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Faculty of Engineering

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ELECTRICAL INSTALLATIONS FOR A TERACED HOUSE BASED ON MAINS AND WIND POWER GENERATION

Graduation Project
EE-400

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ABSTRACT

To provide an electrical installation for building is one of the main and most important tasks for the electrical engineers.

The main objective of this project is to design the electrical installation system for a two stairs building. It showed that all electrical installations must consider the safety side, like protections against fires and electrical shock.

For this purpose, we applied IEE wiring regulations, which covers wiring techniques, conductors, cables, installation methods, lighting, and small power circuits.

One of the new things this project tries to implement is the use of wind generators at houses. Its very good and economic way to produce electric from this renewable energy at wind. This project implemented a wind generator in the building, which can work directly and light the building when the main electric cut off.

INTRODUCTION

This project covers the installation of a two stairs building. It provides in detailed all the parameters and concepts which considered when implementing such a project. The load of the building consists of lighting, small power supply, heating cooling system, and special power installation for wind generator.

Chapter one explains the importance of safety in the electrical installations. Shows that IEE regulations are the reference for all engineers and technical workers, and the protection is the basic point of these regulations.

Chapter two bases on final circuit. They make up the greater part of electrical installations. It includes motors circuits, lamps circuits, choosing cable sizes. Also it focuses on wiring systems which includes conduits, trunkings, and introduces some types of protection devices like HRC and MCB.

Chapter three tries to give the techniques of choosing the lighting system for our area. It briefly explains the discharge and filament lamps. They are the most popular lamps that are using in indoor applications.

Chapter four focuses on the wind power and how to produce electric from the wind and how it will be useful if the building has wind generator that can start to work when electric is off and can supply all lighting circuits building.

Chapter five deals with water pumps. It explains pumps basics and the installation. It represents the centrifugal pump, the control gear and voltage drop.

The conclusion shows the important results, contribution and future thought.

CHAPTER ONE

REQUIREMENTS FOR SAFETY IN ELECTRICAL INSTALLATION PROJECTS

1.1 Overview

The rules and regulations that govern the practice of electrical installation engineering are essential to ensure that all electrical installations provide an adequate degree of safety from fire and shock risks to those who operate the installations and their associated apparatus, equipment and machines. The essence of these statutory regulations are collected in the IEE Regulations. Guidance on specific points of installation, choice of electrical equipment, and the maintenance of electrical apparatus, is the subject of many of the codes of practice issued by the British Standards Institution. The object of this chapter is to introduce these regulations as the main standards of my project that will be based on.

1.2 IEE Regulations

These Regulations are designed to supplement statutory regulations relating to electrical work have evolved over the past century to ensure a maximum degree of safety from tire, shock and burns, when electricity used in and about buildings. Though the Regulations are principally concerned with all aspects of electrical installations, they also touch on certain requirements relating to the selection of electrical equipment used in installations.

As the use of electricity became more popular, it soon became clear that some unified form of regulations, concerning its safe installation into buildings, would be necessary if serious accidents were to be avoided. It was for this reason government put some rules for electricity installations. The regulations set out to achieve the following:

- To safeguard the users of electrical energy from shock
- To minimize the fire risk
- To ensure as far as possible the safe and satisfactory operation of apparatus.

Though these Statutory Regulations are concerned with electrical safety in the respective type of installations listed, there are other Statutory Regulations, which are also

concerned with electrical safety when equipment and appliances are being used. Included in these are the Electricity at Work Regulations which came into force in 1990.

They are stringent in their requirements that all electrical equipment used in schools, colleges, factories and other places of work is in a safe condition and must be subjected to regular testing by competent persons.

It is a requirement of the current edition of the IEE Regulations for Electrical Installations that good workmanship and the use of approved materials contribute to the high level of safety provided in any electrical installation. The British Standards Institution (BSI) is the approved body for the preparation and issue of Standards for testing the quality of materials and their performance once they are installed in buildings.

1.3 Summary

All electrical installations are required to have an in-built safety factor, to protect the users against the risk of electric shock, fire and burns while this can be done at the design stage, much depends on the installer's approach to the work, ensuring that wiring is correctly installed and that equipment is correctly connected.

In TRNC, the chamber of electrical engineering must approve the electrical installation projects before they put into operation to provide the safety.

CHAPTER TWO

WIRING SYSTEMS AND INSTALLATION METHODS

2.1 Overview

Electricity has been one of the most important factors in the social progress made by this country over the past half-century. It affects health, education and housing, standards of living and industrial and agricultural progress. Its universal application is seen in the many different types of current-using appliances found in the home, in the office and in the factory making it possible to perform tasks easily, safely and efficiently. This chapter deals with some of the more common current-using equipment, their applications and their general installation requirements.

2.2 Sheathed wiring systems

A wiring system is an assembly of parts used in the formation of one or more electric circuits. It consists of the conductor, together with its insulation, its protection against mechanical damage (sheathing and/or armouring), and certain wiring accessories for fixing the system, and joining and terminating the conductors.

As implied by the term 'sheathed wiring system', this method of wiring consists of an insulated conductor provided with a sheath, which serves in some degree as a measure of protection against mechanical damage. The insulating materials include impregnated paper, rubber, plastics and mineral insulation. The sheathing materials include lead, tough rubber, plastics, aluminum and textiles. Some of the cables are designed with a view to cheapness and are particularly suited to domestic installations.

2.2.1 PVC (polyvinyl chloride sheathed)

This is an 'all-insulated' wiring system and commonly used for domestic installations. Though it is inferior to rubber, in the context of insulation-resistance and elastic properties, it has many advantages, not least being its comparative cheapness and ease of handling. Its main disadvantage is that it tends to soften at high temperatures, which is why its maximum

operating temperature is 70 ^{0}C. Above this temperature, there is a tendency for the conductors to migrate through the PVC, which leads to much reduced values of insulation resistance, ultimately causing a breakdown to earth. There is also a lower temperature limit, set at 0 "C. At this temperature, the PVC tends to harden and becomes a difficult material to work. The PVC-insulated cables have cores, which are self-colored for identification: red, black, blue and yellow. Blue and yellow are the colors used in three-core cables for two-way wiring. The sheathed cables contain an uninsulated circuit protective conductor, which must be sheathed with insulating sleeving (colored green/yellow) whenever the cable is made off for entry to wiring accessories.

Because the sheath can be damaged, it is recommended that additional protection be provided in situations where there is a possibility of the cable sustaining physical or mechanical damage. These cables are often run in floor spaces and in attics. The IEE Regulations draw attention to the possibility of the cables, run in these situations, coming into contact with thermal insulation material. Particularly where expanded polystyrene granules are used for loft insulation, there is the real chance that some of the plasticizer material used in PVC cable sheaths will 'migrate' and produce a hardening of the sheath. The other problem with PVC cables in contact with thermal insulation is that their current rating can be drastically reduced. The relevant factors are 0.5 if the cables are surrounded by the material and 0.75 if only one side is in contact.

In this project, we used PVC in our installation. Let us introduce the other kinds of cables.

2.2.2 PVC-S WA cables

Cables insulated with PVC and provided with steel-wire armouring are used extensively for main and sub-main cables and for wiring circuits in industrial installations. The conductors are copper or, where lightness and easy handling are needed, of aluminum. The cables are run on cable trays, racks, or installed in trenches. Terminations are by use of cable glands; flameproof glands are available for hazardous areas. If these cables are run to motor positions, where the machine is mounted on slide rails, a loop should be left in the cable to allow movement.

2.2.3 PIL C (paper-insulated, lead-covered)

Paper-insulated, lead-sheathed and served (compounded jute) cables are mainly used for external underground distribution systems. But this type of cable has a wide application for internal distribution in factories and other industrial premises. It can, therefore, be regarded as a wiring system. The paper is impregnated and must be protected against the ingress of moisture; hence the use of cable-sealing boxes. The current-carrying capacity of this type of cable is greater than that of an equivalent butyl cable. Bending of PJLC cables must be done very carefully. Fixing is normally by cleats. Further protection against mechanical damage is provided by armouring in the form of helical-wound steel wire or tape.

2.2.4 MIMS (mineral-insulated, metal-sheathed)

These cables consist of copper (or aluminum) conductors contained in a copper (or aluminum) sheath; the insulant is compressed mineral magnesium oxide. The most common type is the MICS cable, with copper as the main metal for conductors and sheath. The advantages of MICS cables are that they are self-contained and require no further protection (even against high temperatures and fire); they are impervious to water and oil, and immune from condensation. Because the conductor, sheath and insulant are inorganic, cable is virtually ageless. Installation is simple, though the ends of the cable must be sealed off by special terminations against the ingress of moisture. Fixing is by clips or saddles. Cables can be obtained with a PVC over sheath. Because of the good heat-resisting properties of the cables, the current rating is higher than that of PVC or PILC cables. Applications for the cable include industrial installations and hazardous areas. Because the sheath is copper, it offers an excellent self-contained CPC. A full range of accessories is available for the system, which is adaptable to the screwed-conduit system.

2.3 Conduits, ducts, trunking

2.3.1 Steel conduit

The modern steel conduit system is available in two types or classes: Class A, plain-end conduit, and Class B, screwed-end conduit.

2.3.1.1 Class A conduit

This conduit is known as light gauge', plain, slip, pin-grip and lug-grip, according to the types. It has thin walls and is available as close-joint, brazed or welded joint, and solid-drawn. This type of conduit is not heavy enough to withstand threading and so presents problems where earth continuity must be maintained. Various methods for connecting the conduit with the associated accessories are available, including the more acceptable lug-grip, in which the fittings are held together by slipping the conduit end into, say, a box and holding it securely by tightening screws in the lugs. The conduit must be prepared before connecting by removing the enamel. If the contact surfaces are not cleaned, the electrical contact resistance will be too high. The applications of Class A conduit are limited to situations which are not damp and in which the wires do not require a high degree of protection against mechanical damage. Close-joint conduit cannot be bent or set because the seams tend to open. If care is used, slight bends and sets can be made in brazed or solid drawn conduit. The standard sizes are 16 and 20 mm outside diameter. Fixing is by conduit saddles. The conduits are erected before cables are drawn into them. Unattached terminations are fitted with push-on rubber or composition bushes to prevent the abrasion of cables.

2.3.1.2 Class B conduit

This conduit is known as heavy gauge or screwed conduit and is available as seam-welded, and solid-drawn. Alternative finishes are:

- Black enamel for internal use in dry situations.
- Silver grey finish for internal use in dry situations where the conduit is required to match decorations.
- Hot galvanized or sherries for external use where the conduit will be subjected to dampness or condensation. Because solid-drawn conduit is more expensive than seam-welded, its use is generally restricted to gas-tight and explosion-proof installation work. Welded-seam conduit is used generally for most good quality installation work. The conduits join with the wide range of associated accessories by means of screw threads,

which give good mechanical strength and electrical continuity where the conduit acts as a CPC. The sizes available are from 16 to 32 mm, outside diameter. The thread is a shallow electric thread (ET). A full range of system accessories is available for screwed conduit: bends, elbows, tees and boxes. The first three can be of the inspection type (provided with a detachable lid) or 'solid' (no lid). Boxes have, of course, lids. Inspection bends, elbows and tees of the channel type are permitted, though they are not always suitable. Boxes are preferable to other fittings for drawing in cables, because they allow more space. Rectangular adaptable boxes are used at the intersection of several conduit runs. Fixings include saddles, clips and crumpets.

2.3.2 Flexible conduit

Flexible conduits are generally used for the final connections to machinery (e.g. electric motors), where vibration and the possible need to adjust the position to an equipment makes a rigid conduit connection unsatisfactory. Flexible conduit can also deal with the need for complicated bends and sets.

It is used for short runs where mechanical damage is unlikely to occur. Flexible conduit made from non-metallic material is dealt with in the following section. Flexible metallic conduit consists of a spirally wound, partially interlocked light-gauge galvanized steel strip, and may be watertight or non-watertight. It can be obtained with a PVC over sheath. As the conduit in itself is not accepted as a CPC, a separate CPC must be run between the special brass adaptors used to join the flexible to the ordinary screwed conduit. Sizes available are from 8 to 50 mm, internal diameter. Another type of flexible metallic conduit is the Copex conduit system. This consists of layers of metal and bituminized strip; it is usually supplied in 30 m coils. It is arranged to accommodate standard conduit fittings.

It comes in sizes from 12 to 75 mm, outside diameter. Its great advantage is that once bent into shape it retains its position: no heating is required. The metal steel spiral of the conduit does not give satisfactory CPC facilities and so a separate CPC must be run.

2.3.3 Non-metallic conduit

Non-metallic conduits are obtainable in various grades and with the same diameters as steel conduits. There are two main types: (a) flexible and *(h)* rigid. The flexible type comes in both round and oval section and is supplied in 20 m coils. The rigid type is supplied in standard lengths. Materials used vary widely one of the most common is PVC, used with phenolic-moulded fittings which closely resemble the steel-conduit range. Advantages claimed for the non-metallic conduit systems include: elimination of the need for earthing continuity; absence of fire risk due to breakdown in continuity; easy manipulation without the use of special tools; resistance to corrosion from most industrial liquids; no internal condensation takes place.

The flexible type can be bent without tools, but in cold weather needs the application of warmth. The rigid type is bent with the careful application of a flame to soften it. Fixings are by saddles or clips. When required, the conduit will cut its own thread when screwed into a threaded portion. However, it can be easily threaded using the normal electric thread stocks and dies. If it is necessary to seal the system, the 'Bostik' type of adhesive may be used. Heavy-gauge PVC can be obtained which will withstand a fair amount of rough treatment both in erection and in service.

2.3.4 Trunking systems

The following advantages are claimed for trunking:

- It is much lighter than conduits of the same capacity.
- Fewer fixings are required for one trunking length than a run of multiple conduits.
- Wiring is easier and quicker as the cables are laid-in' instead of being drawn in.
- Erection time is reduced.
- It is an easily adaptable wiring system.
- Multiple-compartment trunking is available where the segregation of services is required.

Trunking is available in sections (square and rectangular). Lengths are joined by couplers normally secured by screws. Earth straps fixed between each section ensure earth continuity along the trunking run. Trunking is available in both light-gauge and heavy-gauge forms; finish is generally enamel, but a galvanized finish can he supplied for certain

installation conditions. There is a very wide range of system fittings which include blank ends, tees, bends of various radii and angles, elbows, couplers, four-way boxes and tire-resisting barriers. Pin-racks are supplied for use in long vertical runs. The cables are wound through the pins for support.

Where the trunking contains busbar, it becomes *(a)* overhead busbar trunking and *(b)* rising-main trunking. The metal-clad overhead busbar system is used for distribution of electrical energy to machines in factories. The usual arrangement is steel trunking containing copper busbar mounted on insulators. At intervals along the length of run a tapping-off point is provided with three HRC fuses mounted in a sheet-steel case. Three contact blades are designed to fit onto the busbar. Connections to machines are then taken from the tap-off boxes by flexible conduits, steel conduits or other wiring system. Though this system has a high initial cost, it enables much of the electrical installation work to be carried out before the machines are set in position. Additions and alterations can be carried out quickly. The factory lighting circuits can be fed from the tap-off boxes.

If long runs of busbars are installed, it is necessary to provide 'expansion' joints at approximately 30 m intervals to allow for expansion and contraction due to changes in temperature. Fire barriers must he installed at suitable intervals, particularly where the trunking passes from one room to another (to prevent the spread of fire).

Among other forms of trunking available are:

- Flush trunking, which fits flush with walls; i entails a lot of builders' work to install.
- Multi-compartment trunking, which is of the normal type (square or rectangular) and provided with segregated compartments so that cables carrying different voltages can be accommodated in the same trunking unit.
- Skirting trunking, designed to take the place of the normal room skirting. It carries power telephone and lighting cables in its various compartments. Socket-outlets can be easily fitted as an integral part of the trunking.

Lighting trunking, designed for use where long rows of continuous lighting are required. The steel enclosure not only carries the fluorescent and/or tungsten fittings, hut also the control gear and supply cables.

- Trunking made from PVC is available, with the attendant advantage of this material.
- Cable-tap trunking. This type does not carry copper bars, but insulated supports which can accommodate rubber or PVC cables, from which supplies to machines an lighting circuits are tapped through fused tap-off boxes.

Rising mains are used to provide power to the various floors of multi-storey buildings. They are sheet-steel trunking containing copper bars on insulated supports. Provision is made for tapping off at each floor. Where required, distribution boards are fixed direct to the trunking.

2.4 Final circuits

A final circuit is defined as 'A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such equipment.' In addition, the regulations require that where an installation comprises more than one final circuit, each circuit shall be connected to a separate way in a distribution board. They also require that the wiring of each final circuit shall be electrically separate from that of every other final circuit. To facilitate disconnection of each final circuit for testing, the neutral conductors shall be connected at the distribution board in the same order as that in which the live conductors are connected to the fuses or circuit-breakers.

Final circuits make up the greater part of electrical installations and can vary from a pair of 1 mm^2 cables feeding one lamp, to a heavy three-core PILC cable feeding a large motor from a circuit-breaker located at a factory switchboard. The main important regulation which applies to final circuits is No. 27 of the Electricity Supply Regulations: 'All conductors and apparatus must be of sufficient size and power for the work they are called on to do, and so constructed, installed and protected as to prevent danger.

There are five general groups of final circuits:

- Rated at not more than 16A.
- Rated over 16A.
- Rated over 16A but confined to feeding 13A socket-outlets with fused plugs.
- Circuits feeding fluorescent and other discharge lamps.
- Circuits feeding motors.

An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation. Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will be relevant.

2.4.1 Domestic Installation planning

It seems to be the simplest to plan, but there are a number of points which are worth considering. And though these might seem obvious at first sight, a close survey of existing installations will reveal rather too many lapses in efficient planning, even h)r a dwelling house. For example, a room which can be entered from two points should he wired for two-way switching; a two-landing staircase should be wired for intermediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of lighting circuits: to wire one lighting point from one circuit within the wiring area of the other circuit. If this is done, there should be a note to this effect displayed at the distribution board.

The lighting in houses should be regarded as an important aspect of interior decoration, as well as supplying lighting on a purely functional basis. In living rooms and bedrooms, wall-mounted fittings can be used, controlled by multi-point switches at the entrance doors. Thought should be given to the provision of 13A socket-outlets for supplying table and standard lamps. The use of local lighting over working surfaces in kitchens is an aspect of good planning. External lighting should not be overlooked, either to light up the front and back doors or to light the way to outhouses such as detached garages, coal stores and greenhouses. In very large houses, driveway lighting may have to be considered.

To facilitate the interchange of fittings and appliances throughout the house, it is recommended that 13A three-pin socket-outlets to BS 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched socket-outlets should be used. Because the past few years have seen a rapid increase in the use of electrical appliances, it is essential that an ample number of socket-outlets be provided, and situated wherever there might arise the need for an electrical outlet.

The average house should have an adequate number of socket-outlets. In the living room, there should be a two-gang socket outlet on each side of the fireplace. Additional socket-outlets should be located less than 2 m from the opposite corners of the room, where they are least likely to be hidden by furniture. In bedrooms, at least a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage (e.g. to supply a bedside lamp and an electric blanket). Additionally, there should be socket-outlets for dressing-table lamps, a heating appliance or a portable television set.

The kitchen probably places the greatest demand on the electrical service. Outlets are required for such varied appliances as washing machines, refrigerators, waste-disposal units, food mixers, can-openers, flat irons, coffee percolators and toasters. As far as possible, the outlets should be located above working surfaces and two-gang units are recommended.

In the dining room, small plate-warmers may be required. In halls and on landings the outlet is generally used for a vacuum cleaner or floor polisher, and perhaps a hail heater. No

provision is made for the use of portable appliances in a room containing a fixed bath or shower. However, an electric shaver unit to BS 3052 may be installed out of reach of a person in the bath or shower. Additionally, a bathroom heater (of the enclosed-element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

2.4.2 Circuits rated under 16A

A final circuit rated at not more than 16A may feed an unlimited number of points provided that the total 'current demand' does not exceed 16A. They include 15, 13, 5 and 2A socket-outlets, lighting outlets, stationary appliances and certain loads which may be neglected because their current demand is negligible (e.g. clocks, bell-transformers, electric shaver supply units), provided that their rating is not greater than 5VA. No diversity is allowed on final circuits. The current rating of the cable must not be exceeded. An important point to note is that if a cable size must be increased to avoid excessive voltage drop in the circuit, the rating of the fuse or circuit-breaker protecting the circuit must not be increased correspondingly. The same condition would apply if the ambient temperature of a cable were to be taken into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favorable circuit conditions, but to provide for the special conditions in which they are being installed. The lighting circuits of domestic installations are rated at 5A. Industrial lighting circuits are usually rated at 15/16A because of the higher wattage of the lamps used.

2.4.3 Circuits rated over 16A

With two exceptions, circuits rated at over 16A should not serve more than one point. The exceptions are circuits which feed 13A socket-outlets and cooker circuits. Final circuits for cooking appliances are assessed for current demand as follows:

The first IOA of the total rated current of the connected cooking appliances, plus 30% of the remainder of the total rated current of the connected cooking appliances, plus 5A, if the cooker control unit has a socket-outlet.

Thus, a cooker with a total load of 11kW at 240V (46A) would in fact be supplied by

cables rated to carry about 26A, depending on the distance the cooker is away from the distribution board. If a large cooker which exceeds 30A is to be installed in domestic premises, and where the protection is offered by fuses, a supply service of more than the normal 60A rating may be required. In this instance, the supply authority should be consulted. Water-heater circuits are terminated in a 20A double-pole isolating switch, fitted with an earthing terminal and a neon pilot lamp.

2.4.4 Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and 13A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maximum floor area of 100 m^2 derived from a 30A protective device. Radial circuits serving a maximum area of 50 m^2 are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

- Each socket-outlet of a two-gang or multiple socket-outlet is to be counted as one socketoutlet.
- Stationary appliances, permanently connected to a radial or ring circuit, must be protected by afuse not exceeding 13A rating and controlled by a switch or a circuit-breaker.
- It is important to realize that the conductor sizes recommended tor ring circuits are minima. They must be increased if necessary where circuits arc installed in groups, or in conditions of high ambient temperature, taking into consideration the class of excess-current protection provided.
- The method of properly connecting circuit conductors of a ring circuit involves correct polarity and security of the terminals.
- Except where a ring circuit is run throughout in metallic conduit, ducts or trunking, the CPC shall be run in the form of a ring, having both ends connected to earth at the distribution hoard (or its equivalent).

- The total number of spurs shall not exceed the total number of socket-outlets and stationary appliances connected directly to the ring.
- Fused spurs from ring circuits must be connected through fused spur boxes, and the rating of the fuse must not exceed the current rating of the cable forming the spur. and in any event must not exceed 13A.
- One socket-outlet or one two-gang socket-outlet unit, or one stationary appliance fed from a connection unit, can be connected to each non-fused spur.

2.4.5 Circuits feeding discharge lamps

One of the main requirements is a consideration of the rating' of a discharge lamp outlet. tor it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge lighting. If a switch is not specifically designed to break an inductive load (quick-make. slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

2.4.6 Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular. cables which carry the starting, accelerating and load currents of a motor must be rated at least to the full-load current rating of the motor. If. however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor takes more than 16A full-load current, it should be fed from its own final circuit.

2.4.7 Final-circuit protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short-circuits between conductors, between conductors and earth, or overloads. The protective gear should he capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit-breaker. Thus, if a fault occurs on a final circuit, the associated gear will conic into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally. where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers. Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

2.4.8 Choosing cable sizes

The selection of the size of a cable to carry a load current involves the consideration of the rating and type of the protective device, the ambient temperature and whether other cables are run alongside the cable (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrent are carried due to overloading and when a short-circuit occurs. Others include the increase in temperature when a number of current carrying cables are bunched together, for instance in conduit and trunking, which is a situation in which each cable contributes its heat to that of others and which, because of the enclosed situation, produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a possible source of fire. At about 80 ^{0}C, PVC becomes very soft, so that a conductor can migrate' or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with an increase in the leakage current which could prove fatal if the installation earthing arrangement is faulty. Eventually, when the insulation breaks down completely, a short-circuit occurs and the circuit is now dependent on the ability of the, over-current protection device to operate to disconnect the circuit from its supply. As is probably realized the time of operation of the protective device is crucial: a semi-enclosed fuse will take longer to operate than would a miniature circuit-breaker. In some circumstances, particularly where PVC insulated cables are used, the time taken by a semi-enclosed fuse to operate may be long enough for the cables to burn out and create a fire hazard.

Another problem which has occurred in recent years concerns the use of thermal insulation in buildings. with cables being installed in conditions where the natural heat produced by even their normal load currents cannot be dissipated easily. The IEE Regulations recognize the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation, each of which is identified by 'Methods'. These classifications are used in the tables, which give the current-carrying capacities of cables. The installation conditions include 'enclosed' (e.g. in conduit. trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray. embedded direct in plaster that is not thermally insulating, and suspended from a

catenary wire): 'defined conditions', which include cables in free air: and cables 'in enclosed trenches'.

From this, it can be seen and appreciated that the selection of a cable to feed a circuit is now required to he undertaken with a number of factors to he considered carefully. Situations which were formerly taken for granted must now be investigated so that the cable is installed in the best conditions which will allow the cable to carry its load current with the safety of the user of the installation in mind.

The IEE Regulations require that the choice of a cable for a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

- the ambient temperature in which the cable is installed;
- the installation condition, e.g. whether grouped or bunched with other current – carrying cables, enclosed or installed 'open';
- whether the cable is surrounded by or in contact with thermal insulating material;
- whether the circuit is protected by semi-enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. All factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every bare conductor or cable conductor shall be such that the drop in voltage from the origin of the installation to any point in that installation does not exceed 4% of the nominal voltage when the conductors are carrying the full load current. The conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

The following process for working out the correct size of cables is as follows:

- First find the load current of the circuit ('B).

- Determine the correction factor for the ambient temperature which of course does not include the heat generated in the cable itself, but is more concerned with the maximum temperature of the medium through which the cable runs.

- Determine the correction factor for grouping. Here we refer to Table 4B1 of the Regulations (Appendix 4).

- Determine the correction factor if the cable is in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.

- Select the rating of the overcurrent device. If this is offering what used to be called 'close' protection, the correction factor is 1. If, however, protection is by means of a semi-enclosed fuse, the factor is 0.725. The rating of the device must at least equal the load current.

- Determine the size of the circuit conductor by calculating its current rating.

- Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

Table 2.1 PVC isolated, sheathed, copper cables

Nominal cable size	Single Phase		Three Phase	
mm^2	Current A	Voltage Drop,mV	Current	Voltage Drop
1.0	11	40	9	35
1.5	13	27	12	23
2.5	18	16	16	14
4	24	10	22	8.8
6	**30**	**6.8**	**27**	**5.9**

We choose our cables for our installation with taking reference from Table 2.1

2.5 Overcurrent protection

IEE Regulation 13-7 states that, where necessary to prevent danger every installation and every circuit 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 rating of the circuit

(ii) Are of adequate breaking capacity

(iii) Are suitably located .and permit ready restoration of the supply without danger'.

Overloading occurs when extra power is taken from the supply system. The increased loading results with the addition of low resistance being connected in parallel with the existing load in a circuit. The decrease in the overall resistance of the circuit produces a proportional rise in the amount of current flowing in the circuit conductors. The increased current will have an immediate effect on the cables: they will begin to heat up. If the overload is sustained the result could be an accelerated deterioration of the cable insulation and its eventual breakdown to cause an electrical fault and perhaps fire.

A heavy sudden overload is not so serious since the overload current flows for a short time (e.g. motor starting), and the rise in cable temperature is neither rapid nor steep. However, this current must flow for a very brief period. Certain types of cable (e.g. paper-

insulated and mineral-insulated) can withstand cyclic overloading. In certain circumstances, a sudden heavy overload may in fact approach the characteristic of a short-circuit.

A short-circuit is a direct contact or connection between a phase conductor and (a) a neutral or return conductor, or (b) earthed metalwork, the contact usually being the result of an accident. The result of a short-circuit is to present a conducting path of extremely low resistance which will allow the passage of a current of hundreds or thousands of amperes. If the faulty circuit has no over-current protection, the cables will heat up rapidly and melt; equipment would also suffer severe damage and fire is often the result.

