$ =2100 lm
Room index			
k=(axb)/[hx(a+b)] =	(6.7x4.8)/[3x(6.7+4.	8)] = 0.93	
effeciency of illumin	ation		
k=0.80 η=0.29	9		
k=1.00 η=0.32	3		
interpolation			
△k=0.20	∆η=0.04		
0.13	X=?		
X=0.026			
$\eta$ = 0.29+0.026= 0.3	16=0.32		
$\Phi_{\mathrm{T}}=(\mathrm{ExAxd})/\eta = (1$	50x28.8 x1.25)/0.32=	16875	
$n = \Phi_T / \Phi_L = 16875 / I$	2100=8.0357		
we can use 8 Armatu	ıre		
3. Hasta Muayene	Odası		
a= 6.2m b=4.3	m h=3m	$A=24m^2$	d= 1.25
Ceiling= 0.80	Wall= 0.50		Graund= 0.10
E=150 lux	Armature Type=2x	18w floresent	$\Phi_L=2100 \text{ lm}$
Room index			
k=(axb)/[hx(a+b)]	= (6.2x4.3)/[3x(6.2+4)]	1.3)] = 0.85	
effeciency of illumi	nation		
k=0.80 η=0.2	29		
k=1.00 η=0.2	33		
interpolation		-	-
∆k=0.20	∆η=0.04		
0.05	X=?		
X=0.01			
$\eta$ = 0.29+0.01= 0.3	0		
$\Phi_{T} = (ExAxd)/\eta = ($	150x24 x1.25)/0.30=	15000	
$n = \Phi_{\rm T} / \Phi_{\rm L} = 15000$	)/2100=7.1428		
we can use 7 Arma	ture		

## 3. Kat

## 1. Ameliyathane

a= 4.8m b=6.7m	h=3m	$A = 32.5 m^2$	d= 1.25
Ceiling= 0.80	Wall= 0.50		Graund= 0.10
E=500 lux Arm	nature Type=4x	18w floresent	$\Phi_L$ =4200 lm
Room index			
k=(axb)/[hx(a+b)] = (4.8)	x6.7)/[3x(4.8+6	5.7)] = 0.93	
effeciency of illumination	l		
k=0.80 η=0.29			
k=1.00 η=0.33			
interpolation			
$\triangle k=0.20$ $\triangle n$	=0.04		
<u>0.13 X=</u>	?		
X=0.026			
$\eta$ = 0.29+0.026= 0.316=0	.32		
$\Phi_{\rm T}$ =(ExAxd)/ $\eta$ = (500x3	2.5x1.25)/0.32=	63477	
$n = \Phi_T / \Phi_L = 63477/4200$	=15.1135		
we can use 15 Armature			

# 2. Ameliyathane

a= 4.9m	b=6.15m	h=3m	$A = 30.13 m^2$	d= 1.25
Ceiling= 0.80	)	Wall= 0.50	)	Graund= 0.10
E=500 lux	Arma	ture Type=42	x18w floresent	$\Phi_L$ =4200 lm
Room index				
k= (axb)/[hx(	(4.9x) = (4.9x)	6.15)/[3x(4.9	+6.15)] = 0.91	
effeciency of	illumination			
k=0.80	η=0.29			
k=1.00	η=0.33			
interpolation				
△k=0.20	$\Delta \eta = 0$	0.04		
0.11	X=?			
X=0.022				
η= 0.29+0.022	2= 0.312=0.3			
$\Phi_T = (ExAxd)/$	$\eta = (500 \times 30.1)$	3x1.25)/0.31	= 60746	
$n = \Phi_T / \Phi_L = 6$	50746/4200=1	4.4633		
we can use 14	Armature			
3. Yoğun Bak	am			
a= 7.30m	b=4.30m	h=3m	$A = 31.3 m^2$	d= 1.25
Ceiling= 0.80		Wall= 0.50		Graund= 0.10
E=400 lux	Armat	ure Type=4x	18w floresent	$\Phi_L$ =4200 lm
Room index				
k= (axb)/[hx(a	(+b)] = (7.30x)	4.30)/[3x(7.3	[30+4.30)] = 0.90	
effeciency of i	llumination			
k=0.80	η=0.29			
k=1.00	η=0.33			
interpolation			1.14	
△k=0.20	∆η=0	.04		
0.10	<u>X</u> =?			
X=0.02				
$\eta = 0.29 + 0.02 =$	0.31			
$\Phi_{\rm T}=({\rm ExAxd})/r$	$\eta = (400 \times 31.3)$	x1.25)/0.31=	50484	
$n = \Phi_{\rm T} / \Phi_{\rm L} = 5$	0484/4200=12			
we can use 12	Armature			