The form which protection against overcurrent takes is either a fuse or a circuit breaker. Each has characteristics that offer the protected circuit a degree of protection according to circuit conditions.

2.6 The fuse

The fuse was the earliest means used to protect against overcurrent in conductors. The fuse consists of a short length of suitable material, often in the form of a wire which has a very small cross-sectional area. When a current flows, which is greater than the current rating of the wire, the wire, will get hot. This happens because its resistance per unit length is greater than its associated circuit conductors (so giving greater power loss and heat) and because this increased heat is concentrated in the smaller volume of the material. The size of the wire is designed to carry indefinitely the normal circuit current.

There are three general types of fuse:

- Rewirable;
- Cartridge;
- HRC (high-rupturing capacity), which is a development of the cartridge fuse.

The HRC fuse was introduced in the 1930s. The modern type consists of a barrel of high-grade ceramic able to withstand the shock conditions, which occur when a heavy fault

current is interrupted. The end caps and fixing tags are suitably plated to give a good electrical contact. The fixing tags are also planished to ensure satisfactory alignment between contact-making surfaces. Except for very low ratings, the fuse-element is of pure silver wire or tape with a waist at its centre designed to give the required operational characteristic. The filler within the barrel is powdered silica, carefully dried before use. When used, the filler is compacted in the barrels by mechanical vibration to ensure complete filling. An indicator is sometimes provided to show when the fuse has blown. This consists of a glass bead held in position in a recess in the external barrel wall by a fine resistance wire, connected in parallel with the fuse-element. The barrels are accurately ground and the caps are a force-fit. Correct grades of solder are used for the element and tag fixings. The larger types of multi-element fuses have the elements welded in addition to soldering.

The short-time characteristics of the HRC fuse enable it to take care of short-circuits conditions in the protection of 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). HRC fuses are often used in motor circuits for 'back-up' protection for the machines. Motors are normally protected against damage by overload by thermal magnetic devices in the motor starter~ the fuses are required only to give protection against short-circuit currents and severe overloads outside the capacity of the starter protective devices. For instance, modern squirrel-cage induction motors can take up to ten times normal full-load current when stalled. The rating of a fuse link for a motor circuit should be that of the smallest current that will withstand the starting current while providing at the same time the necessary margin of safety.

2.7 The circuit breaker

The circuit breaker is a mechanical device for making and breaking a circuit, both under normal and abnormal conditions, such as those of a short-circuit, the circuit being broken automatically. The circuit breaker differs from the switch. Whereas the switch is capable of making and breaking a current not greatly in excess of its normal rated current,

the circuit breaker is capable of disconnecting automatically a faulty circuit, even in short-circuit conditions. A circuit breaker is selected for a particular duty, taking the following into consideration:

(a) The normal current it will have to carry

(b) The amount of current, which the supply system will feed into the circuit fault, which current the circuit breaker will have to interrupt without damage to itself.

Because the circuit-breaker is a protective device, its basic function is *(a)* to permit the installation or appliance it protects to be used up to its full rated capacity, and *(b)* to detect, and to protect equipment against dangerous conditions. Circuit-breakers are also able to provide a closer and more accurate degree of excess-current protection than that normally provided by either semi-enclosed or cartridge fuses. Circuit-breakers also perform duties as local circuit-control switches and as fault-making isolation switches. These latter types are switches capable of making and breaking rated current, and also of being closed against existing short-circuit fault.

The circuit-breaker has a mechanism which, when it is 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 or thermal means.

The circuit breaker with magnetic tripping (the term used to indicate the opening of the circuit-breaker contacts) employs a solenoid, which is a coil with an iron slug. The normal circuit current which flows through the coil is not sufficiently strong to produce a significant magnetic flux. As soon as the circuit current increases to a predetermined level, the magnetic field strength increases to cause the iron slug to move within the solenoid and collapse the attached tripping linkage to open the contacts.

Thermal tripping uses a heat-sensitive bimetal element. When the element is heated to a predetermined temperature, the resultant deflection is arranged to trip the circuit-breaker. The time taken to heat the element to this temperature provides the necessary time-delay characteristic. The bimetal element may be arranged to carry the circuit current and so be directly self-heated. Indirect heating of the element may also be used. Because of the time

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ELECTRICAL INSTALLATIONS FOR A TERACED HOUSE BASED ON MAINS AND WIND POWER GENERATION

Graduation Project
EE-400

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ABSTRACT

To provide an electrical installation for building is one of the main and most important tasks for the electrical engineers.

The main objective of this project is to design the electrical installation system for a two stairs building. It showed that all electrical installations must consider the safety side, like protections against fires and electrical shock.

For this purpose, we applied IEE wiring regulations, which covers wiring techniques, conductors, cables, installation methods, lighting, and small power circuits.

One of the new things this project tries to implement is the use of wind generators at houses. Its very good and economic way to produce electric from this renewable energy at wind. This project implemented a wind generator in the building, which can work directly and light the building when the main electric cut off.

INTRODUCTION

This project covers the installation of a two stairs building. It provides in detailed all the parameters and concepts which considered when implementing such a project. The load of the building consists of lighting, small power supply, heating cooling system, and special power installation for wind generator.

Chapter one explains the importance of safety in the electrical installations. Shows that IEE regulations are the reference for all engineers and technical workers, and the protection is the basic point of these regulations.

Chapter two bases on final circuit. They make up the greater part of electrical installations. It includes motors circuits, lamps circuits, choosing cable sizes. Also it focuses on wiring systems which includes conduits, trunkings, and introduces some types of protection devices like HRC and MCB.

Chapter three tries to give the techniques of choosing the lighting system for our area. It briefly explains the discharge and filament lamps. They are the most popular lamps that are using in indoor applications.

Chapter four focuses on the wind power and how to produce electric from the wind and how it will be useful if the building has wind generator that can start to work when electric is off and can supply all lighting circuits building.

Chapter five deals with water pumps. It explains pumps basics and the installation. It represents the centrifugal pump, the control gear and voltage drop.

The conclusion shows the important results, contribution and future thought.

CHAPTER ONE

REQUIREMENTS FOR SAFETY IN ELECTRICAL INSTALLATION PROJECTS

1.1 Overview

The rules and regulations that govern the practice of electrical installation engineering are essential to ensure that all electrical installations provide an adequate degree of safety from fire and shock risks to those who operate the installations and their associated apparatus, equipment and machines. The essence of these statutory regulations are collected in the IEE Regulations. Guidance on specific points of installation, choice of electrical equipment, and the maintenance of electrical apparatus, is the subject of many of the codes of practice issued by the British Standards Institution. The object of this chapter is to introduce these regulations as the main standards of my project that will be based on.

1.2 IEE Regulations

These Regulations are designed to supplement statutory regulations relating to electrical work have evolved over the past century to ensure a maximum degree of safety from tire, shock and burns, when electricity used in and about buildings. Though the Regulations are principally concerned with all aspects of electrical installations, they also touch on certain requirements relating to the selection of electrical equipment used in installations.

As the use of electricity became more popular, it soon became clear that some unified form of regulations, concerning its safe installation into buildings, would be necessary if serious accidents were to be avoided. It was for this reason government put some rules for electricity installations. The regulations set out to achieve the following:

- To safeguard the users of electrical energy from shock
- To minimize the fire risk
- To ensure as far as possible the safe and satisfactory operation of apparatus.

Though these Statutory Regulations are concerned with electrical safety in the respective type of installations listed, there are other Statutory Regulations, which are also

concerned with electrical safety when equipment and appliances are being used. Included in these are the Electricity at Work Regulations which came into force in 1990.

They are stringent in their requirements that all electrical equipment used in schools, colleges, factories and other places of work is in a safe condition and must be subjected to regular testing by competent persons.

It is a requirement of the current edition of the IEE Regulations for Electrical Installations that good workmanship and the use of approved materials contribute to the high level of safety provided in any electrical installation. The British Standards Institution (BSI) is the approved body for the preparation and issue of Standards for testing the quality of materials and their performance once they are installed in buildings.

1.3 Summary

All electrical installations are required to have an in-built safety factor, to protect the users against the risk of electric shock, fire and burns while this can be done at the design stage, much depends on the installer's approach to the work, ensuring that wiring is correctly installed and that equipment is correctly connected.

In TRNC, the chamber of electrical engineering must approve the electrical installation projects before they put into operation to provide the safety.

CHAPTER TWO

WIRING SYSTEMS AND INSTALLATION METHODS

2.1 Overview

Electricity has been one of the most important factors in the social progress made by this country over the past half-century. It affects health, education and housing, standards of living and industrial and agricultural progress. Its universal application is seen in the many different types of current-using appliances found in the home, in the office and in the factory making it possible to perform tasks easily, safely and efficiently. This chapter deals with some of the more common current-using equipment, their applications and their general installation requirements.

2.2 Sheathed wiring systems

A wiring system is an assembly of parts used in the formation of one or more electric circuits. It consists of the conductor, together with its insulation, its protection against mechanical damage (sheathing and/or armouring), and certain wiring accessories for fixing the system, and joining and terminating the conductors.

As implied by the term 'sheathed wiring system', this method of wiring consists of an insulated conductor provided with a sheath, which serves in some degree as a measure of protection against mechanical damage. The insulating materials include impregnated paper, rubber, plastics and mineral insulation. The sheathing materials include lead, tough rubber, plastics, aluminum and textiles. Some of the cables are designed with a view to cheapness and are particularly suited to domestic installations.

2.2.1 PVC (polyvinyl chloride sheathed)

This is an 'all-insulated' wiring system and commonly used for domestic installations. Though it is inferior to rubber, in the context of insulation-resistance and elastic properties, it has many advantages, not least being its comparative cheapness and ease of handling. Its main disadvantage is that it tends to soften at high temperatures, which is why its maximum

operating temperature is 70 ^{0}C. Above this temperature, there is a tendency for the conductors to migrate through the PVC, which leads to much reduced values of insulation resistance, ultimately causing a breakdown to earth. There is also a lower temperature limit, set at 0 "C. At this temperature, the PVC tends to harden and becomes a difficult material to work. The PVC-insulated cables have cores, which are self-colored for identification: red, black, blue and yellow. Blue and yellow are the colors used in three-core cables for two-way wiring. The sheathed cables contain an uninsulated circuit protective conductor, which must be sheathed with insulating sleeving (colored green/yellow) whenever the cable is made off for entry to wiring accessories.

Because the sheath can be damaged, it is recommended that additional protection be provided in situations where there is a possibility of the cable sustaining physical or mechanical damage. These cables are often run in floor spaces and in attics. The IEE Regulations draw attention to the possibility of the cables, run in these situations, coming into contact with thermal insulation material. Particularly where expanded polystyrene granules are used for loft insulation, there is the real chance that some of the plasticizer material used in PVC cable sheaths will 'migrate' and produce a hardening of the sheath. The other problem with PVC cables in contact with thermal insulation is that their current rating can be drastically reduced. The relevant factors are 0.5 if the cables are surrounded by the material and 0.75 if only one side is in contact.

In this project, we used PVC in our installation. Let us introduce the other kinds of cables.

2.2.2 PVC-S WA cables

Cables insulated with PVC and provided with steel-wire armouring are used extensively for main and sub-main cables and for wiring circuits in industrial installations. The conductors are copper or, where lightness and easy handling are needed, of aluminum. The cables are run on cable trays, racks, or installed in trenches. Terminations are by use of cable glands; flameproof glands are available for hazardous areas. If these cables are run to motor positions, where the machine is mounted on slide rails, a loop should be left in the cable to allow movement.

2.2.3 PIL C (paper-insulated, lead-covered)

Paper-insulated, lead-sheathed and served (compounded jute) cables are mainly used for external underground distribution systems. But this type of cable has a wide application for internal distribution in factories and other industrial premises. It can, therefore, be regarded as a wiring system. The paper is impregnated and must be protected against the ingress of moisture; hence the use of cable-sealing boxes. The current-carrying capacity of this type of cable is greater than that of an equivalent butyl cable. Bending of PJLC cables must be done very carefully. Fixing is normally by cleats. Further protection against mechanical damage is provided by armouring in the form of helical-wound steel wire or tape.

2.2.4 MIMS (mineral-insulated, metal-sheathed)

These cables consist of copper (or aluminum) conductors contained in a copper (or aluminum) sheath; the insulant is compressed mineral magnesium oxide. The most common type is the MICS cable, with copper as the main metal for conductors and sheath. The advantages of MICS cables are that they are self-contained and require no further protection (even against high temperatures and fire); they are impervious to water and oil, and immune from condensation. Because the conductor, sheath and insulant are inorganic, cable is virtually ageless. Installation is simple, though the ends of the cable must be sealed off by special terminations against the ingress of moisture. Fixing is by clips or saddles. Cables can be obtained with a PVC over sheath. Because of the good heat-resisting properties of the cables, the current rating is higher than that of PVC or PILC cables. Applications for the cable include industrial installations and hazardous areas. Because the sheath is copper, it offers an excellent self-contained CPC. A full range of accessories is available for the system, which is adaptable to the screwed-conduit system.

2.3 Conduits, ducts, trunking

2.3.1 Steel conduit

The modern steel conduit system is available in two types or classes: Class A, plain-end conduit, and Class B, screwed-end conduit.

2.3.1.1 Class A conduit

This conduit is known as light gauge', plain, slip, pin-grip and lug-grip, according to the types. It has thin walls and is available as close-joint, brazed or welded joint, and solid-drawn. This type of conduit is not heavy enough to withstand threading and so presents problems where earth continuity must be maintained. Various methods for connecting the conduit with the associated accessories are available, including the more acceptable lug-grip, in which the fittings are held together by slipping the conduit end into, say, a box and holding it securely by tightening screws in the lugs. The conduit must be prepared before connecting by removing the enamel. If the contact surfaces are not cleaned, the electrical contact resistance will be too high. The applications of Class A conduit are limited to situations which are not damp and in which the wires do not require a high degree of protection against mechanical damage. Close-joint conduit cannot be bent or set because the seams tend to open. If care is used, slight bends and sets can be made in brazed or solid drawn conduit. The standard sizes are 16 and 20 mm outside diameter. Fixing is by conduit saddles. The conduits are erected before cables are drawn into them. Unattached terminations are fitted with push-on rubber or composition bushes to prevent the abrasion of cables.

2.3.1.2 Class B conduit

This conduit is known as heavy gauge or screwed conduit and is available as seam-welded, and solid-drawn. Alternative finishes are:

- Black enamel for internal use in dry situations.
- Silver grey finish for internal use in dry situations where the conduit is required to match decorations.
- Hot galvanized or sherries for external use where the conduit will be subjected to dampness or condensation. Because solid-drawn conduit is more expensive than seam-welded, its use is generally restricted to gas-tight and explosion-proof installation work. Welded-seam conduit is used generally for most good quality installation work. The conduits join with the wide range of associated accessories by means of screw threads,

which give good mechanical strength and electrical continuity where the conduit acts as a CPC. The sizes available are from 16 to 32 mm, outside diameter. The thread is a shallow electric thread (ET). A full range of system accessories is available for screwed conduit: bends, elbows, tees and boxes. The first three can be of the inspection type (provided with a detachable lid) or 'solid' (no lid). Boxes have, of course, lids. Inspection bends, elbows and tees of the channel type are permitted, though they are not always suitable. Boxes are preferable to other fittings for drawing in cables, because they allow more space. Rectangular adaptable boxes are used at the intersection of several conduit runs. Fixings include saddles, clips and crumpets.

2.3.2 Flexible conduit

Flexible conduits are generally used for the final connections to machinery (e.g. electric motors), where vibration and the possible need to adjust the position to an equipment makes a rigid conduit connection unsatisfactory. Flexible conduit can also deal with the need for complicated bends and sets.

It is used for short runs where mechanical damage is unlikely to occur. Flexible conduit made from non-metallic material is dealt with in the following section. Flexible metallic conduit consists of a spirally wound, partially interlocked light-gauge galvanized steel strip, and may be watertight or non-watertight. It can be obtained with a PVC over sheath. As the conduit in itself is not accepted as a CPC, a separate CPC must be run between the special brass adaptors used to join the flexible to the ordinary screwed conduit. Sizes available are from 8 to 50 mm, internal diameter. Another type of flexible metallic conduit is the Copex conduit system. This consists of layers of metal and bituminized strip; it is usually supplied in 30 m coils. It is arranged to accommodate standard conduit fittings.

It comes in sizes from 12 to 75 mm, outside diameter. Its great advantage is that once bent into shape it retains its position: no heating is required. The metal steel spiral of the conduit does not give satisfactory CPC facilities and so a separate CPC must be run.

2.3.3 Non-metallic conduit

Non-metallic conduits are obtainable in various grades and with the same diameters as steel conduits. There are two main types: (a) flexible and *(h)* rigid. The flexible type comes in both round and oval section and is supplied in 20 m coils. The rigid type is supplied in standard lengths. Materials used vary widely one of the most common is PVC, used with phenolic-moulded fittings which closely resemble the steel-conduit range. Advantages claimed for the non-metallic conduit systems include: elimination of the need for earthing continuity; absence of fire risk due to breakdown in continuity; easy manipulation without the use of special tools; resistance to corrosion from most industrial liquids; no internal condensation takes place.

The flexible type can be bent without tools, but in cold weather needs the application of warmth. The rigid type is bent with the careful application of a flame to soften it. Fixings are by saddles or clips. When required, the conduit will cut its own thread when screwed into a threaded portion. However, it can be easily threaded using the normal electric thread stocks and dies. If it is necessary to seal the system, the 'Bostik' type of adhesive may be used. Heavy-gauge PVC can be obtained which will withstand a fair amount of rough treatment both in erection and in service.

2.3.4 Trunking systems

The following advantages are claimed for trunking:

- It is much lighter than conduits of the same capacity.
- Fewer fixings are required for one trunking length than a run of multiple conduits.
- Wiring is easier and quicker as the cables are laid-in' instead of being drawn in.
- Erection time is reduced.
- It is an easily adaptable wiring system.
- Multiple-compartment trunking is available where the segregation of services is required.

Trunking is available in sections (square and rectangular). Lengths are joined by couplers normally secured by screws. Earth straps fixed between each section ensure earth continuity along the trunking run. Trunking is available in both light-gauge and heavy-gauge forms; finish is generally enamel, but a galvanized finish can he supplied for certain

installation conditions. There is a very wide range of system fittings which include blank ends, tees, bends of various radii and angles, elbows, couplers, four-way boxes and tire-resisting barriers. Pin-racks are supplied for use in long vertical runs. The cables are wound through the pins for support.

Where the trunking contains busbar, it becomes *(a)* overhead busbar trunking and *(b)* rising-main trunking. The metal-clad overhead busbar system is used for distribution of electrical energy to machines in factories. The usual arrangement is steel trunking containing copper busbar mounted on insulators. At intervals along the length of run a tapping-off point is provided with three HRC fuses mounted in a sheet-steel case. Three contact blades are designed to fit onto the busbar. Connections to machines are then taken from the tap-off boxes by flexible conduits, steel conduits or other wiring system. Though this system has a high initial cost, it enables much of the electrical installation work to be carried out before the machines are set in position. Additions and alterations can be carried out quickly. The factory lighting circuits can be fed from the tap-off boxes.

If long runs of busbars are installed, it is necessary to provide 'expansion' joints at approximately 30 m intervals to allow for expansion and contraction due to changes in temperature. Fire barriers must he installed at suitable intervals, particularly where the trunking passes from one room to another (to prevent the spread of fire).

Among other forms of trunking available are:

- Flush trunking, which fits flush with walls; i entails a lot of builders' work to install.
- Multi-compartment trunking, which is of the normal type (square or rectangular) and provided with segregated compartments so that cables carrying different voltages can be accommodated in the same trunking unit.
- Skirting trunking, designed to take the place of the normal room skirting. It carries power telephone and lighting cables in its various compartments. Socket-outlets can be easily fitted as an integral part of the trunking.

Lighting trunking, designed for use where long rows of continuous lighting are required. The steel enclosure not only carries the fluorescent and/or tungsten fittings, hut also the control gear and supply cables.

- Trunking made from PVC is available, with the attendant advantage of this material.
- Cable-tap trunking. This type does not carry copper bars, but insulated supports which can accommodate rubber or PVC cables, from which supplies to machines an lighting circuits are tapped through fused tap-off boxes.

Rising mains are used to provide power to the various floors of multi-storey buildings. They are sheet-steel trunking containing copper bars on insulated supports. Provision is made for tapping off at each floor. Where required, distribution boards are fixed direct to the trunking.

2.4 Final circuits

A final circuit is defined as 'A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such equipment.' In addition, the regulations require that where an installation comprises more than one final circuit, each circuit shall be connected to a separate way in a distribution board. They also require that the wiring of each final circuit shall be electrically separate from that of every other final circuit. To facilitate disconnection of each final circuit for testing, the neutral conductors shall be connected at the distribution board in the same order as that in which the live conductors are connected to the fuses or circuit-breakers.

Final circuits make up the greater part of electrical installations and can vary from a pair of 1 mm^2 cables feeding one lamp, to a heavy three-core PILC cable feeding a large motor from a circuit-breaker located at a factory switchboard. The main important regulation which applies to final circuits is No. 27 of the Electricity Supply Regulations: 'All conductors and apparatus must be of sufficient size and power for the work they are called on to do, and so constructed, installed and protected as to prevent danger.

There are five general groups of final circuits:

- Rated at not more than 16A.
- Rated over 16A.
- Rated over 16A but confined to feeding 13A socket-outlets with fused plugs.
- Circuits feeding fluorescent and other discharge lamps.
- Circuits feeding motors.

An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation. Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will be relevant.

2.4.1 Domestic Installation planning

It seems to be the simplest to plan, but there are a number of points which are worth considering. And though these might seem obvious at first sight, a close survey of existing installations will reveal rather too many lapses in efficient planning, even h)r a dwelling house. For example, a room which can be entered from two points should he wired for two-way switching; a two-landing staircase should be wired for intermediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of lighting circuits: to wire one lighting point from one circuit within the wiring area of the other circuit. If this is done, there should be a note to this effect displayed at the distribution board.

The lighting in houses should be regarded as an important aspect of interior decoration, as well as supplying lighting on a purely functional basis. In living rooms and bedrooms, wall-mounted fittings can be used, controlled by multi-point switches at the entrance doors. Thought should be given to the provision of 13A socket-outlets for supplying table and standard lamps. The use of local lighting over working surfaces in kitchens is an aspect of good planning. External lighting should not be overlooked, either to light up the front and back doors or to light the way to outhouses such as detached garages, coal stores and greenhouses. In very large houses, driveway lighting may have to be considered.

To facilitate the interchange of fittings and appliances throughout the house, it is recommended that 13A three-pin socket-outlets to BS 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched socket-outlets should be used. Because the past few years have seen a rapid increase in the use of electrical appliances, it is essential that an ample number of socket-outlets be provided, and situated wherever there might arise the need for an electrical outlet.

The average house should have an adequate number of socket-outlets. In the living room, there should be a two-gang socket outlet on each side of the fireplace. Additional socket-outlets should be located less than 2 m from the opposite corners of the room, where they are least likely to be hidden by furniture. In bedrooms, at least a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage (e.g. to supply a bedside lamp and an electric blanket). Additionally, there should be socket-outlets for dressing-table lamps, a heating appliance or a portable television set.

The kitchen probably places the greatest demand on the electrical service. Outlets are required for such varied appliances as washing machines, refrigerators, waste-disposal units, food mixers, can-openers, flat irons, coffee percolators and toasters. As far as possible, the outlets should be located above working surfaces and two-gang units are recommended.

In the dining room, small plate-warmers may be required. In halls and on landings the outlet is generally used for a vacuum cleaner or floor polisher, and perhaps a hail heater. No

provision is made for the use of portable appliances in a room containing a fixed bath or shower. However, an electric shaver unit to BS 3052 may be installed out of reach of a person in the bath or shower. Additionally, a bathroom heater (of the enclosed-element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

2.4.2 Circuits rated under 16A

A final circuit rated at not more than 16A may feed an unlimited number of points provided that the total 'current demand' does not exceed 16A. They include 15, 13, 5 and 2A socket-outlets, lighting outlets, stationary appliances and certain loads which may be neglected because their current demand is negligible (e.g. clocks, bell-transformers, electric shaver supply units), provided that their rating is not greater than 5VA. No diversity is allowed on final circuits. The current rating of the cable must not be exceeded. An important point to note is that if a cable size must be increased to avoid excessive voltage drop in the circuit, the rating of the fuse or circuit-breaker protecting the circuit must not be increased correspondingly. The same condition would apply if the ambient temperature of a cable were to be taken into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favorable circuit conditions, but to provide for the special conditions in which they are being installed. The lighting circuits of domestic installations are rated at 5A. Industrial lighting circuits are usually rated at 15/16A because of the higher wattage of the lamps used.

2.4.3 Circuits rated over 16A

With two exceptions, circuits rated at over 16A should not serve more than one point. The exceptions are circuits which feed 13A socket-outlets and cooker circuits. Final circuits for cooking appliances are assessed for current demand as follows:

The first IOA of the total rated current of the connected cooking appliances, plus 30% of the remainder of the total rated current of the connected cooking appliances, plus 5A, if the cooker control unit has a socket-outlet.

Thus, a cooker with a total load of 11kW at 240V (46A) would in fact be supplied by

cables rated to carry about 26A, depending on the distance the cooker is away from the distribution board. If a large cooker which exceeds 30A is to be installed in domestic premises, and where the protection is offered by fuses, a supply service of more than the normal 60A rating may be required. In this instance, the supply authority should be consulted. Water-heater circuits are terminated in a 20A double-pole isolating switch, fitted with an earthing terminal and a neon pilot lamp.

2.4.4 Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and 13A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maximum floor area of 100 m^2 derived from a 30A protective device. Radial circuits serving a maximum area of 50 m^2 are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

- Each socket-outlet of a two-gang or multiple socket-outlet is to be counted as one socketoutlet.
- Stationary appliances, permanently connected to a radial or ring circuit, must be protected by afuse not exceeding 13A rating and controlled by a switch or a circuit-breaker.
- It is important to realize that the conductor sizes recommended tor ring circuits are minima. They must be increased if necessary where circuits arc installed in groups, or in conditions of high ambient temperature, taking into consideration the class of excess-current protection provided.
- The method of properly connecting circuit conductors of a ring circuit involves correct polarity and security of the terminals.
- Except where a ring circuit is run throughout in metallic conduit, ducts or trunking, the CPC shall be run in the form of a ring, having both ends connected to earth at the distribution hoard (or its equivalent).

- The total number of spurs shall not exceed the total number of socket-outlets and stationary appliances connected directly to the ring.
- Fused spurs from ring circuits must be connected through fused spur boxes, and the rating of the fuse must not exceed the current rating of the cable forming the spur. and in any event must not exceed 13A.
- One socket-outlet or one two-gang socket-outlet unit, or one stationary appliance fed from a connection unit, can be connected to each non-fused spur.

2.4.5 Circuits feeding discharge lamps

One of the main requirements is a consideration of the rating' of a discharge lamp outlet. tor it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge lighting. If a switch is not specifically designed to break an inductive load (quick-make. slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

2.4.6 Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular. cables which carry the starting, accelerating and load currents of a motor must be rated at least to the full-load current rating of the motor. If. however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor takes more than 16A full-load current, it should be fed from its own final circuit.

2.4.7 Final-circuit protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short-circuits between conductors, between conductors and earth, or overloads. The protective gear should he capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit-breaker. Thus, if a fault occurs on a final circuit, the associated gear will conic into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally. where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers. Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

2.4.8 Choosing cable sizes

The selection of the size of a cable to carry a load current involves the consideration of the rating and type of the protective device, the ambient temperature and whether other cables are run alongside the cable (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrent are carried due to overloading and when a short-circuit occurs. Others include the increase in temperature when a number of current carrying cables are bunched together, for instance in conduit and trunking, which is a situation in which each cable contributes its heat to that of others and which, because of the enclosed situation, produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a possible source of fire. At about 80 ^{0}C, PVC becomes very soft, so that a conductor can migrate' or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with an increase in the leakage current which could prove fatal if the installation earthing arrangement is faulty. Eventually, when the insulation breaks down completely, a short-circuit occurs and the circuit is now dependent on the ability of the, over-current protection device to operate to disconnect the circuit from its supply. As is probably realized the time of operation of the protective device is crucial: a semi-enclosed fuse will take longer to operate than would a miniature circuit-breaker. In some circumstances, particularly where PVC insulated cables are used, the time taken by a semi-enclosed fuse to operate may be long enough for the cables to burn out and create a fire hazard.

Another problem which has occurred in recent years concerns the use of thermal insulation in buildings. with cables being installed in conditions where the natural heat produced by even their normal load currents cannot be dissipated easily. The IEE Regulations recognize the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation, each of which is identified by 'Methods'. These classifications are used in the tables, which give the current-carrying capacities of cables. The installation conditions include 'enclosed' (e.g. in conduit. trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray. embedded direct in plaster that is not thermally insulating, and suspended from a

catenary wire): 'defined conditions', which include cables in free air: and cables 'in enclosed trenches'.

From this, it can be seen and appreciated that the selection of a cable to feed a circuit is now required to he undertaken with a number of factors to he considered carefully. Situations which were formerly taken for granted must now be investigated so that the cable is installed in the best conditions which will allow the cable to carry its load current with the safety of the user of the installation in mind.

The IEE Regulations require that the choice of a cable for a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

- the ambient temperature in which the cable is installed;
- the installation condition, e.g. whether grouped or bunched with other current – carrying cables, enclosed or installed 'open';
- whether the cable is surrounded by or in contact with thermal insulating material;
- whether the circuit is protected by semi-enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. All factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every bare conductor or cable conductor shall be such that the drop in voltage from the origin of the installation to any point in that installation does not exceed 4% of the nominal voltage when the conductors are carrying the full load current. The conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

The following process for working out the correct size of cables is as follows:

- First find the load current of the circuit ('B).
- Determine the correction factor for the ambient temperature which of course does not include the heat generated in the cable itself, but is more concerned with the maximum temperature of the medium through which the cable runs.
- Determine the correction factor for grouping. Here we refer to Table 4B1 of the Regulations (Appendix 4).
- Determine the correction factor if the cable is in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.
- Select the rating of the overcurrent device. If this is offering what used to be called 'close' protection, the correction factor is 1. If, however, protection is by means of a semi-enclosed fuse, the factor is 0.725. The rating of the device must at least equal the load current.
- Determine the size of the circuit conductor by calculating its current rating.
- Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

Table 2.1 PVC isolated, sheathed, copper cables

Nominal cable size	Single Phase		Three Phase	
mm^2	Current A	Voltage Drop,mV	Current	Voltage Drop
1.0	11	40	9	35
1.5	13	27	12	23
2.5	18	16	16	14
4	24	10	22	8.8
6	**30**	**6.8**	**27**	**5.9**

We choose our cables for our installation with taking reference from Table 2.1

2.5 Overcurrent protection

IEE Regulation 13-7 states that, where necessary to prevent danger every installation and every circuit 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 rating of the circuit

(ii) Are of adequate breaking capacity

(iii) Are suitably located .and permit ready restoration of the supply without danger'.

Overloading occurs when extra power is taken from the supply system. The increased loading results with the addition of low resistance being connected in parallel with the existing load in a circuit. The decrease in the overall resistance of the circuit produces a proportional rise in the amount of current flowing in the circuit conductors. The increased current will have an immediate effect on the cables: they will begin to heat up. If the overload is sustained the result could be an accelerated deterioration of the cable insulation and its eventual breakdown to cause an electrical fault and perhaps fire.

A heavy sudden overload is not so serious since the overload current flows for a short time (e.g. motor starting), and the rise in cable temperature is neither rapid nor steep. However, this current must flow for a very brief period. Certain types of cable (e.g. paper-

insulated and mineral-insulated) can withstand cyclic overloading. In certain circumstances, a sudden heavy overload may in fact approach the characteristic of a short-circuit.

A short-circuit is a direct contact or connection between a phase conductor and (a) a neutral or return conductor, or (b) earthed metalwork, the contact usually being the result of an accident. The result of a short-circuit is to present a conducting path of extremely low resistance which will allow the passage of a current of hundreds or thousands of amperes. If the faulty circuit has no over-current protection, the cables will heat up rapidly and melt; equipment would also suffer severe damage and fire is often the result.

The form which protection against overcurrent takes is either a fuse or a circuit breaker. Each has characteristics that offer the protected circuit a degree of protection according to circuit conditions.

2.6 The fuse

The fuse was the earliest means used to protect against overcurrent in conductors. The fuse consists of a short length of suitable material, often in the form of a wire which has a very small cross-sectional area. When a current flows, which is greater than the current rating of the wire, the wire, will get hot. This happens because its resistance per unit length is greater than its associated circuit conductors (so giving greater power loss and heat) and because this increased heat is concentrated in the smaller volume of the material. The size of the wire is designed to carry indefinitely the normal circuit current.

There are three general types of fuse:

- Rewirable;
- Cartridge;
- HRC (high-rupturing capacity), which is a development of the cartridge fuse.

The HRC fuse was introduced in the 1930s. The modern type consists of a barrel of high-grade ceramic able to withstand the shock conditions, which occur when a heavy fault

current is interrupted. The end caps and fixing tags are suitably plated to give a good electrical contact. The fixing tags are also planished to ensure satisfactory alignment between contact-making surfaces. Except for very low ratings, the fuse-element is of pure silver wire or tape with a waist at its centre designed to give the required operational characteristic. The filler within the barrel is powdered silica, carefully dried before use. When used, the filler is compacted in the barrels by mechanical vibration to ensure complete filling. An indicator is sometimes provided to show when the fuse has blown. This consists of a glass bead held in position in a recess in the external barrel wall by a fine resistance wire, connected in parallel with the fuse-element. The barrels are accurately ground and the caps are a force-fit. Correct grades of solder are used for the element and tag fixings. The larger types of multi-element fuses have the elements welded in addition to soldering.

The short-time characteristics of the HRC fuse enable it to take care of short-circuits conditions in the protection of 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). HRC fuses are often used in motor circuits for 'back-up' protection for the machines. Motors are normally protected against damage by overload by thermal magnetic devices in the motor starter~ the fuses are required only to give protection against short-circuit currents and severe overloads outside the capacity of the starter protective devices. For instance, modern squirrel-cage induction motors can take up to ten times normal full-load current when stalled. The rating of a fuse link for a motor circuit should be that of the smallest current that will withstand the starting current while providing at the same time the necessary margin of safety.

2.7 The circuit breaker

The circuit breaker is a mechanical device for making and breaking a circuit, both under normal and abnormal conditions, such as those of a short-circuit, the circuit being broken automatically. The circuit breaker differs from the switch. Whereas the switch is capable of making and breaking a current not greatly in excess of its normal rated current,

the circuit breaker is capable of disconnecting automatically a faulty circuit, even in short-circuit conditions. A circuit breaker is selected for a particular duty, taking the following into consideration:

(a) The normal current it will have to carry

(b) The amount of current, which the supply system will feed into the circuit fault, which current the circuit breaker will have to interrupt without damage to itself.

Because the circuit-breaker is a protective device, its basic function is *(a)* to permit the installation or appliance it protects to be used up to its full rated capacity, and *(b)* to detect, and to protect equipment against dangerous conditions. Circuit-breakers are also able to provide a closer and more accurate degree of excess-current protection than that normally provided by either semi-enclosed or cartridge fuses. Circuit-breakers also perform duties as local circuit-control switches and as fault-making isolation switches. These latter types are switches capable of making and breaking rated current, and also of being closed against existing short-circuit fault.

The circuit-breaker has a mechanism which, when it is 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 or thermal means.

The circuit breaker with magnetic tripping (the term used to indicate the opening of the circuit-breaker contacts) employs a solenoid, which is a coil with an iron slug. The normal circuit current which flows through the coil is not sufficiently strong to produce a significant magnetic flux. As soon as the circuit current increases to a predetermined level, the magnetic field strength increases to cause the iron slug to move within the solenoid and collapse the attached tripping linkage to open the contacts.

Thermal tripping uses a heat-sensitive bimetal element. When the element is heated to a predetermined temperature, the resultant deflection is arranged to trip the circuit-breaker. The time taken to heat the element to this temperature provides the necessary time-delay characteristic. The bimetal element may be arranged to carry the circuit current and so be directly self-heated. Indirect heating of the element may also be used. Because of the time

lag associated with heating, tripping by this means is not so rapid as with magnetic tripping. In the circuit condition when a small-sustained overload occurs, the thermal trip will come into operation after a few seconds or even minutes. However, when a heavier overload occurs, the magnetic trip coil operates quickly to disconnect the faulty circuit.

Circuit breakers are used instead of fuses in many installations 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. The over-current 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 is avoided 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 of time. Circuit-breaker contacts separate either in air or under insulating oil .

The miniature circuit breaker (MCB) has found an increasing application in domestic and small industrial installations. It is used as an alternative to the fuse and has certain advantages: it can be reset or reclosed easily while the fault is present in the circuit; it gives a close degree of excess-current protection (the tripping factor is 1. 1); it will trip on a small sustained overcurrent, but not on a harmless transient overcurrent such as a switching surge (e.g. on fluorescent lamp circuits). For most 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 HRC or rewirable fuses. MCBs are available in distribution units for final circuit protection. In my design, I used MCBs.

2.8 Switchgear

Though 'switchgear' can range from small switches for domestic and small industrial installations to large outdoor 275kV units, the following deals with the type of gear associated with medium-size industrial installations. Generally, the switchgear is of one of

two main types:

1. Truck type, in which the circuit breaker (oil or air-break) is mounted on a truck, which can be withdrawn to the front of the switchboard of which the unit is a part. With this type of gear, sufficient space must be allowed for the withdrawal of the truck.

2. Metal clad, in which all parts are enclosed in metal cases, and the units are factory built. The bus bars for high voltages are either oil-or compound-insulated in special chambers. Disconnection of the circuit breaker from the bus bars is made by withdrawing downwards or outwards.

In the truck-type gear, the circuit-breaker and associated current- and voltage-transformers (for the indicating instruments) are mounted in a with-draw able framework or truck. Thus, maintenance can be readily carried out on the circuit breaker. The fixed portion of the unit contains the live bus bars and feeder cable box. The spout apertures within the Unit, into which the circuit-breaker spout contact is inserted when in service, are fitted with automatic drop shutters which close off the spout apertures when the circuit-breaker is lowered and the truck withdrawn. When the truck is replaced in the unit housing and raised, these shutters open to allow the breaker spout contacts to make contact with the live bus bars of the switchboard. To ensure that the circuit cannot be interrupted on the isolating spouts by withdrawing the truck before the circuit-breaker is opened, an interlock is provided which effectively locks the truck in the closed position until the circuit-breaker is tripped.A switchgear is the ease of examining the circuit-breaker contacts. When the breaker carriage is withdrawn, the switch unit can be lowered mechanically to the floor,' the tank bolts removed and the switch unit raised again leaving the oil-filled tank on the floor and the switch contacts open to inspection. This type of gear is usually found on systems up to 11kv. In the oil-filled circuit breaker, the contacts separate under oil. The oil in this instance acts to quench the arc, which is drawn out between the separating contacts when the circuit breaker trips when there is current flowing in the circuit. Air-break circuit breakers have arc-chutes and coolers to help dissipate the arc and its gas products.

2.9 Water heating

Electric water heating is very efficient because the heating element is entirely immersed in the water to be heated. The greatest proportion of electric water heating is represented by immersion heaters, most of which are fitted in storage cylinders or tanks which sometimes have complementary means of heating. There are two types of immersion heater. The withdraw able type is a heater so constructed that the heating element can be withdrawn from the enclosing sheath without breaking water joint. The non-withdraw able type is a heater so constructed that the heating element cannot be removed without breaking water joint. As for the storage vessels, there are four general types in use:

2.9.1 The Non-pressure or Open-outlet.

This has a capacity of from *56* to 450 liters, with an immersion heater of rating in the region of 14kW. This type is controlled by a stop valve fitted on the water-inlet pipe and is usually fed directly from a water main or, alternatively, from a cistern. A non-return valve is usually fitted in the inlet pipe. The heating element and the associated thermostat are located in the bottom of the container. For domestic purposes, this type of heater has a capacity of about 12 liters and is most often used to provide hot water in an instant for washing-up duties. The type is also used in cloakrooms where there is an intermittent demand for hot water for hygiene. The tank is insulated against heat losses by a lagging of fiberglass or granulated cork. When the inlet valve is opened, the incoming cold water pushes the less-dense hot water into the outlet pipe.

2.9.2 The Pressure.

Water heaters of this type are connected to a cistern. Capacities range from 15 to 370 liters. The heater ratings are 1kW and above. In domestic installations, the usual rating is a 3kW heater in a 100-litre tank. The water supplied from the mains to the cistern is controlled by a float-ball valve. Hot-water outlets are fed under pressure supplied by the head (vertical height) of the cold water available.

2.9.3 The Cistern.

This type incorporates a feed tank with ball-valve, arranged for direct connection to the water main. A connection for an overflow pipe is also provided, for which any special requirements of the local water-supply undertaking should be observed. They must always be installed above the level of the highest hot-water tap in the house. The feed pipe, draw-off and vent pipes are all inside the heater unit. Capacities range from 15 to 100 liters; heater ratings are between 1 and 3kw.

2.9.4 The Dual-heater

This is a special development of the pressure-type of heater. The unit of 60 or 100 liters capacity is designed primarily for installation under the draining board next to the kitchen sink. This position is taken because the kitchen tap is the most frequently used hot-water outlet in a dwelling. The unit is usually also coupled to the bathroom hot-water taps. The unit is provided with two heaters, each controlled by a thermostat. One heater, located near the top of the tank, is of low rating (usually 0.5kw). It provides sufficient hot water for ordinary domestic purposes. The main heater, of a higher rating (2.5kw) is placed near the bottom of the tank and can be switched on manually before a bath is required. The complete unit, as manufactured, comprises a thermally insulated cylinder, electric-heating elements, thermostats and pipe connections. The unit of 100-litre capacity is often designed to be coupled to, and to operate in conjunction with, a fuel-fired domestic water-heater.

There are two basic types of thermostat for the control of domestic hot-water systems: the long, thin-stemmed type (usually known as the rod thermostat) and the short-stem type. The rod-type thermostat operates on the principle of differential expansion between 'invar' and copper, and usually takes the form of an invar rod (which is the lower expansion material) housed within a copper tube, which has a higher coefficient of expansion. The lower end of the copper tube is brazed to the invar rod, while the upper end is brazed to a solid portion of the switch mechanism. The invar rod is thus free to move up and down, which it does with the contraction and expansion of the copper tube under the effects of varying temperature. These thermostats are made in 18, 22, and 44 cm lengths. The 22 and 44 cm lengths are most commonly used for the control of vertical domestic heaters. The 18

cm model is generally used for horizontal or side-entry heaters. The short-stem thermostat contains a snap-action switch similar to that used in the rod-type thermostat. However, operation of the switch is by means of a piece of bimetal which replaced the combination of invar rod and copper tube.

In most water-heating installations, the immersion-heater with its associated thermostat is installed in the conventional hot-water cylinder in such a way that both heater and thermostat hang vertically downwards. Horizontal mounting is also a less-common practice. With horizontal mounting, the heater lies horizontally across the cylinder, which means that it imparts maximum turbulence to the water above the heater. Thus, virtually all the water in the tank is heated to the temperature at which the thermostat is set, before the latter trips the circuit. With vertical mounting, the degree of turbulence in the cylinder is not so great, because the heated water tends to flow upwards along the elements of the heater. Consequently, when the thermostat switches off, there is a gradient between the top and bottom of the heater element of some 20 to 30°C.

2.10 Summary

In this chapter, we deal with the final circuits, wiring techniques, choosing the cable sizes, trunking systems, conduits. In addition, we chose the cables from Table 2.1 for our requirements. The electrical equipments and their installation rules which is referenced from IEE Wiring Regulations 16th Edition. This is the most important section for the installation engineers.

CHAPTER THREE

INSTALLING LIGHTING

3.1 Overview

In this chapter, you will find how we choose the true light in our design, how much power we need, what kind of lamp we should use, how we should fix the lamps in our area, and the formulas to make our design. In addition, you will see a brief explanation of some kinds of lamps that are using today: filament, fluorescent, mercury vapor, metal halide, neon. All these have specific advantages and applications. In these kinds of lamps, we will pay attention to the filament and fluorescent lamps.

3.2 Filament lamps

A filament made from tungsten and rose to about 2,500 ^{0}C to produce a light, which, though it looks white, actually has a lot of red in it. Various methods are used to produce an efficient light-emitting filament (coiled, coiled-coil, etc). The common filament lamps used today have a luminous efficacy of about 16 lm/W. Slightly higher outputs are available when the light bulb is filled with an inert gas such as argon. One problem with filament lamps is the tendency of the evaporation; the result of this process is seen in the blackening of the inside of the glass bulb. Another problem is the heat produced by the lamp. General filament lamps use much more energy than other types of lamp, such as the fluorescent.

The nominal life of a filament lamp is 1,000 hours. However, a number of factors influence this figure. For instance, a 240 V lamp operating at 250 V will reduce the life expectancy by 43 per cent. Frequent switching also tends to reduce the life of a lamp, as will vibration. Because of the relatively low life expectancy of a filament lamp, lamp replacement costs tend to be higher than those for, say, fluorescent lamps (7,500-10,000 hours burning).

The standard type of filament lamp is the GLS (general lighting service). Two cap fittings are available: BC (bayonet cap) and ES (Edison screw). The former type of fitting is used for lamps rated from 15 W to 150 W: above this size, the ES fitting is used. Incandescent lamps are used for many purposes and are available with many variations. 'Pearl' lamps have the glass bulb internally frosted. Other types have the glass bulb silica-

coated internally.

In my installation design, I used incandescent lamps and fluorescent tubes, which is in the discharge lamps category.

3.3 Discharge lamps

The most familiar type of discharge lamp is the fluorescent lamp. It consists of a glass tube filled with mercury vapor at a low pressure. The electrodes are located at the ends of the tube. When the lamp is switched on, an arc-discharge excites a barely visible radiation, the greater part of which consists of ultra-violet radiation. The interior wall of the tube is coated with a fluorescent powder, which transforms the ultra-violet rays into visible radiation or light. The type of light (that is. the color range) is determined by the composition of the fluorescent powder. For starting, the mercury vapor is mixed with a small quantity of argon gas. The light produced by the fluorescent lamp varies from 45 lm/W to 55 lm/W. The colors available from the fluorescent lamp include a near-daylight and a color-corrected light for use where colors (of wool, paints, etc.) must be seen correctly. The practical application of this type of lamp includes the lighting of shops, domestic premises, factories, streets, ships, in transportation vehicles (buses), tunnels and coalmines.

The nominal life of a fluorescent lamp is between 5,000 hours and 7,500 hours. With switched or switch less starting gear, the control gear losses generally amount to about 15 per cent of lamp watts. Thus, the circuit of an 80 W fluorescent lamp will take from the supply a total of 92W

3.4 Lamp summary

- Filament: 16 lm/W; 1,000 hours nominal burning; lamp caps: BC or ES; color: white with red content; types available: general lighting service (GLS); rough service (RS); fire glow (for fire-effect electric heaters); colored (for outside decorations); architectural (linear lamps used for mirrors, display cabinets, etc.); reflector lamps.
- Halogen: 25 lm/W; 2,000 hours nominal life; color: white with reddish content; wattages from 200 W to 2 kW; larger ratings used for floodlighting.

- Fluorescent: 75 lm/W; up to 10,000 hours nominal life; colors can include 'warm white', 'daylight' and 'north light' (used where color rendering is important, such as in textiles, painting, printing; cap: bi-pin).

3.5 Light Measurement

The amount of light falling on a surface is measured (in lumens per m^2; unit = lux) by an instrument called a photometer or light meter. It consists of a cell made from three layers of metal:

- A transparent film of gold;
- A film of selenium;
- A steel base plate.

A connecting ring makes contact with the transparent film. Another connection is taken from the steel plate. These connections are taken to a very sensitive moving-coil instrument, which has a scale graduated in lm/m^2. When rays of light fall on the surface of the cell between the gold and selenium films, electrons are freed, to cause a current to flow in the moving-coil of the meter movement. This current is approximately proportional to the amount of light falling on the cell. The instrument is used to check that the amount of light falling on working planes (tables, desks, benches) is sufficient for a particular job to be done with no strain on the eyes of the worker. The Illuminating Engineering Society publishes tables indicating the optimum amount of light required to perform various tasks in industry and in the home.

3.6 IEE Regulations Summary

If any circuit is used predominantly for discharge lighting, the neutral conductor must be of the same size as the phase conductor. Mineral-insulated cables should not be used for discharge lighting circuits unless surge arresters are used. The reason for this is that the inductive currents associated with such circuits produce high voltage surges, which could puncture the mineral insulation and earth the sheath. When ES lamp holders are used, the centre contact must always be connected to the phase conductor.

When bulkhead or well-glass luminaries are installed on the exterior wall of a building, they are regarded as being outside the equipotent zone (the earthing and bonding of all

metalwork in the building). Circuits supplying such luminaries must have a disconnection time of 0.4 second if an earth fault occurs. If the luminary is taken off from a circuit within the building, the disconnection time is also 0.4 second.

All insulated conductors taken into a bulkhead luminary must be sheathed with heat-resisting sleeving (this is because of the significant heat build-up inside the fitting).

When calculating the current taken by fluorescent luminaries, account must be taken of the fact that the associated circuits take more current than is indicated by the lamps' wattage, thus

$$I = (\text{Total wattage} \times 1.8) / \text{voltage}$$

According to this formula, we can calculate the current for our installation. As we will see, we used two fluorescent tubes with 40 W in the hall.

$$I = (80\times 1.8) / 240 = 0.6 \text{ A.}$$

Where the factor of 1.8 includes such factors as the power factor of the circuit and the wattage loss in the choke (inductor).

Switches for fluorescent luminary circuits should be rated for inductive loads, if they are not, their rating must be reduced by a factor of 0.5.

3.7 Design Process

We will start to our design process from determination of the number of fittings and selection the type of lamp, which would be best, suited for the area.

In this illumination design, I used the following formulas:

- $N = E_{(s)} A_{(s)} / n F (LLF) UF_{(s)}$
- $R_I = L W / H (L+W)$

$E_{(s)}$ = Average illuminance of the reference surface

$A_{(s)}$ = Area of the room surface

n = The number of tubes in a fitting

F = Total Flux of the tube

LLF = The light loss factor

$UF_{(s)}$ = The utilization factor of the surface area.

In calculations, I assumed to use LLF and $UF_{(s)}$ as one.

The light flux of the tube is 3000 lumens = 36 W Luminaries, 5800 lumens = 70 W.

In addition to, for average illuminance of hall, kitchen, and bedrooms I assumed this value as 350 lux.

As I assumed LLF and $UF_{(s)}$ as one, no need to calculate the room index.

Let us start to our calculations.

- **Kitchen**

$N= 350\ (6\times4.15\times2.4) / 1\times3000\times1\times1 = 2.9$.

From Table 3.1 we can choose, 2, 40-watt fluorescent lamps.

Table 3.1 The characteristics of some fluorescent lamps

The power of the lamp	Light Flux(lumen)
20	1200
40	3000
65	4900
18	1300

- **The Hall**

$N= 350\times (6\times4.95\times2.4) / 1\times5800\times1\times1= 4.30$

If we assume 70 W luminaries = 5800 lumens, instead of using 4 lamps with 70 W; I will use 1 lamp with 100 W.

- **The Toilet**

According to the Project Handbook of The Chamber of Electrical Engineering, I will use $E_{(s)}$ as 50 lux for toilet, stairs and corridors. Instead of 3000 lumens, I will use 300 lumens.

$N=50\times (2.5\times1\times2.4) / 1\times300\times1\times1=1$

We can use one incandescent lamp with 40 W.

- **The empty area in the first floor**

$N=350\times (6.75\times4.6\times2.4) / 1\times5800\times1\times1= 4.49$

With the conditions in the hall calculation, I will use one lamp with 100 W.

- **Bedroom 1**

N= N=350× (3×3.7×2.4) / 1×5800×1×1=1.60

We can use one incandescent lamp with 75 W

- **Bedroom 2**

N=350× (4.6×5.25×2.4) / 1×5800×1×1= 3.49

As in the hall calculation, I will use one 100 W incandescent lamp.

- **Bedroom 3**

N=350× (3.7×3.2×2.4) / 1×5800×1×1= 1.71

We can use one lamp with 75 W.

- **Bathroom**

N=350× (3.35×3.2 ×2.4) / 1×5800×1×1= 1.55

We can use one incandescent lamp with 75 W.

- **Balcony 1**

N=50× (6.2×1.55×2.4) / 1×1000×1×1= 1.15

This balcony is quite long so it is better to use two lamps with 40 W.

- **Balcony 2**

N=50× (3.3×3×2.4) / 1×1000×1×1= 1.18

In balcony 2, in the corridor, in the wind generator room and in the stairs I will use 40 W lamps.

3.8 Summary

The best lighting system provides the required amount and quality of light at the least cost, total installation and operating costs of the system must be considered when selecting a fixture type and lamp size. We chose the true lamps according to our necessity using the light formulas, IEE Regulations and TRNC electric standards. We saw a few kinds of lamps that are using today. We used in our design, two kinds of lamps: One of them is incandescent lamps, which are available to use for many purposes, and fluorescent lamps which are the most practical.

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ELECTRICAL INSTALLATIONS FOR A TERACED HOUSE BASED ON MAINS AND WIND POWER GENERATION

Graduation Project
EE-400

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ABSTRACT

To provide an electrical installation for building is one of the main and most important tasks for the electrical engineers.

The main objective of this project is to design the electrical installation system for a two stairs building. It showed that all electrical installations must consider the safety side, like protections against fires and electrical shock.

For this purpose, we applied IEE wiring regulations, which covers wiring techniques, conductors, cables, installation methods, lighting, and small power circuits.

One of the new things this project tries to implement is the use of wind generators at houses. Its very good and economic way to produce electric from this renewable energy at wind. This project implemented a wind generator in the building, which can work directly and light the building when the main electric cut off.

INTRODUCTION

This project covers the installation of a two stairs building. It provides in detailed all the parameters and concepts which considered when implementing such a project. The load of the building consists of lighting, small power supply, heating cooling system, and special power installation for wind generator.

Chapter one explains the importance of safety in the electrical installations. Shows that IEE regulations are the reference for all engineers and technical workers, and the protection is the basic point of these regulations.

Chapter two bases on final circuit. They make up the greater part of electrical installations. It includes motors circuits, lamps circuits, choosing cable sizes. Also it focuses on wiring systems which includes conduits, trunkings, and introduces some types of protection devices like HRC and MCB.

Chapter three tries to give the techniques of choosing the lighting system for our area. It briefly explains the discharge and filament lamps. They are the most popular lamps that are using in indoor applications.

Chapter four focuses on the wind power and how to produce electric from the wind and how it will be useful if the building has wind generator that can start to work when electric is off and can supply all lighting circuits building.

Chapter five deals with water pumps. It explains pumps basics and the installation. It represents the centrifugal pump, the control gear and voltage drop.

The conclusion shows the important results, contribution and future thought.

CHAPTER ONE

REQUIREMENTS FOR SAFETY IN ELECTRICAL INSTALLATION PROJECTS

1.1 Overview

The rules and regulations that govern the practice of electrical installation engineering are essential to ensure that all electrical installations provide an adequate degree of safety from fire and shock risks to those who operate the installations and their associated apparatus, equipment and machines. The essence of these statutory regulations are collected in the IEE Regulations. Guidance on specific points of installation, choice of electrical equipment, and the maintenance of electrical apparatus, is the subject of many of the codes of practice issued by the British Standards Institution. The object of this chapter is to introduce these regulations as the main standards of my project that will be based on.

1.2 IEE Regulations

These Regulations are designed to supplement statutory regulations relating to electrical work have evolved over the past century to ensure a maximum degree of safety from tire, shock and burns, when electricity used in and about buildings. Though the Regulations are principally concerned with all aspects of electrical installations, they also touch on certain requirements relating to the selection of electrical equipment used in installations.