4.Doğumhane		
a= 6.00m b=4.60m	$h=3m$ $A=20.1m^2$	d= 1.25
Ceiling= 0.80	Wall= 0.50	Graund= 0.10
E=250 lux Arma	ature Type=4x18w floresent	$\Phi_L$ =4200 lm
Room index		
k = (axb)/[hx(a+b)] = (6.00)	(x4.60)/[3x(6+4.60)] = 0.87	
effeciency of illumination		
k=0.80 η=0.29		
k=1.00 η=0.33		
interpolation		
$\triangle k=0.20$ $\triangle n=$	0.04	
0.07 X=?		
X=0.014		
$n = 0.29 \pm 0.014 = 0.304 = 0.304$	)	
$\Phi = (T_{22} + 0.014 - 0.004 - 0.004)$		
$\Phi_{\rm T} - (\rm ExAxd)/\eta = (250x20.$	1x1.25)/0.30=20938	
$n = \Phi_T / \Phi_L = 20938/4200 = 4$	.98	
we can use 5 Armature		
4. Septik Doğumhane		
a=4.1m b=3.7m	h=3m $A=15.6m^2$	d= 1.25
Ceiling= 0.80	Wall= 0.50	Graund= 0.10
E=250 lux Arma	ture Type=4x18w floresent	$\Phi_L$ =4200 lm
Room index		
k=(axb)/[hx(a+b)] = (4.1x3)	3.7)/[3x(4.1+3.7)] = 0.65	
effeciency of illumination		
k=0.60 η=0.23	- 3 - 4	
k=0.80 η=0.29		
interpolation		50 000,20 ·
$\Delta k=0.20$ $\Delta m=0$	06	
0.05 X=?		
X=0.015		
$n = 0.23 \pm 0.015 = 0.245 \pm 0.25$		
$\Phi = (E_{11} A_{12} + 0.01) = (0.243 - 0.23)$	1.05 /0.05	
$\Psi_{T}$ (CXAXU)/ $\eta = (250 \times 15.6)$	$(x_{1.25})/0.25 = 19500$	