As the use of electricity became more popular, it soon became clear that some unified form of regulations, concerning its safe installation into buildings, would be necessary if serious accidents were to be avoided. It was for this reason government put some rules for electricity installations. The regulations set out to achieve the following:

- To safeguard the users of electrical energy from shock
- To minimize the fire risk
- To ensure as far as possible the safe and satisfactory operation of apparatus.

Though these Statutory Regulations are concerned with electrical safety in the respective type of installations listed, there are other Statutory Regulations, which are also

concerned with electrical safety when equipment and appliances are being used. Included in these are the Electricity at Work Regulations which came into force in 1990.

They are stringent in their requirements that all electrical equipment used in schools, colleges, factories and other places of work is in a safe condition and must be subjected to regular testing by competent persons.

It is a requirement of the current edition of the IEE Regulations for Electrical Installations that good workmanship and the use of approved materials contribute to the high level of safety provided in any electrical installation. The British Standards Institution (BSI) is the approved body for the preparation and issue of Standards for testing the quality of materials and their performance once they are installed in buildings.

1.3 Summary

All electrical installations are required to have an in-built safety factor, to protect the users against the risk of electric shock, fire and burns while this can be done at the design stage, much depends on the installer's approach to the work, ensuring that wiring is correctly installed and that equipment is correctly connected.

In TRNC, the chamber of electrical engineering must approve the electrical installation projects before they put into operation to provide the safety.

CHAPTER TWO

WIRING SYSTEMS AND INSTALLATION METHODS

2.1 Overview

Electricity has been one of the most important factors in the social progress made by this country over the past half-century. It affects health, education and housing, standards of living and industrial and agricultural progress. Its universal application is seen in the many different types of current-using appliances found in the home, in the office and in the factory making it possible to perform tasks easily, safely and efficiently. This chapter deals with some of the more common current-using equipment, their applications and their general installation requirements.

2.2 Sheathed wiring systems

A wiring system is an assembly of parts used in the formation of one or more electric circuits. It consists of the conductor, together with its insulation, its protection against mechanical damage (sheathing and/or armouring), and certain wiring accessories for fixing the system, and joining and terminating the conductors.

As implied by the term 'sheathed wiring system', this method of wiring consists of an insulated conductor provided with a sheath, which serves in some degree as a measure of protection against mechanical damage. The insulating materials include impregnated paper, rubber, plastics and mineral insulation. The sheathing materials include lead, tough rubber, plastics, aluminum and textiles. Some of the cables are designed with a view to cheapness and are particularly suited to domestic installations.

2.2.1 PVC (polyvinyl chloride sheathed)

This is an 'all-insulated' wiring system and commonly used for domestic installations. Though it is inferior to rubber, in the context of insulation-resistance and elastic properties, it has many advantages, not least being its comparative cheapness and ease of handling. Its main disadvantage is that it tends to soften at high temperatures, which is why its maximum

operating temperature is 70 ^{0}C. Above this temperature, there is a tendency for the conductors to migrate through the PVC, which leads to much reduced values of insulation resistance, ultimately causing a breakdown to earth. There is also a lower temperature limit, set at 0 "C. At this temperature, the PVC tends to harden and becomes a difficult material to work. The PVC-insulated cables have cores, which are self-colored for identification: red, black, blue and yellow. Blue and yellow are the colors used in three-core cables for two-way wiring. The sheathed cables contain an uninsulated circuit protective conductor, which must be sheathed with insulating sleeving (colored green/yellow) whenever the cable is made off for entry to wiring accessories.

Because the sheath can be damaged, it is recommended that additional protection be provided in situations where there is a possibility of the cable sustaining physical or mechanical damage. These cables are often run in floor spaces and in attics. The IEE Regulations draw attention to the possibility of the cables, run in these situations, coming into contact with thermal insulation material. Particularly where expanded polystyrene granules are used for loft insulation, there is the real chance that some of the plasticizer material used in PVC cable sheaths will 'migrate' and produce a hardening of the sheath. The other problem with PVC cables in contact with thermal insulation is that their current rating can be drastically reduced. The relevant factors are 0.5 if the cables are surrounded by the material and 0.75 if only one side is in contact.

In this project, we used PVC in our installation. Let us introduce the other kinds of cables.

2.2.2 PVC-S WA cables

Cables insulated with PVC and provided with steel-wire armouring are used extensively for main and sub-main cables and for wiring circuits in industrial installations. The conductors are copper or, where lightness and easy handling are needed, of aluminum. The cables are run on cable trays, racks, or installed in trenches. Terminations are by use of cable glands; flameproof glands are available for hazardous areas. If these cables are run to motor positions, where the machine is mounted on slide rails, a loop should be left in the cable to allow movement.

2.2.3 PIL C (paper-insulated, lead-covered)

Paper-insulated, lead-sheathed and served (compounded jute) cables are mainly used for external underground distribution systems. But this type of cable has a wide application for internal distribution in factories and other industrial premises. It can, therefore, be regarded as a wiring system. The paper is impregnated and must be protected against the ingress of moisture; hence the use of cable-sealing boxes. The current-carrying capacity of this type of cable is greater than that of an equivalent butyl cable. Bending of PJLC cables must be done very carefully. Fixing is normally by cleats. Further protection against mechanical damage is provided by armouring in the form of helical-wound steel wire or tape.

2.2.4 MIMS (mineral-insulated, metal-sheathed)

These cables consist of copper (or aluminum) conductors contained in a copper (or aluminum) sheath; the insulant is compressed mineral magnesium oxide. The most common type is the MICS cable, with copper as the main metal for conductors and sheath. The advantages of MICS cables are that they are self-contained and require no further protection (even against high temperatures and fire); they are impervious to water and oil, and immune from condensation. Because the conductor, sheath and insulant are inorganic, cable is virtually ageless. Installation is simple, though the ends of the cable must be sealed off by special terminations against the ingress of moisture. Fixing is by clips or saddles. Cables can be obtained with a PVC over sheath. Because of the good heat-resisting properties of the cables, the current rating is higher than that of PVC or PILC cables. Applications for the cable include industrial installations and hazardous areas. Because the sheath is copper, it offers an excellent self-contained CPC. A full range of accessories is available for the system, which is adaptable to the screwed-conduit system.

2.3 Conduits, ducts, trunking

2.3.1 Steel conduit

The modern steel conduit system is available in two types or classes: Class A, plain-end conduit, and Class B, screwed-end conduit.

2.3.1.1 Class A conduit

This conduit is known as light gauge', plain, slip, pin-grip and lug-grip, according to the types. It has thin walls and is available as close-joint, brazed or welded joint, and solid-drawn. This type of conduit is not heavy enough to withstand threading and so presents problems where earth continuity must be maintained. Various methods for connecting the conduit with the associated accessories are available, including the more acceptable lug-grip, in which the fittings are held together by slipping the conduit end into, say, a box and holding it securely by tightening screws in the lugs. The conduit must be prepared before connecting by removing the enamel. If the contact surfaces are not cleaned, the electrical contact resistance will be too high. The applications of Class A conduit are limited to situations which are not damp and in which the wires do not require a high degree of protection against mechanical damage. Close-joint conduit cannot be bent or set because the seams tend to open. If care is used, slight bends and sets can be made in brazed or solid drawn conduit. The standard sizes are 16 and 20 mm outside diameter. Fixing is by conduit saddles. The conduits are erected before cables are drawn into them. Unattached terminations are fitted with push-on rubber or composition bushes to prevent the abrasion of cables.

2.3.1.2 Class B conduit

This conduit is known as heavy gauge or screwed conduit and is available as seam-welded, and solid-drawn. Alternative finishes are:

- Black enamel for internal use in dry situations.
- Silver grey finish for internal use in dry situations where the conduit is required to match decorations.
- Hot galvanized or sherries for external use where the conduit will be subjected to dampness or condensation. Because solid-drawn conduit is more expensive than seam-welded, its use is generally restricted to gas-tight and explosion-proof installation work. Welded-seam conduit is used generally for most good quality installation work. The conduits join with the wide range of associated accessories by means of screw threads,

which give good mechanical strength and electrical continuity where the conduit acts as a CPC. The sizes available are from 16 to 32 mm, outside diameter. The thread is a shallow electric thread (ET). A full range of system accessories is available for screwed conduit: bends, elbows, tees and boxes. The first three can be of the inspection type (provided with a detachable lid) or 'solid' (no lid). Boxes have, of course, lids. Inspection bends, elbows and tees of the channel type are permitted, though they are not always suitable. Boxes are preferable to other fittings for drawing in cables, because they allow more space. Rectangular adaptable boxes are used at the intersection of several conduit runs. Fixings include saddles, clips and crumpets.

2.3.2 Flexible conduit

Flexible conduits are generally used for the final connections to machinery (e.g. electric motors), where vibration and the possible need to adjust the position to an equipment makes a rigid conduit connection unsatisfactory. Flexible conduit can also deal with the need for complicated bends and sets.

It is used for short runs where mechanical damage is unlikely to occur. Flexible conduit made from non-metallic material is dealt with in the following section. Flexible metallic conduit consists of a spirally wound, partially interlocked light-gauge galvanized steel strip, and may be watertight or non-watertight. It can be obtained with a PVC over sheath. As the conduit in itself is not accepted as a CPC, a separate CPC must be run between the special brass adaptors used to join the flexible to the ordinary screwed conduit. Sizes available are from 8 to 50 mm, internal diameter. Another type of flexible metallic conduit is the Copex conduit system. This consists of layers of metal and bituminized strip; it is usually supplied in 30 m coils. It is arranged to accommodate standard conduit fittings.

It comes in sizes from 12 to 75 mm, outside diameter. Its great advantage is that once bent into shape it retains its position: no heating is required. The metal steel spiral of the conduit does not give satisfactory CPC facilities and so a separate CPC must be run.

2.3.3 Non-metallic conduit

Non-metallic conduits are obtainable in various grades and with the same diameters as steel conduits. There are two main types: (a) flexible and *(h)* rigid. The flexible type comes in both round and oval section and is supplied in 20 m coils. The rigid type is supplied in standard lengths. Materials used vary widely one of the most common is PVC, used with phenolic-moulded fittings which closely resemble the steel-conduit range. Advantages claimed for the non-metallic conduit systems include: elimination of the need for earthing continuity; absence of fire risk due to breakdown in continuity; easy manipulation without the use of special tools; resistance to corrosion from most industrial liquids; no internal condensation takes place.

The flexible type can be bent without tools, but in cold weather needs the application of warmth. The rigid type is bent with the careful application of a flame to soften it. Fixings are by saddles or clips. When required, the conduit will cut its own thread when screwed into a threaded portion. However, it can be easily threaded using the normal electric thread stocks and dies. If it is necessary to seal the system, the 'Bostik' type of adhesive may be used. Heavy-gauge PVC can be obtained which will withstand a fair amount of rough treatment both in erection and in service.

2.3.4 Trunking systems

The following advantages are claimed for trunking:

- It is much lighter than conduits of the same capacity.
- Fewer fixings are required for one trunking length than a run of multiple conduits.
- Wiring is easier and quicker as the cables are laid-in' instead of being drawn in.
- Erection time is reduced.
- It is an easily adaptable wiring system.
- Multiple-compartment trunking is available where the segregation of services is required.

Trunking is available in sections (square and rectangular). Lengths are joined by couplers normally secured by screws. Earth straps fixed between each section ensure earth continuity along the trunking run. Trunking is available in both light-gauge and heavy-gauge forms; finish is generally enamel, but a galvanized finish can he supplied for certain

installation conditions. There is a very wide range of system fittings which include blank ends, tees, bends of various radii and angles, elbows, couplers, four-way boxes and tire-resisting barriers. Pin-racks are supplied for use in long vertical runs. The cables are wound through the pins for support.

Where the trunking contains busbar, it becomes *(a)* overhead busbar trunking and *(b)* rising-main trunking. The metal-clad overhead busbar system is used for distribution of electrical energy to machines in factories. The usual arrangement is steel trunking containing copper busbar mounted on insulators. At intervals along the length of run a tapping-off point is provided with three HRC fuses mounted in a sheet-steel case. Three contact blades are designed to fit onto the busbar. Connections to machines are then taken from the tap-off boxes by flexible conduits, steel conduits or other wiring system. Though this system has a high initial cost, it enables much of the electrical installation work to be carried out before the machines are set in position. Additions and alterations can be carried out quickly. The factory lighting circuits can be fed from the tap-off boxes.

If long runs of busbars are installed, it is necessary to provide 'expansion' joints at approximately 30 m intervals to allow for expansion and contraction due to changes in temperature. Fire barriers must he installed at suitable intervals, particularly where the trunking passes from one room to another (to prevent the spread of fire).

Among other forms of trunking available are:

- Flush trunking, which fits flush with walls; i entails a lot of builders' work to install.
- Multi-compartment trunking, which is of the normal type (square or rectangular) and provided with segregated compartments so that cables carrying different voltages can be accommodated in the same trunking unit.
- Skirting trunking, designed to take the place of the normal room skirting. It carries power telephone and lighting cables in its various compartments. Socket-outlets can be easily fitted as an integral part of the trunking.

Lighting trunking, designed for use where long rows of continuous lighting are required. The steel enclosure not only carries the fluorescent and/or tungsten fittings, hut also the control gear and supply cables.

- Trunking made from PVC is available, with the attendant advantage of this material.
- Cable-tap trunking. This type does not carry copper bars, but insulated supports which can accommodate rubber or PVC cables, from which supplies to machines an lighting circuits are tapped through fused tap-off boxes.

Rising mains are used to provide power to the various floors of multi-storey buildings. They are sheet-steel trunking containing copper bars on insulated supports. Provision is made for tapping off at each floor. Where required, distribution boards are fixed direct to the trunking.

2.4 Final circuits

A final circuit is defined as 'A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such equipment.' In addition, the regulations require that where an installation comprises more than one final circuit, each circuit shall be connected to a separate way in a distribution board. They also require that the wiring of each final circuit shall be electrically separate from that of every other final circuit. To facilitate disconnection of each final circuit for testing, the neutral conductors shall be connected at the distribution board in the same order as that in which the live conductors are connected to the fuses or circuit-breakers.

Final circuits make up the greater part of electrical installations and can vary from a pair of 1 mm^2 cables feeding one lamp, to a heavy three-core PILC cable feeding a large motor from a circuit-breaker located at a factory switchboard. The main important regulation which applies to final circuits is No. 27 of the Electricity Supply Regulations: 'All conductors and apparatus must be of sufficient size and power for the work they are called on to do, and so constructed, installed and protected as to prevent danger.

There are five general groups of final circuits:

- Rated at not more than 16A.
- Rated over 16A.
- Rated over 16A but confined to feeding 13A socket-outlets with fused plugs.
- Circuits feeding fluorescent and other discharge lamps.
- Circuits feeding motors.

An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation. Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will be relevant.

2.4.1 Domestic Installation planning

It seems to be the simplest to plan, but there are a number of points which are worth considering. And though these might seem obvious at first sight, a close survey of existing installations will reveal rather too many lapses in efficient planning, even h)r a dwelling house. For example, a room which can be entered from two points should he wired for two-way switching; a two-landing staircase should be wired for intermediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of lighting circuits: to wire one lighting point from one circuit within the wiring area of the other circuit. If this is done, there should be a note to this effect displayed at the distribution board.

The lighting in houses should be regarded as an important aspect of interior decoration, as well as supplying lighting on a purely functional basis. In living rooms and bedrooms, wall-mounted fittings can be used, controlled by multi-point switches at the entrance doors. Thought should be given to the provision of 13A socket-outlets for supplying table and standard lamps. The use of local lighting over working surfaces in kitchens is an aspect of good planning. External lighting should not be overlooked, either to light up the front and back doors or to light the way to outhouses such as detached garages, coal stores and greenhouses. In very large houses, driveway lighting may have to be considered.

To facilitate the interchange of fittings and appliances throughout the house, it is recommended that 13A three-pin socket-outlets to BS 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched socket-outlets should be used. Because the past few years have seen a rapid increase in the use of electrical appliances, it is essential that an ample number of socket-outlets be provided, and situated wherever there might arise the need for an electrical outlet.

The average house should have an adequate number of socket-outlets. In the living room, there should be a two-gang socket outlet on each side of the fireplace. Additional socket-outlets should be located less than 2 m from the opposite corners of the room, where they are least likely to be hidden by furniture. In bedrooms, at least a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage (e.g. to supply a bedside lamp and an electric blanket). Additionally, there should be socket-outlets for dressing-table lamps, a heating appliance or a portable television set.

The kitchen probably places the greatest demand on the electrical service. Outlets are required for such varied appliances as washing machines, refrigerators, waste-disposal units, food mixers, can-openers, flat irons, coffee percolators and toasters. As far as possible, the outlets should be located above working surfaces and two-gang units are recommended.

In the dining room, small plate-warmers may be required. In halls and on landings the outlet is generally used for a vacuum cleaner or floor polisher, and perhaps a hail heater. No

provision is made for the use of portable appliances in a room containing a fixed bath or shower. However, an electric shaver unit to BS 3052 may be installed out of reach of a person in the bath or shower. Additionally, a bathroom heater (of the enclosed-element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

2.4.2 Circuits rated under 16A

A final circuit rated at not more than 16A may feed an unlimited number of points provided that the total 'current demand' does not exceed 16A. They include 15, 13, 5 and 2A socket-outlets, lighting outlets, stationary appliances and certain loads which may be neglected because their current demand is negligible (e.g. clocks, bell-transformers, electric shaver supply units), provided that their rating is not greater than 5VA. No diversity is allowed on final circuits. The current rating of the cable must not be exceeded. An important point to note is that if a cable size must be increased to avoid excessive voltage drop in the circuit, the rating of the fuse or circuit-breaker protecting the circuit must not be increased correspondingly. The same condition would apply if the ambient temperature of a cable were to be taken into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favorable circuit conditions, but to provide for the special conditions in which they are being installed. The lighting circuits of domestic installations are rated at 5A. Industrial lighting circuits are usually rated at 15/16A because of the higher wattage of the lamps used.

2.4.3 Circuits rated over 16A

With two exceptions, circuits rated at over 16A should not serve more than one point. The exceptions are circuits which feed 13A socket-outlets and cooker circuits. Final circuits for cooking appliances are assessed for current demand as follows:

The first IOA of the total rated current of the connected cooking appliances, plus 30% of the remainder of the total rated current of the connected cooking appliances, plus 5A, if the cooker control unit has a socket-outlet.

Thus, a cooker with a total load of 11kW at 240V (46A) would in fact be supplied by

cables rated to carry about 26A, depending on the distance the cooker is away from the distribution board. If a large cooker which exceeds 30A is to be installed in domestic premises, and where the protection is offered by fuses, a supply service of more than the normal 60A rating may be required. In this instance, the supply authority should be consulted. Water-heater circuits are terminated in a 20A double-pole isolating switch, fitted with an earthing terminal and a neon pilot lamp.

2.4.4 Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and 13A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maximum floor area of 100 m^2 derived from a 30A protective device. Radial circuits serving a maximum area of 50 m^2 are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

- Each socket-outlet of a two-gang or multiple socket-outlet is to be counted as one socketoutlet.
- Stationary appliances, permanently connected to a radial or ring circuit, must be protected by afuse not exceeding 13A rating and controlled by a switch or a circuit-breaker.
- It is important to realize that the conductor sizes recommended tor ring circuits are minima. They must be increased if necessary where circuits arc installed in groups, or in conditions of high ambient temperature, taking into consideration the class of excess-current protection provided.
- The method of properly connecting circuit conductors of a ring circuit involves correct polarity and security of the terminals.
- Except where a ring circuit is run throughout in metallic conduit, ducts or trunking, the CPC shall be run in the form of a ring, having both ends connected to earth at the distribution hoard (or its equivalent).

- The total number of spurs shall not exceed the total number of socket-outlets and stationary appliances connected directly to the ring.
- Fused spurs from ring circuits must be connected through fused spur boxes, and the rating of the fuse must not exceed the current rating of the cable forming the spur. and in any event must not exceed 13A.
- One socket-outlet or one two-gang socket-outlet unit, or one stationary appliance fed from a connection unit, can be connected to each non-fused spur.

2.4.5 Circuits feeding discharge lamps

One of the main requirements is a consideration of the rating' of a discharge lamp outlet. tor it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge lighting. If a switch is not specifically designed to break an inductive load (quick-make. slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

2.4.6 Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular. cables which carry the starting, accelerating and load currents of a motor must be rated at least to the full-load current rating of the motor. If. however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor takes more than 16A full-load current, it should be fed from its own final circuit.

2.4.7 Final-circuit protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short-circuits between conductors, between conductors and earth, or overloads. The protective gear should he capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit-breaker. Thus, if a fault occurs on a final circuit, the associated gear will conic into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally. where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers. Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

2.4.8 Choosing cable sizes

The selection of the size of a cable to carry a load current involves the consideration of the rating and type of the protective device, the ambient temperature and whether other cables are run alongside the cable (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrent are carried due to overloading and when a short-circuit occurs. Others include the increase in temperature when a number of current carrying cables are bunched together, for instance in conduit and trunking, which is a situation in which each cable contributes its heat to that of others and which, because of the enclosed situation, produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a possible source of fire. At about 80 ^{0}C, PVC becomes very soft, so that a conductor can migrate' or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with an increase in the leakage current which could prove fatal if the installation earthing arrangement is faulty. Eventually, when the insulation breaks down completely, a short-circuit occurs and the circuit is now dependent on the ability of the, over-current protection device to operate to disconnect the circuit from its supply. As is probably realized the time of operation of the protective device is crucial: a semi-enclosed fuse will take longer to operate than would a miniature circuit-breaker. In some circumstances, particularly where PVC insulated cables are used, the time taken by a semi-enclosed fuse to operate may be long enough for the cables to burn out and create a fire hazard.

Another problem which has occurred in recent years concerns the use of thermal insulation in buildings. with cables being installed in conditions where the natural heat produced by even their normal load currents cannot be dissipated easily. The IEE Regulations recognize the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation, each of which is identified by 'Methods'. These classifications are used in the tables, which give the current-carrying capacities of cables. The installation conditions include 'enclosed' (e.g. in conduit. trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray. embedded direct in plaster that is not thermally insulating, and suspended from a

catenary wire): 'defined conditions', which include cables in free air: and cables 'in enclosed trenches'.

From this, it can be seen and appreciated that the selection of a cable to feed a circuit is now required to he undertaken with a number of factors to he considered carefully. Situations which were formerly taken for granted must now be investigated so that the cable is installed in the best conditions which will allow the cable to carry its load current with the safety of the user of the installation in mind.

The IEE Regulations require that the choice of a cable for a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

- the ambient temperature in which the cable is installed;
- the installation condition, e.g. whether grouped or bunched with other current – carrying cables, enclosed or installed 'open';
- whether the cable is surrounded by or in contact with thermal insulating material;
- whether the circuit is protected by semi-enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. All factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every bare conductor or cable conductor shall be such that the drop in voltage from the origin of the installation to any point in that installation does not exceed 4% of the nominal voltage when the conductors are carrying the full load current. The conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

The following process for working out the correct size of cables is as follows:

- First find the load current of the circuit ('B).
- Determine the correction factor for the ambient temperature which of course does not include the heat generated in the cable itself, but is more concerned with the maximum temperature of the medium through which the cable runs.
- Determine the correction factor for grouping. Here we refer to Table 4B1 of the Regulations (Appendix 4).
- Determine the correction factor if the cable is in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.
- Select the rating of the overcurrent device. If this is offering what used to be called 'close' protection, the correction factor is 1. If, however, protection is by means of a semi-enclosed fuse, the factor is 0.725. The rating of the device must at least equal the load current.
- Determine the size of the circuit conductor by calculating its current rating.
- Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

Table 2.1 PVC isolated, sheathed, copper cables

Nominal cable size	Single Phase		Three Phase	
mm^2	Current A	Voltage Drop,mV	Current	Voltage Drop
1.0	11	40	9	35
1.5	13	27	12	23
2.5	18	16	16	14
4	24	10	22	8.8
6	**30**	**6.8**	**27**	**5.9**

We choose our cables for our installation with taking reference from Table 2.1

2.5 Overcurrent protection

IEE Regulation 13-7 states that, where necessary to prevent danger every installation and every circuit 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 rating of the circuit

(ii) Are of adequate breaking capacity

(iii) Are suitably located .and permit ready restoration of the supply without danger'.

Overloading occurs when extra power is taken from the supply system. The increased loading results with the addition of low resistance being connected in parallel with the existing load in a circuit. The decrease in the overall resistance of the circuit produces a proportional rise in the amount of current flowing in the circuit conductors. The increased current will have an immediate effect on the cables: they will begin to heat up. If the overload is sustained the result could be an accelerated deterioration of the cable insulation and its eventual breakdown to cause an electrical fault and perhaps fire.

A heavy sudden overload is not so serious since the overload current flows for a short time (e.g. motor starting), and the rise in cable temperature is neither rapid nor steep. However, this current must flow for a very brief period. Certain types of cable (e.g. paper-

insulated and mineral-insulated) can withstand cyclic overloading. In certain circumstances, a sudden heavy overload may in fact approach the characteristic of a short-circuit.

A short-circuit is a direct contact or connection between a phase conductor and (a) a neutral or return conductor, or (b) earthed metalwork, the contact usually being the result of an accident. The result of a short-circuit is to present a conducting path of extremely low resistance which will allow the passage of a current of hundreds or thousands of amperes. If the faulty circuit has no over-current protection, the cables will heat up rapidly and melt; equipment would also suffer severe damage and fire is often the result.

The form which protection against overcurrent takes is either a fuse or a circuit breaker. Each has characteristics that offer the protected circuit a degree of protection according to circuit conditions.

2.6 The fuse

The fuse was the earliest means used to protect against overcurrent in conductors. The fuse consists of a short length of suitable material, often in the form of a wire which has a very small cross-sectional area. When a current flows, which is greater than the current rating of the wire, the wire, will get hot. This happens because its resistance per unit length is greater than its associated circuit conductors (so giving greater power loss and heat) and because this increased heat is concentrated in the smaller volume of the material. The size of the wire is designed to carry indefinitely the normal circuit current.

There are three general types of fuse:

- Rewirable;
- Cartridge;
- HRC (high-rupturing capacity), which is a development of the cartridge fuse.

The HRC fuse was introduced in the 1930s. The modern type consists of a barrel of high-grade ceramic able to withstand the shock conditions, which occur when a heavy fault

current is interrupted. The end caps and fixing tags are suitably plated to give a good electrical contact. The fixing tags are also planished to ensure satisfactory alignment between contact-making surfaces. Except for very low ratings, the fuse-element is of pure silver wire or tape with a waist at its centre designed to give the required operational characteristic. The filler within the barrel is powdered silica, carefully dried before use. When used, the filler is compacted in the barrels by mechanical vibration to ensure complete filling. An indicator is sometimes provided to show when the fuse has blown. This consists of a glass bead held in position in a recess in the external barrel wall by a fine resistance wire, connected in parallel with the fuse-element. The barrels are accurately ground and the caps are a force-fit. Correct grades of solder are used for the element and tag fixings. The larger types of multi-element fuses have the elements welded in addition to soldering.

The short-time characteristics of the HRC fuse enable it to take care of short-circuits conditions in the protection of 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). HRC fuses are often used in motor circuits for 'back-up' protection for the machines. Motors are normally protected against damage by overload by thermal magnetic devices in the motor starter~ the fuses are required only to give protection against short-circuit currents and severe overloads outside the capacity of the starter protective devices. For instance, modern squirrel-cage induction motors can take up to ten times normal full-load current when stalled. The rating of a fuse link for a motor circuit should be that of the smallest current that will withstand the starting current while providing at the same time the necessary margin of safety.

2.7 The circuit breaker

The circuit breaker is a mechanical device for making and breaking a circuit, both under normal and abnormal conditions, such as those of a short-circuit, the circuit being broken automatically. The circuit breaker differs from the switch. Whereas the switch is capable of making and breaking a current not greatly in excess of its normal rated current,

the circuit breaker is capable of disconnecting automatically a faulty circuit, even in short-circuit conditions. A circuit breaker is selected for a particular duty, taking the following into consideration:

(a) The normal current it will have to carry

(b) The amount of current, which the supply system will feed into the circuit fault, which current the circuit breaker will have to interrupt without damage to itself.

Because the circuit-breaker is a protective device, its basic function is *(a)* to permit the installation or appliance it protects to be used up to its full rated capacity, and *(b)* to detect, and to protect equipment against dangerous conditions. Circuit-breakers are also able to provide a closer and more accurate degree of excess-current protection than that normally provided by either semi-enclosed or cartridge fuses. Circuit-breakers also perform duties as local circuit-control switches and as fault-making isolation switches. These latter types are switches capable of making and breaking rated current, and also of being closed against existing short-circuit fault.

The circuit-breaker has a mechanism which, when it is 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 or thermal means.

The circuit breaker with magnetic tripping (the term used to indicate the opening of the circuit-breaker contacts) employs a solenoid, which is a coil with an iron slug. The normal circuit current which flows through the coil is not sufficiently strong to produce a significant magnetic flux. As soon as the circuit current increases to a predetermined level, the magnetic field strength increases to cause the iron slug to move within the solenoid and collapse the attached tripping linkage to open the contacts.

Thermal tripping uses a heat-sensitive bimetal element. When the element is heated to a predetermined temperature, the resultant deflection is arranged to trip the circuit-breaker. The time taken to heat the element to this temperature provides the necessary time-delay characteristic. The bimetal element may be arranged to carry the circuit current and so be directly self-heated. Indirect heating of the element may also be used. Because of the time

lag associated with heating, tripping by this means is not so rapid as with magnetic tripping. In the circuit condition when a small-sustained overload occurs, the thermal trip will come into operation after a few seconds or even minutes. However, when a heavier overload occurs, the magnetic trip coil operates quickly to disconnect the faulty circuit.

Circuit breakers are used instead of fuses in many installations 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. The over-current 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 is avoided 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 of time. Circuit-breaker contacts separate either in air or under insulating oil .

The miniature circuit breaker (MCB) has found an increasing application in domestic and small industrial installations. It is used as an alternative to the fuse and has certain advantages: it can be reset or reclosed easily while the fault is present in the circuit; it gives a close degree of excess-current protection (the tripping factor is 1. 1); it will trip on a small sustained overcurrent, but not on a harmless transient overcurrent such as a switching surge (e.g. on fluorescent lamp circuits). For most 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 HRC or rewirable fuses. MCBs are available in distribution units for final circuit protection. In my design, I used MCBs.

2.8 Switchgear

Though 'switchgear' can range from small switches for domestic and small industrial installations to large outdoor 275kV units, the following deals with the type of gear associated with medium-size industrial installations. Generally, the switchgear is of one of

two main types:

1. Truck type, in which the circuit breaker (oil or air-break) is mounted on a truck, which can be withdrawn to the front of the switchboard of which the unit is a part. With this type of gear, sufficient space must be allowed for the withdrawal of the truck.

2. Metal clad, in which all parts are enclosed in metal cases, and the units are factory built. The bus bars for high voltages are either oil-or compound-insulated in special chambers. Disconnection of the circuit breaker from the bus bars is made by withdrawing downwards or outwards.

In the truck-type gear, the circuit-breaker and associated current- and voltage-transformers (for the indicating instruments) are mounted in a with-draw able framework or truck. Thus, maintenance can be readily carried out on the circuit breaker. The fixed portion of the unit contains the live bus bars and feeder cable box. The spout apertures within the Unit, into which the circuit-breaker spout contact is inserted when in service, are fitted with automatic drop shutters which close off the spout apertures when the circuit-breaker is lowered and the truck withdrawn. When the truck is replaced in the unit housing and raised, these shutters open to allow the breaker spout contacts to make contact with the live bus bars of the switchboard. To ensure that the circuit cannot be interrupted on the isolating spouts by withdrawing the truck before the circuit-breaker is opened, an interlock is provided which effectively locks the truck in the closed position until the circuit-breaker is tripped.A switchgear is the ease of examining the circuit-breaker contacts. When the breaker carriage is withdrawn, the switch unit can be lowered mechanically to the floor,' the tank bolts removed and the switch unit raised again leaving the oil-filled tank on the floor and the switch contacts open to inspection. This type of gear is usually found on systems up to 11kv. In the oil-filled circuit breaker, the contacts separate under oil. The oil in this instance acts to quench the arc, which is drawn out between the separating contacts when the circuit breaker trips when there is current flowing in the circuit. Air-break circuit breakers have arc-chutes and coolers to help dissipate the arc and its gas products.

2.9 Water heating

Electric water heating is very efficient because the heating element is entirely immersed in the water to be heated. The greatest proportion of electric water heating is represented by immersion heaters, most of which are fitted in storage cylinders or tanks which sometimes have complementary means of heating. There are two types of immersion heater. The withdraw able type is a heater so constructed that the heating element can be withdrawn from the enclosing sheath without breaking water joint. The non-withdraw able type is a heater so constructed that the heating element cannot be removed without breaking water joint. As for the storage vessels, there are four general types in use:

2.9.1 The Non-pressure or Open-outlet.

This has a capacity of from *56* to 450 liters, with an immersion heater of rating in the region of 14kW. This type is controlled by a stop valve fitted on the water-inlet pipe and is usually fed directly from a water main or, alternatively, from a cistern. A non-return valve is usually fitted in the inlet pipe. The heating element and the associated thermostat are located in the bottom of the container. For domestic purposes, this type of heater has a capacity of about 12 liters and is most often used to provide hot water in an instant for washing-up duties. The type is also used in cloakrooms where there is an intermittent demand for hot water for hygiene. The tank is insulated against heat losses by a lagging of fiberglass or granulated cork. When the inlet valve is opened, the incoming cold water pushes the less-dense hot water into the outlet pipe.

2.9.2 The Pressure.

Water heaters of this type are connected to a cistern. Capacities range from 15 to 370 liters. The heater ratings are 1kW and above. In domestic installations, the usual rating is a 3kW heater in a 100-litre tank. The water supplied from the mains to the cistern is controlled by a float-ball valve. Hot-water outlets are fed under pressure supplied by the head (vertical height) of the cold water available.

2.9.3 The Cistern.

This type incorporates a feed tank with ball-valve, arranged for direct connection to the water main. A connection for an overflow pipe is also provided, for which any special requirements of the local water-supply undertaking should be observed. They must always be installed above the level of the highest hot-water tap in the house. The feed pipe, draw-off and vent pipes are all inside the heater unit. Capacities range from 15 to 100 liters; heater ratings are between 1 and 3kw.

2.9.4 The Dual-heater

This is a special development of the pressure-type of heater. The unit of 60 or 100 liters capacity is designed primarily for installation under the draining board next to the kitchen sink. This position is taken because the kitchen tap is the most frequently used hot-water outlet in a dwelling. The unit is usually also coupled to the bathroom hot-water taps. The unit is provided with two heaters, each controlled by a thermostat. One heater, located near the top of the tank, is of low rating (usually 0.5kw). It provides sufficient hot water for ordinary domestic purposes. The main heater, of a higher rating (2.5kw) is placed near the bottom of the tank and can be switched on manually before a bath is required. The complete unit, as manufactured, comprises a thermally insulated cylinder, electric-heating elements, thermostats and pipe connections. The unit of 100-litre capacity is often designed to be coupled to, and to operate in conjunction with, a fuel-fired domestic water-heater.

There are two basic types of thermostat for the control of domestic hot-water systems: the long, thin-stemmed type (usually known as the rod thermostat) and the short-stem type. The rod-type thermostat operates on the principle of differential expansion between 'invar' and copper, and usually takes the form of an invar rod (which is the lower expansion material) housed within a copper tube, which has a higher coefficient of expansion. The lower end of the copper tube is brazed to the invar rod, while the upper end is brazed to a solid portion of the switch mechanism. The invar rod is thus free to move up and down, which it does with the contraction and expansion of the copper tube under the effects of varying temperature. These thermostats are made in 18, 22, and 44 cm lengths. The 22 and 44 cm lengths are most commonly used for the control of vertical domestic heaters. The 18

cm model is generally used for horizontal or side-entry heaters. The short-stem thermostat contains a snap-action switch similar to that used in the rod-type thermostat. However, operation of the switch is by means of a piece of bimetal which replaced the combination of invar rod and copper tube.

In most water-heating installations, the immersion-heater with its associated thermostat is installed in the conventional hot-water cylinder in such a way that both heater and thermostat hang vertically downwards. Horizontal mounting is also a less-common practice. With horizontal mounting, the heater lies horizontally across the cylinder, which means that it imparts maximum turbulence to the water above the heater. Thus, virtually all the water in the tank is heated to the temperature at which the thermostat is set, before the latter trips the circuit. With vertical mounting, the degree of turbulence in the cylinder is not so great, because the heated water tends to flow upwards along the elements of the heater. Consequently, when the thermostat switches off, there is a gradient between the top and bottom of the heater element of some 20 to 30°C.

2.10 Summary

In this chapter, we deal with the final circuits, wiring techniques, choosing the cable sizes, trunking systems, conduits. In addition, we chose the cables from Table 2.1 for our requirements. The electrical equipments and their installation rules which is referenced from IEE Wiring Regulations 16th Edition. This is the most important section for the installation engineers.

CHAPTER THREE
INSTALLING LIGHTING

3.1 Overview

In this chapter, you will find how we choose the true light in our design, how much power we need, what kind of lamp we should use, how we should fix the lamps in our area, and the formulas to make our design. In addition, you will see a brief explanation of some kinds of lamps that are using today: filament, fluorescent, mercury vapor, metal halide, neon. All these have specific advantages and applications. In these kinds of lamps, we will pay attention to the filament and fluorescent lamps.

3.2 Filament lamps

A filament made from tungsten and rose to about 2,500 ^{0}C to produce a light, which, though it looks white, actually has a lot of red in it. Various methods are used to produce an efficient light-emitting filament (coiled, coiled-coil, etc). The common filament lamps used today have a luminous efficacy of about 16 lm/W. Slightly higher outputs are available when the light bulb is filled with an inert gas such as argon. One problem with filament lamps is the tendency of the evaporation; the result of this process is seen in the blackening of the inside of the glass bulb. Another problem is the heat produced by the lamp. General filament lamps use much more energy than other types of lamp, such as the fluorescent.

The nominal life of a filament lamp is 1,000 hours. However, a number of factors influence this figure. For instance, a 240 V lamp operating at 250 V will reduce the life expectancy by 43 per cent. Frequent switching also tends to reduce the life of a lamp, as will vibration. Because of the relatively low life expectancy of a filament lamp, lamp replacement costs tend to be higher than those for, say, fluorescent lamps (7,500-10,000 hours burning).

The standard type of filament lamp is the GLS (general lighting service). Two cap fittings are available: BC (bayonet cap) and ES (Edison screw). The former type of fitting is used for lamps rated from 15 W to 150 W: above this size, the ES fitting is used. Incandescent lamps are used for many purposes and are available with many variations. 'Pearl' lamps have the glass bulb internally frosted. Other types have the glass bulb silica-

coated internally.

In my installation design, I used incandescent lamps and fluorescent tubes, which is in the discharge lamps category.

3.3 Discharge lamps

The most familiar type of discharge lamp is the fluorescent lamp. It consists of a glass tube filled with mercury vapor at a low pressure. The electrodes are located at the ends of the tube. When the lamp is switched on, an arc-discharge excites a barely visible radiation, the greater part of which consists of ultra-violet radiation. The interior wall of the tube is coated with a fluorescent powder, which transforms the ultra-violet rays into visible radiation or light. The type of light (that is. the color range) is determined by the composition of the fluorescent powder. For starting, the mercury vapor is mixed with a small quantity of argon gas. The light produced by the fluorescent lamp varies from 45 lm/W to 55 lm/W. The colors available from the fluorescent lamp include a near-daylight and a color-corrected light for use where colors (of wool, paints, etc.) must be seen correctly. The practical application of this type of lamp includes the lighting of shops, domestic premises, factories, streets, ships, in transportation vehicles (buses), tunnels and coalmines.

The nominal life of a fluorescent lamp is between 5,000 hours and 7,500 hours. With switched or switch less starting gear, the control gear losses generally amount to about 15 per cent of lamp watts. Thus, the circuit of an 80 W fluorescent lamp will take from the supply a total of 92W

3.4 Lamp summary

- Filament: 16 lm/W; 1,000 hours nominal burning; lamp caps: BC or ES; color: white with red content; types available: general lighting service (GLS); rough service (RS); fire glow (for fire-effect electric heaters); colored (for outside decorations); architectural (linear lamps used for mirrors, display cabinets, etc.); reflector lamps.
- Halogen: 25 lm/W; 2,000 hours nominal life; color: white with reddish content; wattages from 200 W to 2 kW; larger ratings used for floodlighting.

- Fluorescent: 75 lm/W; up to 10,000 hours nominal life; colors can include 'warm white', 'daylight' and 'north light' (used where color rendering is important, such as in textiles, painting, printing; cap: bi-pin).

3.5 Light Measurement

The amount of light falling on a surface is measured (in lumens per m^{2}; unit = lux) by an instrument called a photometer or light meter. It consists of a cell made from three layers of metal:

- A transparent film of gold;
- A film of selenium;
- A steel base plate.

A connecting ring makes contact with the transparent film. Another connection is taken from the steel plate. These connections are taken to a very sensitive moving-coil instrument, which has a scale graduated in lm/m^2. When rays of light fall on the surface of the cell between the gold and selenium films, electrons are freed, to cause a current to flow in the moving-coil of the meter movement. This current is approximately proportional to the amount of light falling on the cell. The instrument is used to check that the amount of light falling on working planes (tables, desks, benches) is sufficient for a particular job to be done with no strain on the eyes of the worker. The Illuminating Engineering Society publishes tables indicating the optimum amount of light required to perform various tasks in industry and in the home.

3.6 IEE Regulations Summary

If any circuit is used predominantly for discharge lighting, the neutral conductor must be of the same size as the phase conductor. Mineral-insulated cables should not be used for discharge lighting circuits unless surge arresters are used. The reason for this is that the inductive currents associated with such circuits produce high voltage surges, which could puncture the mineral insulation and earth the sheath. When ES lamp holders are used, the centre contact must always be connected to the phase conductor.

When bulkhead or well-glass luminaries are installed on the exterior wall of a building, they are regarded as being outside the equipotent zone (the earthing and bonding of all

metalwork in the building). Circuits supplying such luminaries must have a disconnection time of 0.4 second if an earth fault occurs. If the luminary is taken off from a circuit within the building, the disconnection time is also 0.4 second.

All insulated conductors taken into a bulkhead luminary must be sheathed with heat-resisting sleeving (this is because of the significant heat build-up inside the fitting).

When calculating the current taken by fluorescent luminaries, account must be taken of the fact that the associated circuits take more current than is indicated by the lamps' wattage, thus

$$I = (\text{Total wattage} \times 1.8) / \text{voltage}$$

According to this formula, we can calculate the current for our installation. As we will see, we used two fluorescent tubes with 40 W in the hall.

$$I = (80 \times 1.8) / 240 = 0.6 \text{ A.}$$

Where the factor of 1.8 includes such factors as the power factor of the circuit and the wattage loss in the choke (inductor).

Switches for fluorescent luminary circuits should be rated for inductive loads, if they are not, their rating must be reduced by a factor of 0.5.

3.7 Design Process

We will start to our design process from determination of the number of fittings and selection the type of lamp, which would be best, suited for the area.

In this illumination design, I used the following formulas:

- $N = E_{(s)}\, A_{(s)} / n\, F\, (LLF)\, UF_{(s)}$
- $R_I = L\, W / H\, (L+W)$

$E_{(s)}$ = Average illuminance of the reference surface

$A_{(s)}$ = Area of the room surface

n = The number of tubes in a fitting

F = Total Flux of the tube

LLF = The light loss factor

$UF_{(s)}$ = The utilization factor of the surface area.

In calculations, I assumed to use LLF and $UF_{(s)}$ as one.

The light flux of the tube is 3000 lumens = 36 W Luminaries, 5800 lumens = 70 W.

In addition to, for average illuminance of hall, kitchen, and bedrooms I assumed this value as 350 lux.

As I assumed LLF and $UF_{(s)}$ as one, no need to calculate the room index.

Let us start to our calculations.

- **Kitchen**

N= 350 (6×4.15×2.4) / 1×3000×1×1 =2.9.

From Table 3.1 we can choose, 2, 40-watt fluorescent lamps.

Table 3.1 The characteristics of some fluorescent lamps

The power of the lamp	Light Flux(lumen)
20	1200
40	3000
65	4900
18	1300

- **The Hall**

N= 350× (6×4.95×2.4) / 1×5800×1×1= 4.30

If we assume 70 W luminaries = 5800 lumens, instead of using 4 lamps with 70 W; I will use 1 lamp with 100 W.

- **The Toilet**

According to the Project Handbook of The Chamber of Electrical Engineering, I will use $E_{(s)}$ as 50 lux for toilet, stairs and corridors. Instead of 3000 lumens, I will use 300 lumens.

N=50× (2.5×1×2.4) / 1×300×1×1=1

We can use one incandescent lamp with 40 W.

- **The empty area in the first floor**

N=350× (6.75×4.6×2.4) / 1×5800×1×1= 4.49

With the conditions in the hall calculation, I will use one lamp with 100 W.

- **Bedroom 1**

N= N=350× (3×3.7×2.4) / 1×5800×1×1=1.60

We can use one incandescent lamp with 75 W

- **Bedroom 2**

N=350× (4.6×5.25×2.4) / 1×5800×1×1= 3.49

As in the hall calculation, I will use one 100 W incandescent lamp.

- **Bedroom 3**

N=350× (3.7×3.2×2.4) / 1×5800×1×1= 1.71

We can use one lamp with 75 W.

- **Bathroom**

N=350× (3.35×3.2 ×2.4) / 1×5800×1×1= 1.55

We can use one incandescent lamp with 75 W.

- **Balcony 1**

N=50× (6.2×1.55×2.4) / 1×1000×1×1= 1.15

This balcony is quite long so it is better to use two lamps with 40 W.

- **Balcony 2**

N=50× (3.3×3×2.4) / 1×1000×1×1= 1.18

In balcony 2, in the corridor, in the wind generator room and in the stairs I will use 40 W lamps.

3.8 Summary

The best lighting system provides the required amount and quality of light at the least cost, total installation and operating costs of the system must be considered when selecting a fixture type and lamp size. We chose the true lamps according to our necessity using the light formulas, IEE Regulations and TRNC electric standards. We saw a few kinds of lamps that are using today. We used in our design, two kinds of lamps: One of them is incandescent lamps, which are available to use for many purposes, and fluorescent lamps which are the most practical.

CHAPTER FOUR

WIND GENERATORS

4.1 Overview

The wind started to be important for human, since 1800s. Nowadays, we benefit from wind for producing electric in our roofs. The aim of this chapter to give some idea from techniques of installation a domestic usage wind generator and to explain briefly; why we prefer to design our home electric generator from wind rather than from sun.

4.2 Where does the wind come from?

Wind is the result of the heating and cooling of the earth by the sun. When we experience wind, we are feeling the movement of air from a region of high pressure to a region of low pressure. These pressure differences are a result of differing temperatures between one place and another.

Wind energy can be transformed into mechanical energy and electrical energy. It has been used for centuries as an energy source for sailing ships, pumping water and grinding grain. Wind pumps have been vital to the development of the livestock industry in the world. More recently wind has become an alternative source of electricity for remote sites not connected to the main electricity distribution grid.

Wind generators are used for battery charging, AC utility inertia, water or space heating and direct motor drive for water pumping. A typical system would have the wind generator on a tall tower (tilt-up, self-supporting, pipe or lattice), battery bank for storage, inverter to change DC to 120 volt AC. Depending on the type and size of inverter and wind system, the inverter can power all the loads, part of the loads or sell the surplus back to the utility company. Outputs will vary with wind speed, turbulence, blade diameter and generator size. An average wind speed of 8 mph or more is recommended for a battery charging system and 12 mph or more for a utility inertia system. Most wind generators will begin producing power at 7-10 mph and will reach full output at 25-30 mph. Air density will influence output. Hot temperatures or higher altitude lowers air density, which lowers power generated. Reduce expected output about 3% per 1000' above sea level. Wind generators are mounted at least 30' above nearby trees and buildings within a 300' radius. Tilt-up towers are nice because no climbing is needed. A wind generator, PV modules and Hydro electric unit can all be used to charge the same battery. The wind often blows on cloudy days when solar electric modules have low or no output.

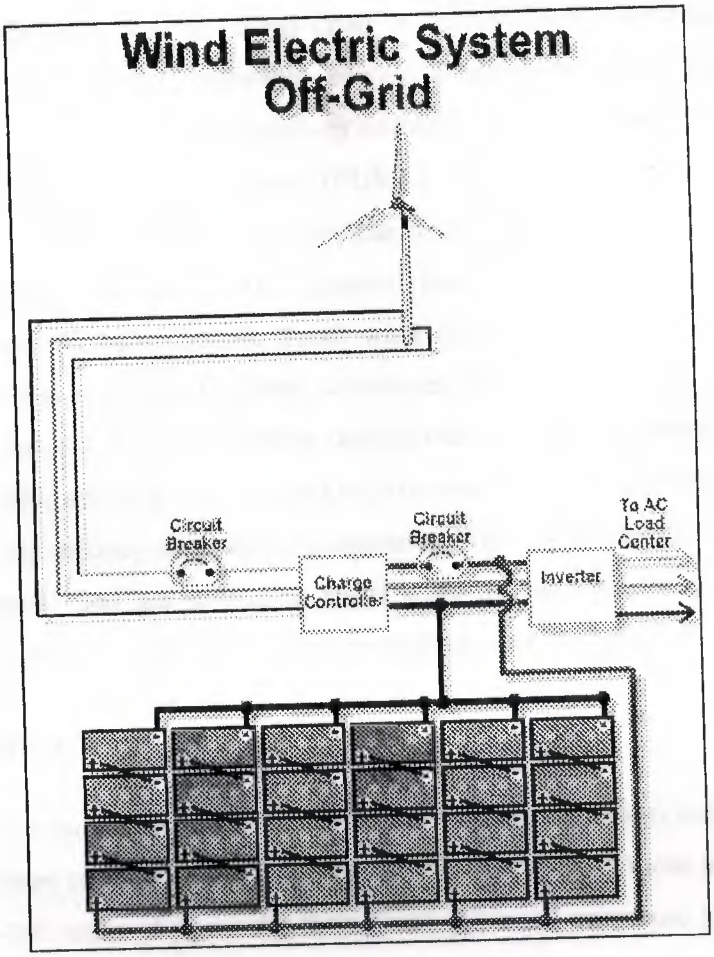


Figure 4.1 Wind Electric System

4.3 History

The wind has been an important source of energy in the U.S. for a long time. The mechanical windmill was one of the two "high-technology" inventions (the other was barbed wire) of the late 1800's that allowed us to develop much of our western frontier. Over 8 million mechanical windmills have been installed in the U.S. since the 1860's and some of these units have been in operation for more than a hundred years. Back in the 1920's and 1930's, before the REA began subsidizing rural electric coops and electric lines, farm families throughout the Midwest used 200-3,000 watt wind generators to power lights, radios, and kitchen appliances. The modest wind industry that had built up by the 1930's was literally driven out of business by government policies favoring the construction of utility lines and fossil fuel power plants. In the late 1970's and early 1980's intense interest was once again focused on wind energy as a possible solution to the energy crisis. As homeowners and farmers looked to various electricity producing renewable energy alternatives, small wind turbines emerged as the most cost effective technology capable of reducing their utility bills. Tax credits and favorable federal regulations (PURPA) made it possible for over 4,500 small, 1-25 kW, utility-intertied wind systems to be installed at individual homes between 1976-1985. Another 1,000 systems were installed in various remote applications during the same period. Small wind turbines were installed in all fifty States. None of the small wind turbine companies, however, were owned by large companies committed to long term market development, so when the federal tax credits expired in late 1985, and oil prices dropped to $10 a barrel two months later, most of the small wind turbine industry once again disappeared. The companies that survived this "market adjustment" and are producing small wind turbines today are those whose machines were the most reliable and whose reputations were the best.

4.4 The Cost Factor

Photovoltaic is an attractive technology in many ways, but cost is not one of them. Small wind turbines can be an attractive alternative, or addition, to those people needing more than 100-200 watts of power for their home, business, or remote facility. Unlike PV's, which stay at basically the same cost per watt independent of array size, wind turbines get less expensive with increasing system size. At the 50 watt size level, for example, a small wind turbine would cost about $8.00/watt compared to approximately $6.00/watt for a PV module. This is why, all things being equal, PV is less expensive for very small loads. As the system size gets larger, however, this "rule-of-thumb" reverses itself. At 300 watts the wind turbine costs are down to $2.50/watt ($1.50/watt in the case of the Southwest Wind power Air 403), while the PV costs are still at $6.00/watt. For a 1,500 watt wind system the cost is down to $2.00/watt and at 10,000 watts the cost of a wind generator (excluding electronics) is down to $1.50/watt. The cost of regulators and controls is essentially the same for PV and wind. Somewhat surprisingly, the cost of towers for the wind turbines is about the same as the cost of equivalent PV racks and trackers. The cost of wiring is usually higher for PV systems because of the large number of connections.

For homeowners connected to the utility grid, small wind turbines are usually the best "next step" after all the conservation and efficiency improvements have been made. A typical home consumes between 800-2,000 kWh of electricity per month and a 4-10 kW wind turbine or PV system is about the right size to meet this demand. At this size wind turbines are much less expensive.

4.5 Reliability

In the past reliability was the "Achilles Heel" of small wind turbine products. Small turbines designed in the late 1970's had a well deserved reputation for not being very reliable. Today's products, however, are technically advanced over these earlier units and they are substantially more reliable. Small turbines are now available that can operate 5 years or more, even at harsh sites, without need for maintenance or inspections and 5-year warranties are available. The reliability and cost of operation of these units is equal to that of photovoltaic systems.

4.6 Wind Energy

Wind energy is a form of solar energy produced by uneven heating of the Earth' surface. Wind resources are best along coastlines, on hills, and in the northern states, but usable wind resources can be found in most areas. As a power source wind energy is less predictable than solar energy, but it is also typically available for more hours in a given day. Wind resources are influenced by terrain and other factors that make it much more site specific than solar energy. In hilly terrain, for example, you and your neighbor are likely to have the exact same solar resource. But you could have a much better wind resource than your neighbor because your property is on top of the hill or it has a better exposure to the prevailing wind direction. Conversely, if your property is in a gully or on the leeward side of the hill, your wind resource could be substantially lower. In this regard, wind energy must be considered more carefully than solar energy. Wind energy follows seasonal patterns that provide the best performance in the winter months and the lowest performance in the summer months. This is just the opposite of solar energy. For this reason wind and solar systems work well together in hybrid systems. These hybrid systems provide a more consistent year-round output than either wind-only or PV-only systems. One of the most active market segments for small wind turbine manufacturers is PV-only system owners who are expanding their system with wind energy.

4.7 Wind Turbines

Most wind turbines are horizontal-axis propeller type systems. Vertical-axis systems, such as the egg-beater like Darrieus and S-rotor type Savonius type systems, have proven to be more expensive. A horizontal-axis wind turbine consists of a rotor, a generator, a mainframe, and, usually, a tail. The rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator. The rotor usually consists of two or three blades. A three blade unit can be a little more efficient and will run smoother than a two blade rotor, but they also cost more. The blades are usually made from either wood or fiberglass because these materials have the needed combination of strength and flexibility (and they don't interfere with television signals!). The generator is usually specifically designed for the wind turbine. Permanent magnet alternators are popular because they eliminate the need for field windings. A low speed direct drive generator is an important feature because systems that use gearboxes or belts have generally not been reliable. The mainframe is the structural backbone of the wind turbine and it includes the "slip-rings" that connect the rotating (as it points itself into changing wind directions) wind turbine and the fixed tower wiring. The tail aligns the rotor into the wind and can be a part of the overspeed protection.

A wind turbine is a deceptively difficult product to develop and many of the early units were not very reliable. A PV module is inherently reliable because it has no moving parts and, in general, one PV module is as reliable as the next. A wind turbine, on the other hand, must have moving parts and the reliability of a specific machine is determined by the level of skill used in its engineering and design. In other words, there can be a big difference in reliability, ruggedness, and life expectancy from one brand to the next. This is a lesson that often seems to escape dealers and customers who are used to working with solar modules.