 $n = \Phi_T \, / \, \Phi_L = 19500 / 4200 = 4.6428$ 

we can use 5 Armature

## 9.2 Cost Calculations

	ELEKT	TI MAAL	/AALİYET HESABI		
				<b>B.FİYATI</b>	TUTARI
NO	YAPILACAK İŞ	MİKTAR	BİRİM	(YTL)	(YTL)
1	4x18W floresent tesisati	198	Adet	382,50	75.735,00
2	2x18W floresent tesisati	110	Adet	200,00	22.000,00
3	Duvar globu tesisatı	26	Adet	50,60	1.315,60
4	Duvar apliği tesisatı	34	Adet	98,50	3.349,00
5	w/p lamba tesisatı	14	Adet	50,60	708,40
6	1x80W floresent tesisati	1	Adet	91,75	91,75
7	Askı tipi lamba tesisatı	1	Adet	42,30	42,30
8	Priz tesisatı (1x13A)	120	Adet	56,00	6.720,00
9	Priz tesisatı (2x13A)	58	Adet	67,00	3.886,00
10	w/p Priz tesisatı (1x13A)	10	Adet	145,00	1.450,00
11	fan coil tesisatı	53	Adet	99,00	5.247,00
12	Telefon prizi tesisatı	18	Adet	61,25	1.102,50
13	TV anten prizi tesisatı	34	Adet	75,25	2.558,50
14	Yangın ihbar santralı (6 zone)	1	Adet	5.000,00	5.000,00
15	Elektro-Optik alev dedektörü	56	Adet	457,75	25.634,00
16	Yangın ihbar butonu	12	Adet	169,25	2.031,00
17	Yangın ihbar sireni	5	Adet	239,00	1.195,00
18	İnterkom tesisatı(4 abone)	1	Adet	660,00	660,00
19	numaratör tesisatı (8 abone)	2	Adet	602,00	1.204,00
20	3 faz cihaz tesisatı (70 kVA)	1	Adet	490,00	490,00
21	3 faz cihaz tesisatı (50 kVA)	1	Adet	490,00	490,00
22	3 faz cihaz tesisatı (100 kW)	1	Adet	490,00	490,00
23	Motor tesisatı (3faz 5.5kW)	2	Adet	110,00	220,00
24	Motor tesisatı(3faz 1.5kW)	6	Adet	75,00	450,00
25	Motor tesisatı(3faz 2.2kW)	3	Adet	75,00	225,00
26	Motor tesisatı(3faz 17kW)	1	Adet	159,25	159,25
27	ADT (3x12 yollu 630A) MCCB'li	1	Adet	7.100,00	7.100,00
28	ADT (3x12) yollu	3	Adet	811,25	2.433,75
29	ADT (3x8) yollu	2	Adet	737,50	1.475,00
30	ADT (3x6) yollu	1	Adet	666,25	666,25
31	ADT (3x4) yollu	1	Adet	612,50	612,50
32	MCB 3x10A	2	Adet	157,50	315,00
33	MCB 3x5A	9	Adet	157,50	1.417,50
34	MCB 3x30A	1	Adet	157,50	157,50
35	MCB 1x30A	17	Adet	34,00	578,00
36	MCB 1x5A	45	Adet	34,00	1.530,00
37	MCB 1x8A	53	Adet	34,00	1.802,00
38	MCB 1x15A	3	Adet	34,00	102,00
39	MCB 1x20A	1	Adet	34,00	34,00
40	Reklam Işığı Tesisatı	1	Adet	56,40	56,40

41	MCCB+ELCB (3x630A)	1	Adet	4.288,00	4.288,00
42	MCCB (3x630A)	4	Adet	3.187,50	12.750,00
43	MCCB (3x225A)	1	Adet	853,75	853,75
44	MCCB (3x100A)	3	Adet	536,25	1.608,75
45	MCCB (3x63A)	6	Adet	353,75	2.122,50
46	Toprak otomatiği (3x63A)	6	Adet	481,00	2.886,00
47	Toprak otomatiği (3x100A)	1	Adet	1.112,00	1.112,00
48	merkezi topraklama	1	Adet	2.250,00	2.250,00
	(4x150+70)mm2 ç.z kablo				
49	tesisatı	40	metre	175,50	7.020,00
	(3x120+70)mm2 XLPE kablo				
50	tes.	45	metre	150,00	6.750,00
51	(3x35+16)mm2 ç.z kablo tes.	25	metre	48,50	1.212,50
52	(3x35+16)mm2 PVC kablo tes.	5	metre	38,25	191,25
53	(3x16+6)mm2 PVC kablo tes.	150	metre	12,75	1.912,50

TOPLAM

225.691,45

## **CONCLUSION**

This thesis is about electrical installation of a hospital. In this thesis I was learn, how I can design an electrical installation of the building and what are need to design for electrical installation.

The thesis is given some information about History of electricity, Weak current installation, Conductors and Cables, Electrical safety-protection\_earthing, Illumination installation, Circuit control devices, Domestic installation and Cost and Illumination calculation.

In the practical part for drawing installation project by using AutoCAD is prepared. The calculation part is by using excel is prepared.

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