4.8 Towers

A wind turbine must have a chance at the wind to perform efficiently. Turbulence, which reduces performance and "works" the turbine harder than smooth air, is highest close to the ground and diminishes with height. Also, wind speed increases with height above the ground. As a general rule of thumb, you should install a wind turbine on a tower such that it is at least 30 ft above any obstacles within 300 ft. Smaller turbines typically go on shorter towers than larger turbines. A 250 watt turbine is often, for example, installed on a 30-50 ft tower, while a 10 kW turbine will usually need a tower of 80-120 ft. We do not recommend mounting wind turbines to small buildings that people live in because of the inherent problems of turbulence, noise, and vibration. The least expensive tower type is the guyed-lattice tower, such as those commonly used for ham radio antennas. Smaller guyed towers are sometimes constructed with tubular sections or pipe. Self-supporting towers, either lattice or tubular in construction, take up less room and are more attractive but they are also more expensive. Telephone poles can be used for smaller wind turbines. Towers, particularly guyed towers, can be hinged at their base and suitably equipped to allow them to be tilted up or down using a winch or vehicle. This allows all work to be done at ground level.

Some towers and turbines can be easily erected by the purchaser, while others are best left to trained professionals. Anti-fall devices, consisting of a wire with a latching runner, are available and are highly recommended for any tower that will be climbed. Aluminum towers should be avoided because they are prone to developing cracks. Towers are usually offered by wind turbine manufacturers and purchasing one from them is the best way to ensure proper compatibility.

4.9 Remote Systems Equipment

The balance-of-systems equipment used with a small wind turbine in a remote application is essentially the same as used with a PV system. Most wind turbines designed for battery charging come with a regulator to prevent overcharge. The regulator is specifically designed to work with that particular turbine. PV regulators are generally not suitable for use with a small wind turbine because they are not designed to handle the voltage and current variations found with turbines. The output from the regulator is typically tied into a DC source center, which also serves as the connection point for other DC sources, loads and the batteries. For a hybrid system the PV and wind systems are connected to the DC source center through separate regulators, but no special controls are generally required. For small wind turbines a general rule-of-thumb is that the AH capacity of the battery bank should be at least six times the maximum renewable charging current, including any PV elements. The wind industry has had good experience using battery banks that are smaller than those typically recommended for PV applications.

4.10 Being Your Own Utility Company

The federal PURPA regulations passed in 1978 allow you to interconnect a suitable renewable energy powered generator to your house or business to reduce your consumption of utility supplied electricity. This same law requires utilities to purchase any excess electricity production at a price (avoided cost) usually below the retail cost of electricity. In about a half-dozen states with "net energy billing options" small systems are allowed to run the meter backwards, so they get the full retail rate for excess production. Because of the high overhead costs to the utilities for keeping a few special hand-processed customer accounts, net energy billing is actually less expensive for them.

These systems do not use batteries. The output of the wind turbine is made compatible with utility power using either a line-commutated inverter or an induction generator. The output is then connected to the household breaker panel on a dedicated breaker, just like a large appliance. When the wind turbine is not operating, or it is not putting out as much electricity as the house needs, the additional electricity needed is supplied by the utility. Likewise, if the turbine puts out more power than the house needs, the excess is instantaneously "sold" to the utility. In effect, the utility act as a very big battery bank and the utility "sees" the wind turbine as a negative load. After over 200 million hours of interconnected operation we now know that small utility-interconnected wind turbines are safe, do not interfere with either utility or customer equipment, and do not need any special safety equipment to operate successfully.

Hundreds of homeowners around the country who installed 4-12 kW wind turbines during the go-go tax credit days in the early 1980's now have everything paid for and enjoy monthly electrical bills of $8-30, while their neighbors have bills in the range of

$100-200 per month. The problem, of course, is that these tax credits are long gone and without them, most homeowners will find the cost of a suitable wind generator prohibitively expensive. A 10 kW turbine (the most common size for homes), for example, will typically cost $28,000-35,000 installed. For those paying 12 cents/kilowatt-hour or more for electricity in an area with an average wind speed of 10 mph or more (DOE Class 2), and with an acre or more of property (the turbines are big), a residential wind turbine is certainly worth considering. Payback periods will generally fall in the range of 8-16 years and some wind turbines are designed to last thirty years or more.

4.11 Performance

The rated power for a wind turbine is not a good basis for comparing one product to the next. This is because manufacturers are free to pick the wind speed at which they rate their turbines. If the rated wind speeds are not the same then comparing the two products is very misleading. Fortunately, the American Wind Energy Association has adopted a standard method of rating energy production performance. Manufacturers who follow the AWEA standard will give information on the Annual Energy Output (AEO) at various annual average wind speeds. These AEO figures are like the EPA Estimated Gas Mileage for your car, they allow you to compare products fairly, but they don't tell you just what your actual performance will be ("Your Performance May Vary").

As a rule of thumb wind energy should be considered if your average wind speed is above 8 mph (most, but not all, Class 1 and all other Classes) for a remote application and 10 mph (Class 2 or better) for a utility- intertied application. If you live in an area that is not too hilly then the DOE wind resource map can be used to fairly accurately calculate the expected performance of a wind turbine at your site. In complex terrain a judgment on the site's exposure must be made to adjust the average wind speed used for this calculation. In most situations it is not necessary to monitor the wind speed with a recording anemometer prior to installing a small wind turbine. But in some situations it is worth spending $300-1,000 and waiting a year to perform a wind survey. Manufacturers and equipment dealers can help sort out these questions

4.12 Advantages and Disadvantages of Wind Generators

4.12.1 Advantages

- Wind is a renewable energy resource. Wind patterns provide strong, steady trade winds in specific areas throughout most of the year.
- Used as a "fuel," wind is free and non-polluting, producing no emissions or chemical wastes.
- Use of wind power as a source of electricity will help reduce the state's almost complete dependence on imported fossil fuels.
- Wind power can be used with battery storage or pumped hydro-energy storage systems to provide a steady flow of energy.
- Wind farms can be combined with agricultural activities such as cattle grazing.
- Wind power is a proven technology and has been used to generate electricity for many years.
- Equipment for wind machines is commercially available.

4.12.2 Disadvantages

- Wind machines must be located where strong, dependable winds are available most of the time.
- Because winds do not blow strongly enough to produce power all the time, energy from wind machines is considered "intermittent," that is, it comes and goes. Therefore, electricity from wind machines must have a back-up supply from another source.
- As wind power is "intermittent," utility companies can use it for only part of their total energy needs.
- Wind towers and turbine blades are subject to damage from high winds and lighting. Rotating parts which are located high off the ground can be difficult and expensive to repair.
- Electricity produced by wind power sometimes fluctuates in voltage and power factor, which can cause difficulties in linking its power to a utility system.

4.13 Solar Electric

There are two forms of energy that we can use them for houses from the sun. One is thermal energy and the other is electric energy. Each one of us experiences thermal energy from the sun. The sun's infrared heat helps warm the planet, our bodies and our homes. The sun's heat can even be concentrated to power steam turbines to generate electricity. Besides thermal, we can directly convert sunlight into electricity using solar cells.

Solar cells or photovoltaic (PV) cells have been around since the age of the transistor, and through the years, they have become much more efficient. They have the ability to turn sunlight directly into electricity using a semiconductor material of silicon. Most everyone has seen a PV cell. They are commonly found in calculators, watches and some portable radios. Similar PV is when attached to each other form solar modules that can power much larger devices or batteries. A number of these modules then can be tied together to produce enough electricity to adequately power residential homes.

4.14 The Advantages and Disadvantages of Solar Electric

4.14.1 Advantages

- Compared to nonrenewable energy such as coal, gas, oil and nuclear, solar electric is totally nonpolluting.
- There are no moving parts in a solar electric system.
- There virtually maintenance is free.
- PV's will last for decades.

4.14.2 Disadvantages

- The most important disadvantage is the installation equipments are very big. Most of the roofs are not big enough for the design. Because the solar cells can just produce 1.372 W power in $1 m^2$.
- The sun does not always shine. Climates vary globally and no matter where you live, solar is only part of the answer to a renewable energy solution.

- In most cases, solar electric is still more expensive than nonrenewable energy. The gap is narrowing though and energy shortages are becoming more commonplace.

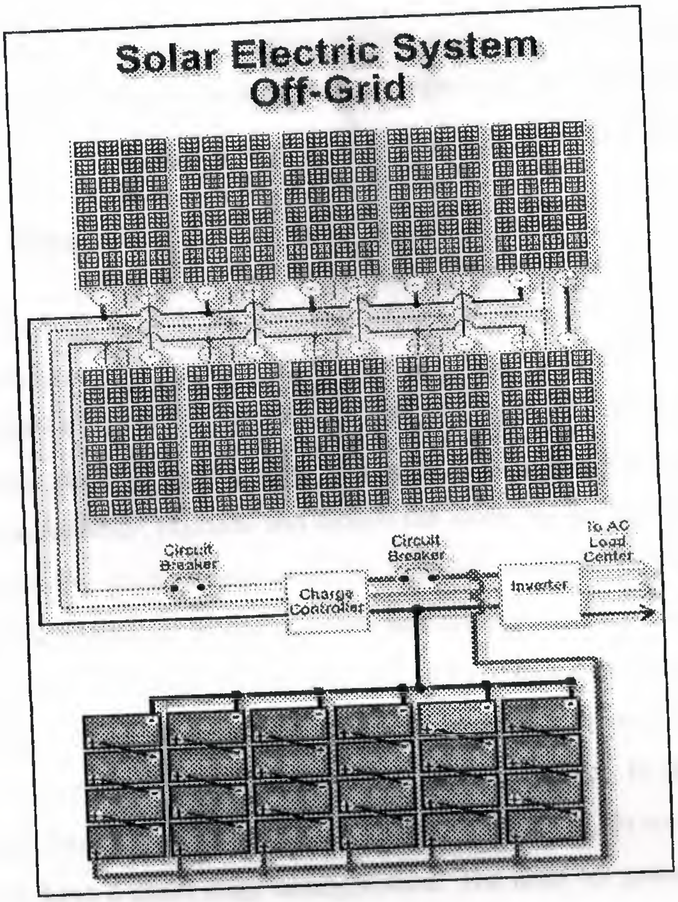


Figure 4.2 Solar Electric System

As we saw above when we pay attention to advantage and disadvantages, we can use wind generator in our project, because our house is quite small (10×11). The wind generator gives us 18 times bigger energy than solar cells.

4.15 Summary

We saw two popular renewable energy sources; wind and sun. When we pay attention to advantage and the disadvantages, which explained above, for a house that has a small roof, it is not a true idea to install the photovoltaic cells. So, we installed to our house a small wind generator that has a charger, inverter and a battery.

CHAPTER FIVE

PUMP BASICS

5.1 Overview

In this chapter, we will see the basics of the mechanism of the centrifugal pumps and their working. It mentioned the most famous types that used for domestic purposes. In addition, we will see the parameters that effect our choosing to the pump type.

5.2 Centrifugal Pumps

A centrifugal pump is of a very simple design. It only has one moving part, an impeller that attached to as haft and driven by the motor. The two main parts of the pump are the impeller and the diffuser. Impellers can be made of bronze, polycarbonate, cast iron, stainless steel as well as other materials. The diffuser (sometimes called a volute) houses the impeller, captures and directs the water off the impeller. Water enters the eye (center) of the impeller and exits the impeller via centrifugal force. As water leaves the eye of the impeller, a low-pressure area created, causing more water to flow into the eye. Atmospheric pressure and centrifugal force cause this to happen. Velocity developed as the water flows through the impeller while it spins at high speed. The water velocity collected by the diffuser and converted to pressure, by specially designed passageways that direct the flow to the discharge of the pump, or to the next impeller should the pump have a multi-stage configuration. The head (or pressure) that a pump will develop is in direct relationship to the impeller diameter, the number of impellers, the size of impeller eye, and shaft speed. Capacity is determined by the exit width of the impeller. All of these factors affect the horsepower size of the motor to be used. The more water to be pumped, the more energy is required. A centrifugal is not positive acting. The greater the depth to the water, the less the pump will pump. In addition, when it pumps against increasing pressure, the less it will pump. For these reasons, it is important to select a centrifugal pump that is designed to do a particular job. For higher pressure or greater lifts, two or more impellers are commonly used; or, a jet ejector is added to assist the impellers in raising pressure.

5.3 Choosing the water pump type

Before we install a new water system, we will need to do a complete assessment of our water usage, such as how many bathrooms our house has, how many spigots are in the yard, or is there any land that we may want to irrigate. All areas where we need water must be taken into account. A good contractor should be able to assess our needs and design a suitable water system

The first important step in planning a sufficient and economical water supply is to estimate the actual capacity required. It is a common mistake to under-estimate the real need. Dissatisfaction and higher cost usually occur because of "doing the job over". Proper planning can eliminate this. A general average for each member of a household, for all purposes, including kitchen, laundry, bath, and toilet (but not including yard fixtures), is 75 gallons per day per person. It is suggested that the total requirement of a 24-hour day be pumped in two (2) hours for two basic reasons:

- To take adequate care of the peak period demand such as several outlets on at one time, and
- To provide an economical pump selection. Added to the normal daily household requirement should be the demand required for any special requirement, such as sprinkling systems, livestock, etc.

In this project I assumed, five people would live in the house.

5 Family members @ 75 gpd = 375 gpd

- Gallons per day divided by 2 = Pump capacity.

375 divided by 2 = 187.5 Gallons per hour or 3.125 gallons per minute.

Using this situation as an example, we will need a pump capable of delivering 3.125 gallons per minute. A competent dealer should be able to recommend which one of the pumps will fit our needs. From Table 5.1 we chose our pump.

Table 5.1 Properties of Centrifugal water pump- series C

WATER PUMP TYPE	POWER		PERFORMANCE			
Single Phase	hp	KW	Capacity l/min	Head meters	inlet	Outlet
C 50	0.6	0.45	10-77	22-10	11/4'	1'
C 70	0.75	0.55	10-90	25-10	11/4'	1'
C 90	0.9	0.67	10-120	27-12	11/4'	1'
C 110	1	0.75	10-123	36-12	11/4'	1'
C 150	1.5	1.1	10-140	38-13	11/4'	1'
C 200	2	1.5	10-150	40-14	11/4'	1'

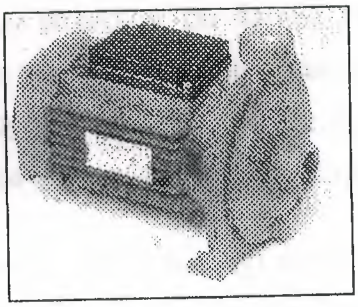


Figure 5.1 Centrifugal Water Pump(C 90)

The current rating of cables feeding a motor should be based on the full-load current taken by the motor. A conductor carries a current

Maximum permissible voltage drop = 4 % of 240 V = 9.6 V.

If we assume the cables are to be single-core, with 85°C insulation. The ambient temperature is taken as 60 °C. Protection is by MCB.

The current of 1 HP motor is 6.7 A.

Rating of protective device (I_n) = 30 A

Current rating of conductor (I_z) $= \dfrac{I_n}{Correction\ \ factor\ \ for\ 60\ °C}$ *amps*

$Correction\ \ factor\ \ for\ 60\ °C = 0.67$

$$\therefore I_z = \frac{30}{0.67} = 44.7\ A$$

The required rating of conductor is 6 mm^2

The total volt drop is $\frac{VD/A/m = I_B \times length\ of\ run}{1000} = \frac{7.7 \times 6.7 \times 38}{1000} = 6.44$

Thus, the conductor size of 6 mm^2 is suitable for the load in the conditions specified.

In the first working of the water pump, it will use the current 6 times bigger than the normal current because of this reason we choose instead of 1 mm^2 cable 2.5 mm^2 cable.

5.4 Control gear

Small squirrel-cage motors, starting on light load, can be switched direct-on-line, but to comply with the IEE Regulations the starters are fitted with isolator, and overcurrent and under-voltage protection. On starting, the motor, if switched direct, takes a current of up to seven times its normal full load current, which decreases as full speed is reached. The supply authorities require that the magnitude and duration of these starting surges be limited and use is often made of special starting gear.

Starling equipment for wound-rotor (slip-ring) motors comprises two parts: a stator switch, which contains the protective devices, and a graded rotor resistance which is cut out as the motor speeds up.

- **Direct-on-line starting**. This can be a hand-operated switch, but more use is now being made of the push-button operated contactor starter. Figure 5.2 shows the circuit diagram of a simple contactor starter.

The start button, when pressed, completes the contactor circuit and closes the three-phase switch establishing the supply to the stator. The motor current passes through the overload coils and if the current becomes excessive, the overcurrent solenoid operates the trip coil and breaks the contactor circuit. Under voltage, protection is inherent, as failure of the supply causes the contactor, which is operated from the supply, to drop out. The stop-button is wired in series with the overload contacts to break the circuit. An isolating switch is mounted in, or near to, the starter so that the circuit can be isolated, and if necessary, this can be locked off for safety during motor maintenance.

If a hand-operated starter is used the overcurrent device actuates the mechanical linkage of the starter. In this case, the under voltage coil is energized from two of the supply terminals and actuates the mechanical linkage if the supply fails. However our installations are one phase we wanted to show the circuit diagram of a contactor starter for three phase circuit.

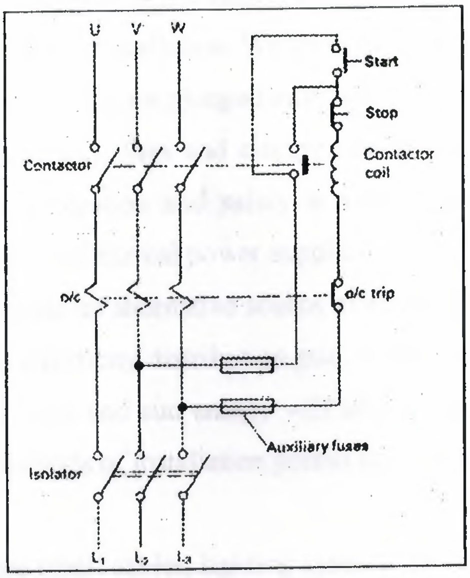


Figure 5.2 circuit diagram of a contactor starter

5.5 Summary

Centrifugal water pumps are ideal for domestic usage. It has a simple design. However, for every specific job we have to choose a special kind of pump. To decide what kind of pump we choose, our water usage needs to do a complete assessment of how many people will live in the house, how many bedrooms we have. We can calculate the pump capacity from how many gallons of water are using per day.

CONCLUSION

Electrical installations require some techniques and rules. Final circuits made up the greatest part of the electrical installation. We used two lighting circuits for one stair, when one circuit fails; the house is not plunged into darkness.

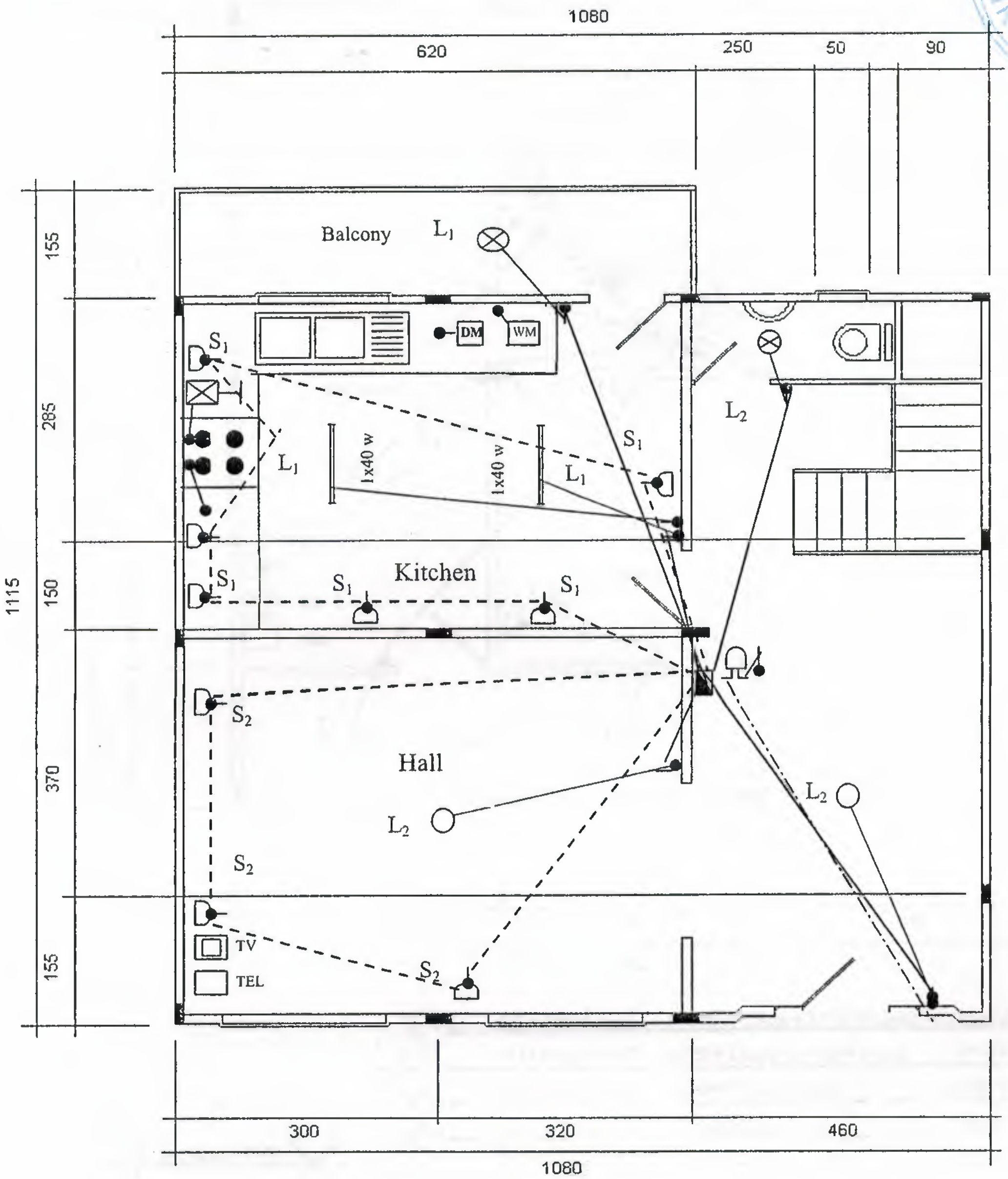
The hazards from electricity, fires and electric shocks are mostly the result of the bad electrical installation protection and safety is very important point in electrical installation and distribution of electrical power supplies.

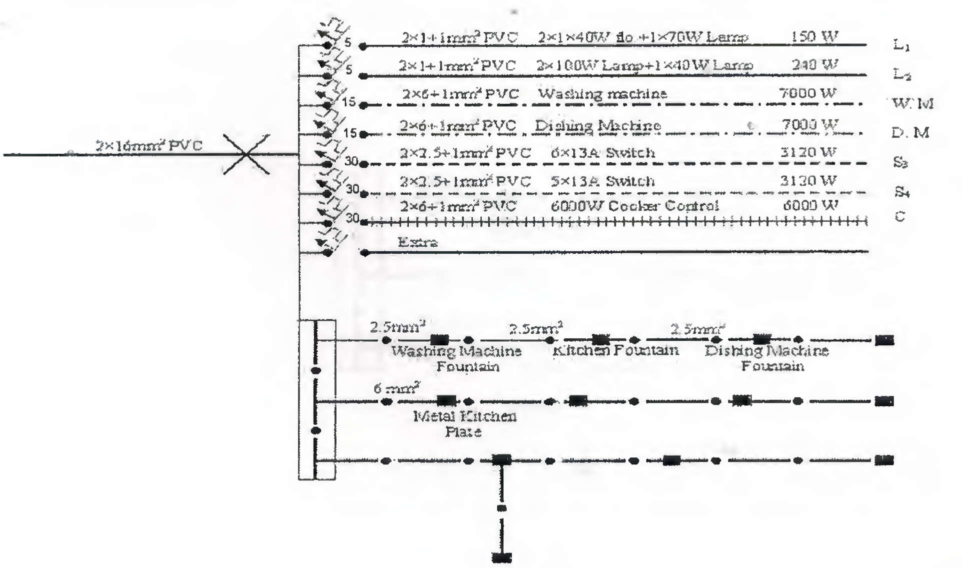
Wind energy has become an alternative source of electricity remote sides, which is not connected to the main electricity distribution grid. Photovoltaic cells need large area for installation. In future wind and sun energy will take much more effective place in our life. The developed methods of installation permit to reduce the hazardous effects of electricity.

In future, we may see smart cables, lighting systems and small electrical devices.

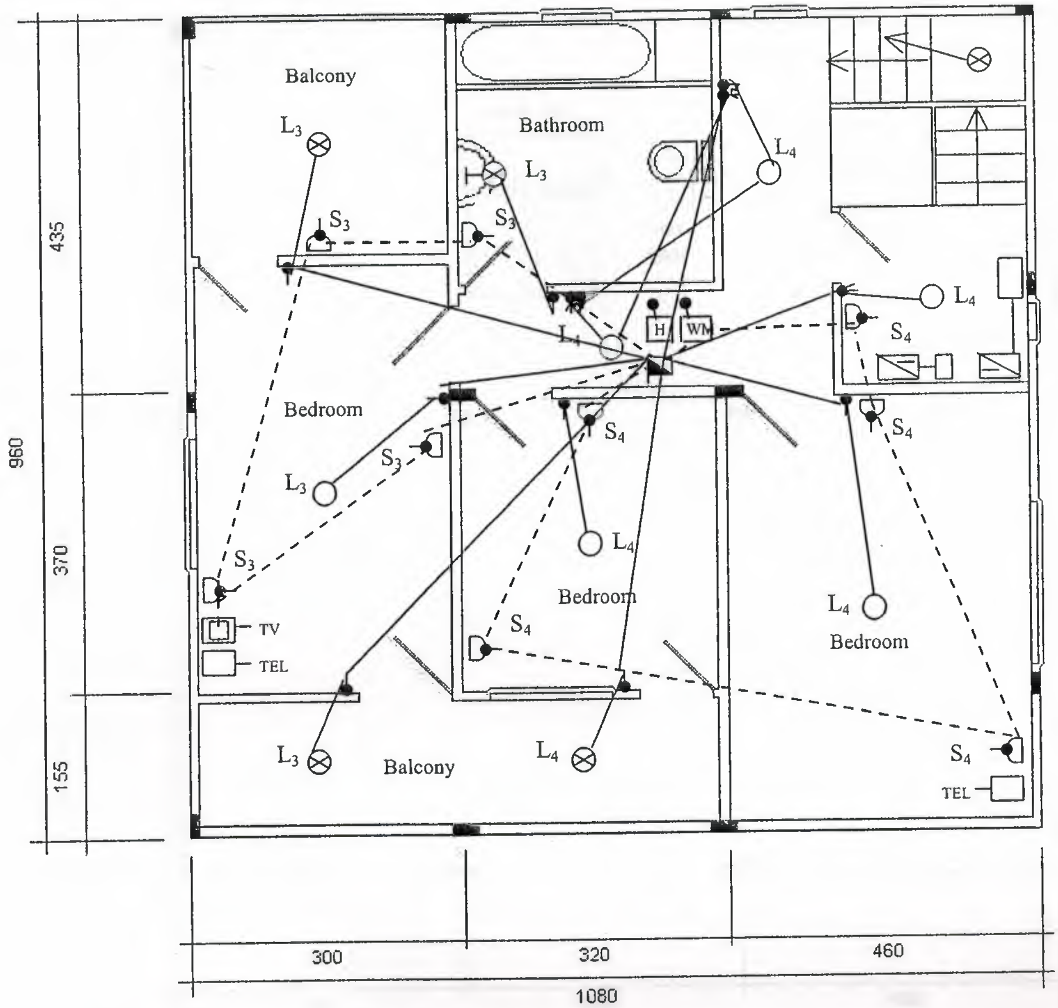
APPENDIX A

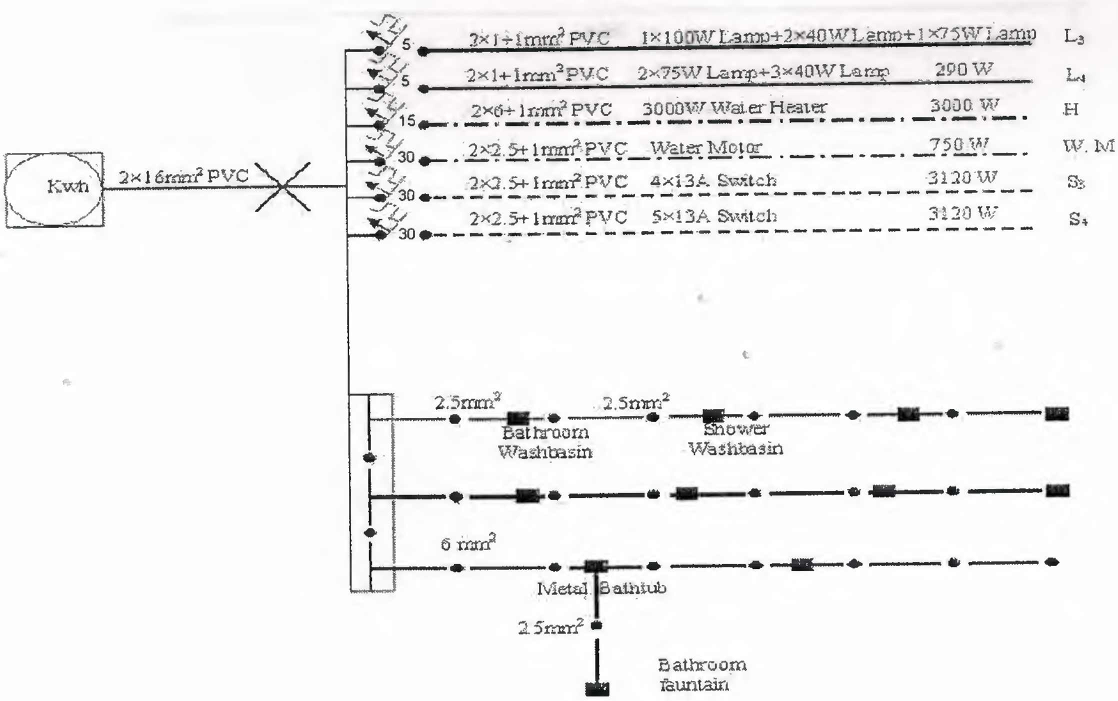
Electrical installation of the first floor



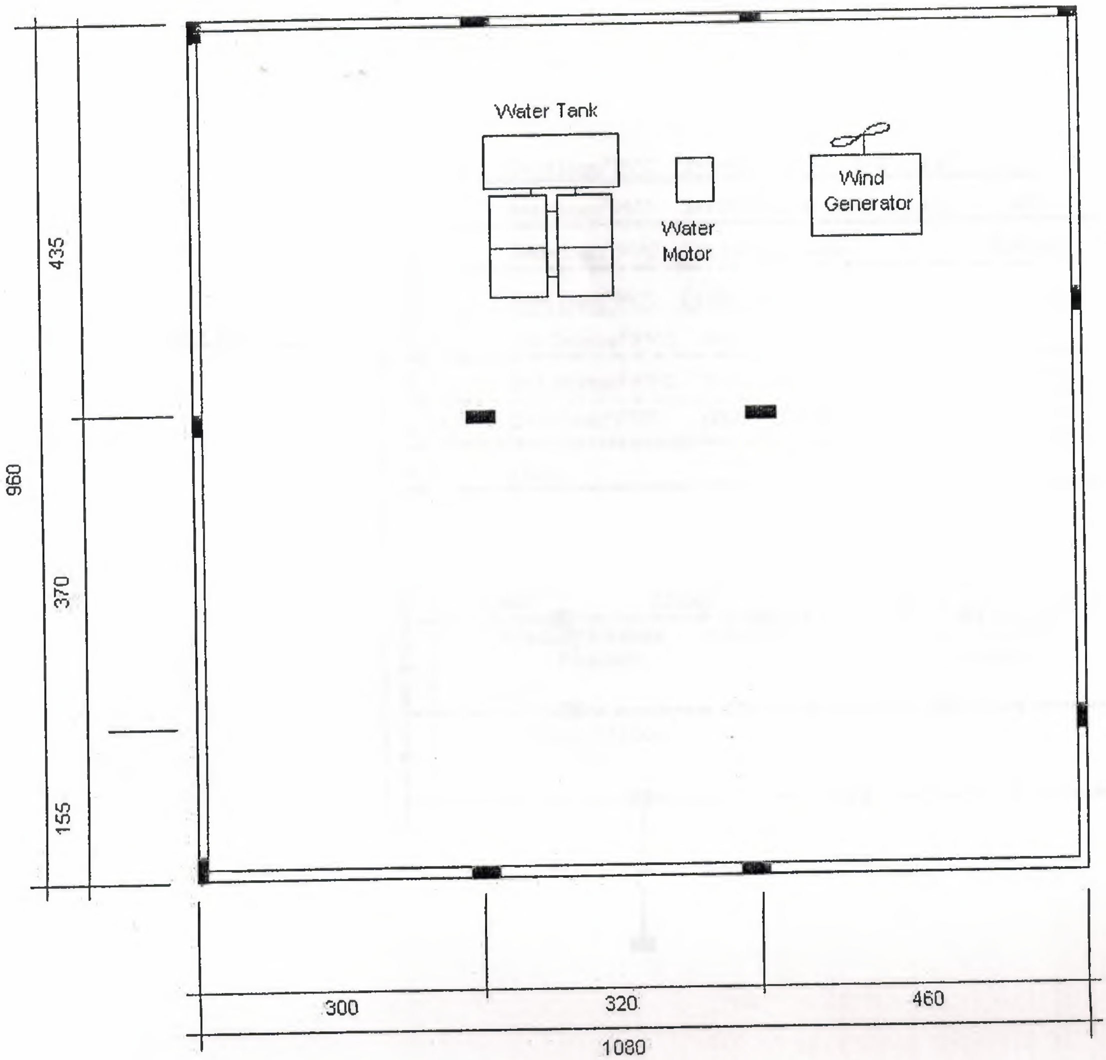


Electrical installation of the second floor

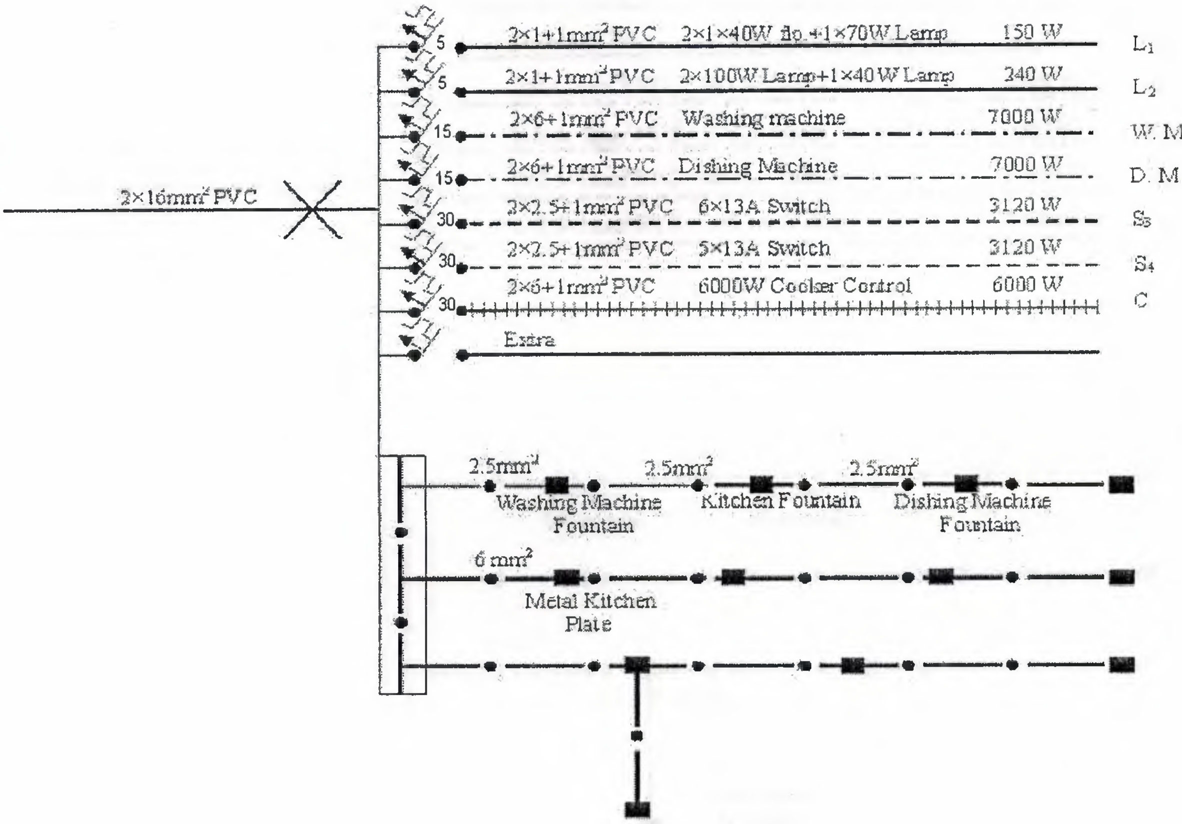




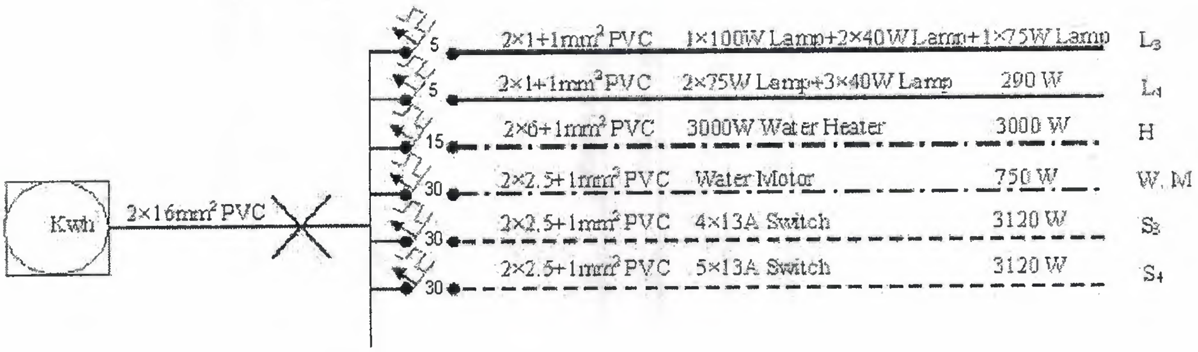
The Roof Plan

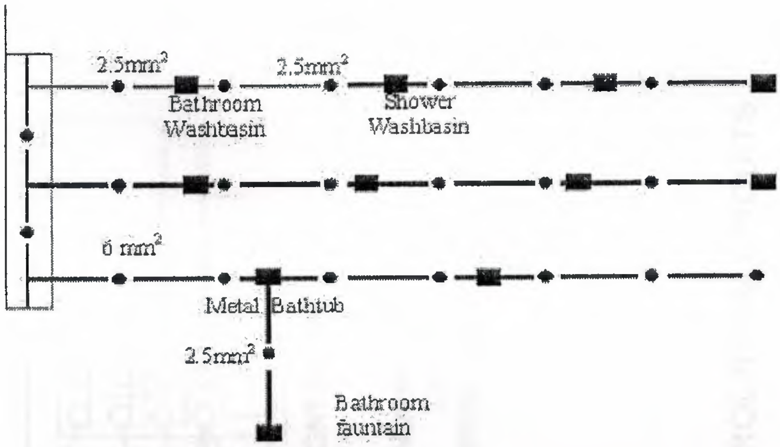


Grounding connections conductor of the first floor



Grounding connections conductor of the second floor





NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ELECTRICAL INSTALLATIONS FOR A TERACED HOUSE BASED ON MAINS AND WIND POWER GENERATION

Graduation Project
EE-400

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NICOSIA-2003

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ABSTRACT

To provide an electrical installation for building is one of the main and most important tasks for the electrical engineers.

The main objective of this project is to design the electrical installation system for a two stairs building. It showed that all electrical installations must consider the safety side, like protections against fires and electrical shock.

For this purpose, we applied IEE wiring regulations, which covers wiring techniques, conductors, cables, installation methods, lighting, and small power circuits.

One of the new things this project tries to implement is the use of wind generators at houses. Its very good and economic way to produce electric from this renewable energy at wind. This project implemented a wind generator in the building, which can work directly and light the building when the main electric cut off.

INTRODUCTION

This project covers the installation of a two stairs building. It provides in detailed all the parameters and concepts which considered when implementing such a project. The load of the building consists of lighting, small power supply, heating cooling system, and special power installation for wind generator.

Chapter one explains the importance of safety in the electrical installations. Shows that IEE regulations are the reference for all engineers and technical workers, and the protection is the basic point of these regulations.

Chapter two bases on final circuit. They make up the greater part of electrical installations. It includes motors circuits, lamps circuits, choosing cable sizes. Also it focuses on wiring systems which includes conduits, trunkings, and introduces some types of protection devices like HRC and MCB.

Chapter three tries to give the techniques of choosing the lighting system for our area. It briefly explains the discharge and filament lamps. They are the most popular lamps that are using in indoor applications.

Chapter four focuses on the wind power and how to produce electric from the wind and how it will be useful if the building has wind generator that can start to work when electric is off and can supply all lighting circuits building.

Chapter five deals with water pumps. It explains pumps basics and the installation. It represents the centrifugal pump, the control gear and voltage drop.

The conclusion shows the important results, contribution and future thought.

CHAPTER ONE

REQUIREMENTS FOR SAFETY IN ELECTRICAL INSTALLATION PROJECTS

1.1 Overview

The rules and regulations that govern the practice of electrical installation engineering are essential to ensure that all electrical installations provide an adequate degree of safety from fire and shock risks to those who operate the installations and their associated apparatus, equipment and machines. The essence of these statutory regulations are collected in the IEE Regulations. Guidance on specific points of installation, choice of electrical equipment, and the maintenance of electrical apparatus, is the subject of many of the codes of practice issued by the British Standards Institution. The object of this chapter is to introduce these regulations as the main standards of my project that will be based on.

1.2 IEE Regulations

These Regulations are designed to supplement statutory regulations relating to electrical work have evolved over the past century to ensure a maximum degree of safety from tire, shock and burns, when electricity used in and about buildings. Though the Regulations are principally concerned with all aspects of electrical installations, they also touch on certain requirements relating to the selection of electrical equipment used in installations.

As the use of electricity became more popular, it soon became clear that some unified form of regulations, concerning its safe installation into buildings, would be necessary if serious accidents were to be avoided. It was for this reason government put some rules for electricity installations. The regulations set out to achieve the following:

- To safeguard the users of electrical energy from shock
- To minimize the fire risk
- To ensure as far as possible the safe and satisfactory operation of apparatus.

Though these Statutory Regulations are concerned with electrical safety in the respective type of installations listed, there are other Statutory Regulations, which are also

concerned with electrical safety when equipment and appliances are being used. Included in these are the Electricity at Work Regulations which came into force in 1990.

They are stringent in their requirements that all electrical equipment used in schools, colleges, factories and other places of work is in a safe condition and must be subjected to regular testing by competent persons.

It is a requirement of the current edition of the IEE Regulations for Electrical Installations that good workmanship and the use of approved materials contribute to the high level of safety provided in any electrical installation. The British Standards Institution (BSI) is the approved body for the preparation and issue of Standards for testing the quality of materials and their performance once they are installed in buildings.

1.3 Summary

All electrical installations are required to have an in-built safety factor, to protect the users against the risk of electric shock, fire and burns while this can be done at the design stage, much depends on the installer's approach to the work, ensuring that wiring is correctly installed and that equipment is correctly connected.

In TRNC, the chamber of electrical engineering must approve the electrical installation projects before they put into operation to provide the safety.

CHAPTER TWO

WIRING SYSTEMS AND INSTALLATION METHODS

2.1 Overview

Electricity has been one of the most important factors in the social progress made by this country over the past half-century. It affects health, education and housing, standards of living and industrial and agricultural progress. Its universal application is seen in the many different types of current-using appliances found in the home, in the office and in the factory making it possible to perform tasks easily, safely and efficiently. This chapter deals with some of the more common current-using equipment, their applications and their general installation requirements.

2.2 Sheathed wiring systems

A wiring system is an assembly of parts used in the formation of one or more electric circuits. It consists of the conductor, together with its insulation, its protection against mechanical damage (sheathing and/or armouring), and certain wiring accessories for fixing the system, and joining and terminating the conductors.

As implied by the term 'sheathed wiring system', this method of wiring consists of an insulated conductor provided with a sheath, which serves in some degree as a measure of protection against mechanical damage. The insulating materials include impregnated paper, rubber, plastics and mineral insulation. The sheathing materials include lead, tough rubber, plastics, aluminum and textiles. Some of the cables are designed with a view to cheapness and are particularly suited to domestic installations.

2.2.1 PVC (polyvinyl chloride sheathed)

This is an 'all-insulated' wiring system and commonly used for domestic installations. Though it is inferior to rubber, in the context of insulation-resistance and elastic properties, it has many advantages, not least being its comparative cheapness and ease of handling. Its main disadvantage is that it tends to soften at high temperatures, which is why its maximum

operating temperature is 70 ^{0}C. Above this temperature, there is a tendency for the conductors to migrate through the PVC, which leads to much reduced values of insulation resistance, ultimately causing a breakdown to earth. There is also a lower temperature limit, set at 0 "C. At this temperature, the PVC tends to harden and becomes a difficult material to work. The PVC-insulated cables have cores, which are self-colored for identification: red, black, blue and yellow. Blue and yellow are the colors used in three-core cables for two-way wiring. The sheathed cables contain an uninsulated circuit protective conductor, which must be sheathed with insulating sleeving (colored green/yellow) whenever the cable is made off for entry to wiring accessories.

Because the sheath can be damaged, it is recommended that additional protection be provided in situations where there is a possibility of the cable sustaining physical or mechanical damage. These cables are often run in floor spaces and in attics. The IEE Regulations draw attention to the possibility of the cables, run in these situations, coming into contact with thermal insulation material. Particularly where expanded polystyrene granules are used for loft insulation, there is the real chance that some of the plasticizer material used in PVC cable sheaths will 'migrate' and produce a hardening of the sheath. The other problem with PVC cables in contact with thermal insulation is that their current rating can be drastically reduced. The relevant factors are 0.5 if the cables are surrounded by the material and 0.75 if only one side is in contact.

In this project, we used PVC in our installation. Let us introduce the other kinds of cables.

2.2.2 PVC-S WA cables

Cables insulated with PVC and provided with steel-wire armouring are used extensively for main and sub-main cables and for wiring circuits in industrial installations. The conductors are copper or, where lightness and easy handling are needed, of aluminum. The cables are run on cable trays, racks, or installed in trenches. Terminations are by use of cable glands; flameproof glands are available for hazardous areas. If these cables are run to motor positions, where the machine is mounted on slide rails, a loop should be left in the cable to allow movement.

2.2.3 PIL C (paper-insulated, lead-covered)

Paper-insulated, lead-sheathed and served (compounded jute) cables are mainly used for external underground distribution systems. But this type of cable has a wide application for internal distribution in factories and other industrial premises. It can, therefore, be regarded as a wiring system. The paper is impregnated and must be protected against the ingress of moisture; hence the use of cable-sealing boxes. The current-carrying capacity of this type of cable is greater than that of an equivalent butyl cable. Bending of PJLC cables must be done very carefully. Fixing is normally by cleats. Further protection against mechanical damage is provided by armouring in the form of helical-wound steel wire or tape.

2.2.4 MIMS (mineral-insulated, metal-sheathed)

These cables consist of copper (or aluminum) conductors contained in a copper (or aluminum) sheath; the insulant is compressed mineral magnesium oxide. The most common type is the MICS cable, with copper as the main metal for conductors and sheath. The advantages of MICS cables are that they are self-contained and require no further protection (even against high temperatures and fire); they are impervious to water and oil, and immune from condensation. Because the conductor, sheath and insulant are inorganic, cable is virtually ageless. Installation is simple, though the ends of the cable must be sealed off by special terminations against the ingress of moisture. Fixing is by clips or saddles. Cables can be obtained with a PVC over sheath. Because of the good heat-resisting properties of the cables, the current rating is higher than that of PVC or PILC cables. Applications for the cable include industrial installations and hazardous areas. Because the sheath is copper, it offers an excellent self-contained CPC. A full range of accessories is available for the system, which is adaptable to the screwed-conduit system.

2.3 Conduits, ducts, trunking

2.3.1 Steel conduit

The modern steel conduit system is available in two types or classes: Class A, plain-end conduit, and Class B, screwed-end conduit.

2.3.1.1 Class A conduit

This conduit is known as light gauge', plain, slip, pin-grip and lug-grip, according to the types. It has thin walls and is available as close-joint, brazed or welded joint, and solid-drawn. This type of conduit is not heavy enough to withstand threading and so presents problems where earth continuity must be maintained. Various methods for connecting the conduit with the associated accessories are available, including the more acceptable lug-grip, in which the fittings are held together by slipping the conduit end into, say, a box and holding it securely by tightening screws in the lugs. The conduit must be prepared before connecting by removing the enamel. If the contact surfaces are not cleaned, the electrical contact resistance will be too high. The applications of Class A conduit are limited to situations which are not damp and in which the wires do not require a high degree of protection against mechanical damage. Close-joint conduit cannot be bent or set because the seams tend to open. If care is used, slight bends and sets can be made in brazed or solid drawn conduit. The standard sizes are 16 and 20 mm outside diameter. Fixing is by conduit saddles. The conduits are erected before cables are drawn into them. Unattached terminations are fitted with push-on rubber or composition bushes to prevent the abrasion of cables.

2.3.1.2 Class B conduit

This conduit is known as heavy gauge or screwed conduit and is available as seam-welded, and solid-drawn. Alternative finishes are:

- Black enamel for internal use in dry situations.
- Silver grey finish for internal use in dry situations where the conduit is required to match decorations.
- Hot galvanized or sherries for external use where the conduit will be subjected to dampness or condensation. Because solid-drawn conduit is more expensive than seam-welded, its use is generally restricted to gas-tight and explosion-proof installation work. Welded-seam conduit is used generally for most good quality installation work. The conduits join with the wide range of associated accessories by means of screw threads,

which give good mechanical strength and electrical continuity where the conduit acts as a CPC. The sizes available are from 16 to 32 mm, outside diameter. The thread is a shallow electric thread (ET). A full range of system accessories is available for screwed conduit: bends, elbows, tees and boxes. The first three can be of the inspection type (provided with a detachable lid) or 'solid' (no lid). Boxes have, of course, lids. Inspection bends, elbows and tees of the channel type are permitted, though they are not always suitable. Boxes are preferable to other fittings for drawing in cables, because they allow more space. Rectangular adaptable boxes are used at the intersection of several conduit runs. Fixings include saddles, clips and crumpets.

2.3.2 Flexible conduit

Flexible conduits are generally used for the final connections to machinery (e.g. electric motors), where vibration and the possible need to adjust the position to an equipment makes a rigid conduit connection unsatisfactory. Flexible conduit can also deal with the need for complicated bends and sets.

It is used for short runs where mechanical damage is unlikely to occur. Flexible conduit made from non-metallic material is dealt with in the following section. Flexible metallic conduit consists of a spirally wound, partially interlocked light-gauge galvanized steel strip, and may be watertight or non-watertight. It can be obtained with a PVC over sheath. As the conduit in itself is not accepted as a CPC, a separate CPC must be run between the special brass adaptors used to join the flexible to the ordinary screwed conduit. Sizes available are from 8 to 50 mm, internal diameter. Another type of flexible metallic conduit is the Copex conduit system. This consists of layers of metal and bituminized strip; it is usually supplied in 30 m coils. It is arranged to accommodate standard conduit fittings.

It comes in sizes from 12 to 75 mm, outside diameter. Its great advantage is that once bent into shape it retains its position: no heating is required. The metal steel spiral of the conduit does not give satisfactory CPC facilities and so a separate CPC must be run.

2.3.3 Non-metallic conduit

Non-metallic conduits are obtainable in various grades and with the same diameters as steel conduits. There are two main types: (a) flexible and *(h)* rigid. The flexible type comes in both round and oval section and is supplied in 20 m coils. The rigid type is supplied in standard lengths. Materials used vary widely one of the most common is PVC, used with phenolic-moulded fittings which closely resemble the steel-conduit range. Advantages claimed for the non-metallic conduit systems include: elimination of the need for earthing continuity; absence of fire risk due to breakdown in continuity; easy manipulation without the use of special tools; resistance to corrosion from most industrial liquids; no internal condensation takes place.

The flexible type can be bent without tools, but in cold weather needs the application of warmth. The rigid type is bent with the careful application of a flame to soften it. Fixings are by saddles or clips. When required, the conduit will cut its own thread when screwed into a threaded portion. However, it can be easily threaded using the normal electric thread stocks and dies. If it is necessary to seal the system, the 'Bostik' type of adhesive may be used. Heavy-gauge PVC can be obtained which will withstand a fair amount of rough treatment both in erection and in service.

2.3.4 Trunking systems

The following advantages are claimed for trunking:

- It is much lighter than conduits of the same capacity.
- Fewer fixings are required for one trunking length than a run of multiple conduits.
- Wiring is easier and quicker as the cables are laid-in' instead of being drawn in.
- Erection time is reduced.
- It is an easily adaptable wiring system.
- Multiple-compartment trunking is available where the segregation of services is required.

Trunking is available in sections (square and rectangular). Lengths are joined by couplers normally secured by screws. Earth straps fixed between each section ensure earth continuity along the trunking run. Trunking is available in both light-gauge and heavy-gauge forms; finish is generally enamel, but a galvanized finish can he supplied for certain

installation conditions. There is a very wide range of system fittings which include blank ends, tees, bends of various radii and angles, elbows, couplers, four-way boxes and tire-resisting barriers. Pin-racks are supplied for use in long vertical runs. The cables are wound through the pins for support.

Where the trunking contains busbar, it becomes *(a)* overhead busbar trunking and *(b)* rising-main trunking. The metal-clad overhead busbar system is used for distribution of electrical energy to machines in factories. The usual arrangement is steel trunking containing copper busbar mounted on insulators. At intervals along the length of run a tapping-off point is provided with three HRC fuses mounted in a sheet-steel case. Three contact blades are designed to fit onto the busbar. Connections to machines are then taken from the tap-off boxes by flexible conduits, steel conduits or other wiring system. Though this system has a high initial cost, it enables much of the electrical installation work to be carried out before the machines are set in position. Additions and alterations can be carried out quickly. The factory lighting circuits can be fed from the tap-off boxes.

If long runs of busbars are installed, it is necessary to provide 'expansion' joints at approximately 30 m intervals to allow for expansion and contraction due to changes in temperature. Fire barriers must he installed at suitable intervals, particularly where the trunking passes from one room to another (to prevent the spread of fire).

Among other forms of trunking available are:

- Flush trunking, which fits flush with walls; i entails a lot of builders' work to install.
- Multi-compartment trunking, which is of the normal type (square or rectangular) and provided with segregated compartments so that cables carrying different voltages can be accommodated in the same trunking unit.
- Skirting trunking, designed to take the place of the normal room skirting. It carries power telephone and lighting cables in its various compartments. Socket-outlets can be easily fitted as an integral part of the trunking.

Lighting trunking, designed for use where long rows of continuous lighting are required. The steel enclosure not only carries the fluorescent and/or tungsten fittings, hut also the control gear and supply cables.

- Trunking made from PVC is available, with the attendant advantage of this material.
- Cable-tap trunking. This type does not carry copper bars, but insulated supports which can accommodate rubber or PVC cables, from which supplies to machines an lighting circuits are tapped through fused tap-off boxes.

Rising mains are used to provide power to the various floors of multi-storey buildings. They are sheet-steel trunking containing copper bars on insulated supports. Provision is made for tapping off at each floor. Where required, distribution boards are fixed direct to the trunking.

2.4 Final circuits

A final circuit is defined as 'A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such equipment.' In addition, the regulations require that where an installation comprises more than one final circuit, each circuit shall be connected to a separate way in a distribution board. They also require that the wiring of each final circuit shall be electrically separate from that of every other final circuit. To facilitate disconnection of each final circuit for testing, the neutral conductors shall be connected at the distribution board in the same order as that in which the live conductors are connected to the fuses or circuit-breakers.

Final circuits make up the greater part of electrical installations and can vary from a pair of 1 mm^2 cables feeding one lamp, to a heavy three-core PILC cable feeding a large motor from a circuit-breaker located at a factory switchboard. The main important regulation which applies to final circuits is No. 27 of the Electricity Supply Regulations: 'All conductors and apparatus must be of sufficient size and power for the work they are called on to do, and so constructed, installed and protected as to prevent danger.

There are five general groups of final circuits:

- Rated at not more than 16A.
- Rated over 16A.
- Rated over 16A but confined to feeding 13A socket-outlets with fused plugs.
- Circuits feeding fluorescent and other discharge lamps.
- Circuits feeding motors.

An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation. Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will be relevant.

2.4.1 Domestic Installation planning

It seems to be the simplest to plan, but there are a number of points which are worth considering. And though these might seem obvious at first sight, a close survey of existing installations will reveal rather too many lapses in efficient planning, even h)r a dwelling house. For example, a room which can be entered from two points should he wired for two-way switching; a two-landing staircase should be wired for intermediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of lighting circuits: to wire one lighting point from one circuit within the wiring area of the other circuit. If this is done, there should be a note to this effect displayed at the distribution board.

The lighting in houses should be regarded as an important aspect of interior decoration, as well as supplying lighting on a purely functional basis. In living rooms and bedrooms, wall-mounted fittings can be used, controlled by multi-point switches at the entrance doors. Thought should be given to the provision of 13A socket-outlets for supplying table and standard lamps. The use of local lighting over working surfaces in kitchens is an aspect of good planning. External lighting should not be overlooked, either to light up the front and back doors or to light the way to outhouses such as detached garages, coal stores and greenhouses. In very large houses, driveway lighting may have to be considered.

To facilitate the interchange of fittings and appliances throughout the house, it is recommended that 13A three-pin socket-outlets to BS 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched socket-outlets should be used. Because the past few years have seen a rapid increase in the use of electrical appliances, it is essential that an ample number of socket-outlets be provided, and situated wherever there might arise the need for an electrical outlet.

The average house should have an adequate number of socket-outlets. In the living room, there should be a two-gang socket outlet on each side of the fireplace. Additional socket-outlets should be located less than 2 m from the opposite corners of the room, where they are least likely to be hidden by furniture. In bedrooms, at least a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage (e.g. to supply a bedside lamp and an electric blanket). Additionally, there should be socket-outlets for dressing-table lamps, a heating appliance or a portable television set.

The kitchen probably places the greatest demand on the electrical service. Outlets are required for such varied appliances as washing machines, refrigerators, waste-disposal units, food mixers, can-openers, flat irons, coffee percolators and toasters. As far as possible, the outlets should be located above working surfaces and two-gang units are recommended.

In the dining room, small plate-warmers may be required. In halls and on landings the outlet is generally used for a vacuum cleaner or floor polisher, and perhaps a hail heater. No

provision is made for the use of portable appliances in a room containing a fixed bath or shower. However, an electric shaver unit to BS 3052 may be installed out of reach of a person in the bath or shower. Additionally, a bathroom heater (of the enclosed-element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

2.4.2 Circuits rated under 16A

A final circuit rated at not more than 16A may feed an unlimited number of points provided that the total 'current demand' does not exceed 16A. They include 15, 13, 5 and 2A socket-outlets, lighting outlets, stationary appliances and certain loads which may be neglected because their current demand is negligible (e.g. clocks, bell-transformers, electric shaver supply units), provided that their rating is not greater than 5VA. No diversity is allowed on final circuits. The current rating of the cable must not be exceeded. An important point to note is that if a cable size must be increased to avoid excessive voltage drop in the circuit, the rating of the fuse or circuit-breaker protecting the circuit must not be increased correspondingly. The same condition would apply if the ambient temperature of a cable were to be taken into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favorable circuit conditions, but to provide for the special conditions in which they are being installed. The lighting circuits of domestic installations are rated at 5A. Industrial lighting circuits are usually rated at 15/16A because of the higher wattage of the lamps used.

2.4.3 Circuits rated over 16A

With two exceptions, circuits rated at over 16A should not serve more than one point. The exceptions are circuits which feed 13A socket-outlets and cooker circuits. Final circuits for cooking appliances are assessed for current demand as follows:

The first IOA of the total rated current of the connected cooking appliances, plus 30% of the remainder of the total rated current of the connected cooking appliances, plus 5A, if the cooker control unit has a socket-outlet.

Thus, a cooker with a total load of 11kW at 240V (46A) would in fact be supplied by

cables rated to carry about 26A, depending on the distance the cooker is away from the distribution board. If a large cooker which exceeds 30A is to be installed in domestic premises, and where the protection is offered by fuses, a supply service of more than the normal 60A rating may be required. In this instance, the supply authority should be consulted. Water-heater circuits are terminated in a 20A double-pole isolating switch, fitted with an earthing terminal and a neon pilot lamp.

2.4.4 Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and 13A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maximum floor area of 100 m^2 derived from a 30A protective device. Radial circuits serving a maximum area of 50 m^2 are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

- Each socket-outlet of a two-gang or multiple socket-outlet is to be counted as one socketoutlet.
- Stationary appliances, permanently connected to a radial or ring circuit, must be protected by afuse not exceeding 13A rating and controlled by a switch or a circuit-breaker.
- It is important to realize that the conductor sizes recommended tor ring circuits are minima. They must be increased if necessary where circuits arc installed in groups, or in conditions of high ambient temperature, taking into consideration the class of excess-current protection provided.
- The method of properly connecting circuit conductors of a ring circuit involves correct polarity and security of the terminals.
- Except where a ring circuit is run throughout in metallic conduit, ducts or trunking, the CPC shall be run in the form of a ring, having both ends connected to earth at the distribution hoard (or its equivalent).

- The total number of spurs shall not exceed the total number of socket-outlets and stationary appliances connected directly to the ring.
- Fused spurs from ring circuits must be connected through fused spur boxes, and the rating of the fuse must not exceed the current rating of the cable forming the spur. and in any event must not exceed 13A.
- One socket-outlet or one two-gang socket-outlet unit, or one stationary appliance fed from a connection unit, can be connected to each non-fused spur.

2.4.5 Circuits feeding discharge lamps

One of the main requirements is a consideration of the rating' of a discharge lamp outlet. tor it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge lighting. If a switch is not specifically designed to break an inductive load (quick-make. slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

2.4.6 Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular. cables which carry the starting, accelerating and load currents of a motor must be rated at least to the full-load current rating of the motor. If. however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor takes more than 16A full-load current, it should be fed from its own final circuit.

2.4.7 Final-circuit protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short-circuits between conductors, between conductors and earth, or overloads. The protective gear should he capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit-breaker. Thus, if a fault occurs on a final circuit, the associated gear will conic into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally. where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers. Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

2.4.8 Choosing cable sizes

The selection of the size of a cable to carry a load current involves the consideration of the rating and type of the protective device, the ambient temperature and whether other cables are run alongside the cable (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrent are carried due to overloading and when a short-circuit occurs. Others include the increase in temperature when a number of current carrying cables are bunched together, for instance in conduit and trunking, which is a situation in which each cable contributes its heat to that of others and which, because of the enclosed situation, produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a possible source of fire. At about 80 ^{0}C, PVC becomes very soft, so that a conductor can migrate' or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with an increase in the leakage current which could prove fatal if the installation earthing arrangement is faulty. Eventually, when the insulation breaks down completely, a short-circuit occurs and the circuit is now dependent on the ability of the, over-current protection device to operate to disconnect the circuit from its supply. As is probably realized the time of operation of the protective device is crucial: a semi-enclosed fuse will take longer to operate than would a miniature circuit-breaker. In some circumstances, particularly where PVC insulated cables are used, the time taken by a semi-enclosed fuse to operate may be long enough for the cables to burn out and create a fire hazard.

Another problem which has occurred in recent years concerns the use of thermal insulation in buildings. with cables being installed in conditions where the natural heat produced by even their normal load currents cannot be dissipated easily. The IEE Regulations recognize the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation, each of which is identified by 'Methods'. These classifications are used in the tables, which give the current-carrying capacities of cables. The installation conditions include 'enclosed' (e.g. in conduit. trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray. embedded direct in plaster that is not thermally insulating, and suspended from a

catenary wire): 'defined conditions', which include cables in free air: and cables 'in enclosed trenches'.

From this, it can be seen and appreciated that the selection of a cable to feed a circuit is now required to he undertaken with a number of factors to he considered carefully. Situations which were formerly taken for granted must now be investigated so that the cable is installed in the best conditions which will allow the cable to carry its load current with the safety of the user of the installation in mind.

The IEE Regulations require that the choice of a cable for a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

- the ambient temperature in which the cable is installed;
- the installation condition, e.g. whether grouped or bunched with other current – carrying cables, enclosed or installed 'open';
- whether the cable is surrounded by or in contact with thermal insulating material;
- whether the circuit is protected by semi-enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. All factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every bare conductor or cable conductor shall be such that the drop in voltage from the origin of the installation to any point in that installation does not exceed 4% of the nominal voltage when the conductors are carrying the full load current. The conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

The following process for working out the correct size of cables is as follows:

- First find the load current of the circuit ('B).
- Determine the correction factor for the ambient temperature which of course does not include the heat generated in the cable itself, but is more concerned with the maximum temperature of the medium through which the cable runs.
- Determine the correction factor for grouping. Here we refer to Table 4B1 of the Regulations (Appendix 4).
- Determine the correction factor if the cable is in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.
- Select the rating of the overcurrent device. If this is offering what used to be called 'close' protection, the correction factor is 1. If, however, protection is by means of a semi-enclosed fuse, the factor is 0.725. The rating of the device must at least equal the load current.
- Determine the size of the circuit conductor by calculating its current rating.
- Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

Table 2.1 PVC isolated, sheathed, copper cables

Nominal cable size	Single Phase		Three Phase	
mm^2	Current A	Voltage Drop,mV	Current	Voltage Drop
1.0	11	40	9	35
1.5	13	27	12	23
2.5	18	16	16	14
4	24	10	22	8.8
6	**30**	**6.8**	**27**	**5.9**

We choose our cables for our installation with taking reference from Table 2.1

2.5 Overcurrent protection

IEE Regulation 13-7 states that, where necessary to prevent danger every installation and every circuit 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 rating of the circuit

(ii) Are of adequate breaking capacity

(iii) Are suitably located .and permit ready restoration of the supply without danger'.

Overloading occurs when extra power is taken from the supply system. The increased loading results with the addition of low resistance being connected in parallel with the existing load in a circuit. The decrease in the overall resistance of the circuit produces a proportional rise in the amount of current flowing in the circuit conductors. The increased current will have an immediate effect on the cables: they will begin to heat up. If the overload is sustained the result could be an accelerated deterioration of the cable insulation and its eventual breakdown to cause an electrical fault and perhaps fire.

A heavy sudden overload is not so serious since the overload current flows for a short time (e.g. motor starting), and the rise in cable temperature is neither rapid nor steep. However, this current must flow for a very brief period. Certain types of cable (e.g. paper-

insulated and mineral-insulated) can withstand cyclic overloading. In certain circumstances, a sudden heavy overload may in fact approach the characteristic of a short-circuit.

A short-circuit is a direct contact or connection between a phase conductor and (a) a neutral or return conductor, or (b) earthed metalwork, the contact usually being the result of an accident. The result of a short-circuit is to present a conducting path of extremely low resistance which will allow the passage of a current of hundreds or thousands of amperes. If the faulty circuit has no over-current protection, the cables will heat up rapidly and melt; equipment would also suffer severe damage and fire is often the result.

The form which protection against overcurrent takes is either a fuse or a circuit breaker. Each has characteristics that offer the protected circuit a degree of protection according to circuit conditions.

2.6 The fuse

The fuse was the earliest means used to protect against overcurrent in conductors. The fuse consists of a short length of suitable material, often in the form of a wire which has a very small cross-sectional area. When a current flows, which is greater than the current rating of the wire, the wire, will get hot. This happens because its resistance per unit length is greater than its associated circuit conductors (so giving greater power loss and heat) and because this increased heat is concentrated in the smaller volume of the material. The size of the wire is designed to carry indefinitely the normal circuit current.

There are three general types of fuse:

- Rewirable;
- Cartridge;
- HRC (high-rupturing capacity), which is a development of the cartridge fuse.

The HRC fuse was introduced in the 1930s. The modern type consists of a barrel of high-grade ceramic able to withstand the shock conditions, which occur when a heavy fault

current is interrupted. The end caps and fixing tags are suitably plated to give a good electrical contact. The fixing tags are also planished to ensure satisfactory alignment between contact-making surfaces. Except for very low ratings, the fuse-element is of pure silver wire or tape with a waist at its centre designed to give the required operational characteristic. The filler within the barrel is powdered silica, carefully dried before use. When used, the filler is compacted in the barrels by mechanical vibration to ensure complete filling. An indicator is sometimes provided to show when the fuse has blown. This consists of a glass bead held in position in a recess in the external barrel wall by a fine resistance wire, connected in parallel with the fuse-element. The barrels are accurately ground and the caps are a force-fit. Correct grades of solder are used for the element and tag fixings. The larger types of multi-element fuses have the elements welded in addition to soldering.

The short-time characteristics of the HRC fuse enable it to take care of short-circuits conditions in the protection of 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). HRC fuses are often used in motor circuits for 'back-up' protection for the machines. Motors are normally protected against damage by overload by thermal magnetic devices in the motor starter~ the fuses are required only to give protection against short-circuit currents and severe overloads outside the capacity of the starter protective devices. For instance, modern squirrel-cage induction motors can take up to ten times normal full-load current when stalled. The rating of a fuse link for a motor circuit should be that of the smallest current that will withstand the starting current while providing at the same time the necessary margin of safety.

2.7 The circuit breaker

The circuit breaker is a mechanical device for making and breaking a circuit, both under normal and abnormal conditions, such as those of a short-circuit, the circuit being broken automatically. The circuit breaker differs from the switch. Whereas the switch is capable of making and breaking a current not greatly in excess of its normal rated current,

the circuit breaker is capable of disconnecting automatically a faulty circuit, even in short-circuit conditions. A circuit breaker is selected for a particular duty, taking the following into consideration:

(a) The normal current it will have to carry

(b) The amount of current, which the supply system will feed into the circuit fault, which current the circuit breaker will have to interrupt without damage to itself.

Because the circuit-breaker is a protective device, its basic function is *(a)* to permit the installation or appliance it protects to be used up to its full rated capacity, and *(b)* to detect, and to protect equipment against dangerous conditions. Circuit-breakers are also able to provide a closer and more accurate degree of excess-current protection than that normally provided by either semi-enclosed or cartridge fuses. Circuit-breakers also perform duties as local circuit-control switches and as fault-making isolation switches. These latter types are switches capable of making and breaking rated current, and also of being closed against existing short-circuit fault.

The circuit-breaker has a mechanism which, when it is 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 or thermal means.

The circuit breaker with magnetic tripping (the term used to indicate the opening of the circuit-breaker contacts) employs a solenoid, which is a coil with an iron slug. The normal circuit current which flows through the coil is not sufficiently strong to produce a significant magnetic flux. As soon as the circuit current increases to a predetermined level, the magnetic field strength increases to cause the iron slug to move within the solenoid and collapse the attached tripping linkage to open the contacts.

Thermal tripping uses a heat-sensitive bimetal element. When the element is heated to a predetermined temperature, the resultant deflection is arranged to trip the circuit-breaker. The time taken to heat the element to this temperature provides the necessary time-delay characteristic. The bimetal element may be arranged to carry the circuit current and so be directly self-heated. Indirect heating of the element may also be used. Because of the time

lag associated with heating, tripping by this means is not so rapid as with magnetic tripping. In the circuit condition when a small-sustained overload occurs, the thermal trip will come into operation after a few seconds or even minutes. However, when a heavier overload occurs, the magnetic trip coil operates quickly to disconnect the faulty circuit.

Circuit breakers are used instead of fuses in many installations 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. The over-current 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 is avoided 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 of time. Circuit-breaker contacts separate either in air or under insulating oil .

The miniature circuit breaker (MCB) has found an increasing application in domestic and small industrial installations. It is used as an alternative to the fuse and has certain advantages: it can be reset or reclosed easily while the fault is present in the circuit; it gives a close degree of excess-current protection (the tripping factor is 1. 1); it will trip on a small sustained overcurrent, but not on a harmless transient overcurrent such as a switching surge (e.g. on fluorescent lamp circuits). For most 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 HRC or rewirable fuses. MCBs are available in distribution units for final circuit protection. In my design, I used MCBs.

2.8 Switchgear

Though 'switchgear' can range from small switches for domestic and small industrial installations to large outdoor 275kV units, the following deals with the type of gear associated with medium-size industrial installations. Generally, the switchgear is of one of

two main types:

1. Truck type, in which the circuit breaker (oil or air-break) is mounted on a truck, which can be withdrawn to the front of the switchboard of which the unit is a part. With this type of gear, sufficient space must be allowed for the withdrawal of the truck.

2. Metal clad, in which all parts are enclosed in metal cases, and the units are factory built. The bus bars for high voltages are either oil-or compound-insulated in special chambers. Disconnection of the circuit breaker from the bus bars is made by withdrawing downwards or outwards.

In the truck-type gear, the circuit-breaker and associated current- and voltage-transformers (for the indicating instruments) are mounted in a with-draw able framework or truck. Thus, maintenance can be readily carried out on the circuit breaker. The fixed portion of the unit contains the live bus bars and feeder cable box. The spout apertures within the Unit, into which the circuit-breaker spout contact is inserted when in service, are fitted with automatic drop shutters which close off the spout apertures when the circuit-breaker is lowered and the truck withdrawn. When the truck is replaced in the unit housing and raised, these shutters open to allow the breaker spout contacts to make contact with the live bus bars of the switchboard. To ensure that the circuit cannot be interrupted on the isolating spouts by withdrawing the truck before the circuit-breaker is opened, an interlock is provided which effectively locks the truck in the closed position until the circuit-breaker is tripped.A switchgear is the ease of examining the circuit-breaker contacts. When the breaker carriage is withdrawn, the switch unit can be lowered mechanically to the floor,' the tank bolts removed and the switch unit raised again leaving the oil-filled tank on the floor and the switch contacts open to inspection. This type of gear is usually found on systems up to 11kv. In the oil-filled circuit breaker, the contacts separate under oil. The oil in this instance acts to quench the arc, which is drawn out between the separating contacts when the circuit breaker trips when there is current flowing in the circuit. Air-break circuit breakers have arc-chutes and coolers to help dissipate the arc and its gas products.

2.9 Water heating

Electric water heating is very efficient because the heating element is entirely immersed in the water to be heated. The greatest proportion of electric water heating is represented by immersion heaters, most of which are fitted in storage cylinders or tanks which sometimes have complementary means of heating. There are two types of immersion heater. The withdraw able type is a heater so constructed that the heating element can be withdrawn from the enclosing sheath without breaking water joint. The non-withdraw able type is a heater so constructed that the heating element cannot be removed without breaking water joint. As for the storage vessels, there are four general types in use:

2.9.1 The Non-pressure or Open-outlet.

This has a capacity of from *56* to 450 liters, with an immersion heater of rating in the region of 14kW. This type is controlled by a stop valve fitted on the water-inlet pipe and is usually fed directly from a water main or, alternatively, from a cistern. A non-return valve is usually fitted in the inlet pipe. The heating element and the associated thermostat are located in the bottom of the container. For domestic purposes, this type of heater has a capacity of about 12 liters and is most often used to provide hot water in an instant for washing-up duties. The type is also used in cloakrooms where there is an intermittent demand for hot water for hygiene. The tank is insulated against heat losses by a lagging of fiberglass or granulated cork. When the inlet valve is opened, the incoming cold water pushes the less-dense hot water into the outlet pipe.

2.9.2 The Pressure.

Water heaters of this type are connected to a cistern. Capacities range from 15 to 370 liters. The heater ratings are 1kW and above. In domestic installations, the usual rating is a 3kW heater in a 100-litre tank. The water supplied from the mains to the cistern is controlled by a float-ball valve. Hot-water outlets are fed under pressure supplied by the head (vertical height) of the cold water available.

2.9.3 The Cistern.

This type incorporates a feed tank with ball-valve, arranged for direct connection to the water main. A connection for an overflow pipe is also provided, for which any special requirements of the local water-supply undertaking should be observed. They must always be installed above the level of the highest hot-water tap in the house. The feed pipe, draw-off and vent pipes are all inside the heater unit. Capacities range from 15 to 100 liters; heater ratings are between 1 and 3kw.

2.9.4 The Dual-heater

This is a special development of the pressure-type of heater. The unit of 60 or 100 liters capacity is designed primarily for installation under the draining board next to the kitchen sink. This position is taken because the kitchen tap is the most frequently used hot-water outlet in a dwelling. The unit is usually also coupled to the bathroom hot-water taps. The unit is provided with two heaters, each controlled by a thermostat. One heater, located near the top of the tank, is of low rating (usually 0.5kw). It provides sufficient hot water for ordinary domestic purposes. The main heater, of a higher rating (2.5kw) is placed near the bottom of the tank and can be switched on manually before a bath is required. The complete unit, as manufactured, comprises a thermally insulated cylinder, electric-heating elements, thermostats and pipe connections. The unit of 100-litre capacity is often designed to be coupled to, and to operate in conjunction with, a fuel-fired domestic water-heater.

There are two basic types of thermostat for the control of domestic hot-water systems: the long, thin-stemmed type (usually known as the rod thermostat) and the short-stem type. The rod-type thermostat operates on the principle of differential expansion between 'invar' and copper, and usually takes the form of an invar rod (which is the lower expansion material) housed within a copper tube, which has a higher coefficient of expansion. The lower end of the copper tube is brazed to the invar rod, while the upper end is brazed to a solid portion of the switch mechanism. The invar rod is thus free to move up and down, which it does with the contraction and expansion of the copper tube under the effects of varying temperature. These thermostats are made in 18, 22, and 44 cm lengths. The 22 and 44 cm lengths are most commonly used for the control of vertical domestic heaters. The 18

cm model is generally used for horizontal or side-entry heaters. The short-stem thermostat contains a snap-action switch similar to that used in the rod-type thermostat. However, operation of the switch is by means of a piece of bimetal which replaced the combination of invar rod and copper tube.

In most water-heating installations, the immersion-heater with its associated thermostat is installed in the conventional hot-water cylinder in such a way that both heater and thermostat hang vertically downwards. Horizontal mounting is also a less-common practice. With horizontal mounting, the heater lies horizontally across the cylinder, which means that it imparts maximum turbulence to the water above the heater. Thus, virtually all the water in the tank is heated to the temperature at which the thermostat is set, before the latter trips the circuit. With vertical mounting, the degree of turbulence in the cylinder is not so great, because the heated water tends to flow upwards along the elements of the heater. Consequently, when the thermostat switches off, there is a gradient between the top and bottom of the heater element of some 20 to 30°C.

2.10 Summary

In this chapter, we deal with the final circuits, wiring techniques, choosing the cable sizes, trunking systems, conduits. In addition, we chose the cables from Table 2.1 for our requirements. The electrical equipments and their installation rules which is referenced from IEE Wiring Regulations 16th Edition. This is the most important section for the installation engineers.

CHAPTER THREE
INSTALLING LIGHTING

3.1 Overview

In this chapter, you will find how we choose the true light in our design, how much power we need, what kind of lamp we should use, how we should fix the lamps in our area, and the formulas to make our design. In addition, you will see a brief explanation of some kinds of lamps that are using today: filament, fluorescent, mercury vapor, metal halide, neon. All these have specific advantages and applications. In these kinds of lamps, we will pay attention to the filament and fluorescent lamps.

3.2 Filament lamps

A filament made from tungsten and rose to about 2,500 ^{0}C to produce a light, which, though it looks white, actually has a lot of red in it. Various methods are used to produce an efficient light-emitting filament (coiled, coiled-coil, etc). The common filament lamps used today have a luminous efficacy of about 16 lm/W. Slightly higher outputs are available when the light bulb is filled with an inert gas such as argon. One problem with filament lamps is the tendency of the evaporation; the result of this process is seen in the blackening of the inside of the glass bulb. Another problem is the heat produced by the lamp. General filament lamps use much more energy than other types of lamp, such as the fluorescent.

The nominal life of a filament lamp is 1,000 hours. However, a number of factors influence this figure. For instance, a 240 V lamp operating at 250 V will reduce the life expectancy by 43 per cent. Frequent switching also tends to reduce the life of a lamp, as will vibration. Because of the relatively low life expectancy of a filament lamp, lamp replacement costs tend to be higher than those for, say, fluorescent lamps (7,500-10,000 hours burning).

The standard type of filament lamp is the GLS (general lighting service). Two cap fittings are available: BC (bayonet cap) and ES (Edison screw). The former type of fitting is used for lamps rated from 15 W to 150 W: above this size, the ES fitting is used. Incandescent lamps are used for many purposes and are available with many variations. 'Pearl' lamps have the glass bulb internally frosted. Other types have the glass bulb silica-

coated internally.

In my installation design, I used incandescent lamps and fluorescent tubes, which is in the discharge lamps category.

3.3 Discharge lamps

The most familiar type of discharge lamp is the fluorescent lamp. It consists of a glass tube filled with mercury vapor at a low pressure. The electrodes are located at the ends of the tube. When the lamp is switched on, an arc-discharge excites a barely visible radiation, the greater part of which consists of ultra-violet radiation. The interior wall of the tube is coated with a fluorescent powder, which transforms the ultra-violet rays into visible radiation or light. The type of light (that is. the color range) is determined by the composition of the fluorescent powder. For starting, the mercury vapor is mixed with a small quantity of argon gas. The light produced by the fluorescent lamp varies from 45 lm/W to 55 lm/W. The colors available from the fluorescent lamp include a near-daylight and a color-corrected light for use where colors (of wool, paints, etc.) must be seen correctly. The practical application of this type of lamp includes the lighting of shops, domestic premises, factories, streets, ships, in transportation vehicles (buses), tunnels and coalmines.

The nominal life of a fluorescent lamp is between 5,000 hours and 7,500 hours. With switched or switch less starting gear, the control gear losses generally amount to about 15 per cent of lamp watts. Thus, the circuit of an 80 W fluorescent lamp will take from the supply a total of 92W

3.4 Lamp summary

- Filament: 16 lm/W; 1,000 hours nominal burning; lamp caps: BC or ES; color: white with red content; types available: general lighting service (GLS); rough service (RS); fire glow (for fire-effect electric heaters); colored (for outside decorations); architectural (linear lamps used for mirrors, display cabinets, etc.); reflector lamps.
- Halogen: 25 lm/W; 2,000 hours nominal life; color: white with reddish content; wattages from 200 W to 2 kW; larger ratings used for floodlighting.

- Fluorescent: 75 lm/W; up to 10,000 hours nominal life; colors can include 'warm white', 'daylight' and 'north light' (used where color rendering is important, such as in textiles, painting, printing; cap: bi-pin).

3.5 Light Measurement

The amount of light falling on a surface is measured (in lumens per m^{2}; unit = lux) by an instrument called a photometer or light meter. It consists of a cell made from three layers of metal:

- A transparent film of gold;
- A film of selenium;
- A steel base plate.

A connecting ring makes contact with the transparent film. Another connection is taken from the steel plate. These connections are taken to a very sensitive moving-coil instrument, which has a scale graduated in lm/m^2. When rays of light fall on the surface of the cell between the gold and selenium films, electrons are freed, to cause a current to flow in the moving-coil of the meter movement. This current is approximately proportional to the amount of light falling on the cell. The instrument is used to check that the amount of light falling on working planes (tables, desks, benches) is sufficient for a particular job to be done with no strain on the eyes of the worker. The Illuminating Engineering Society publishes tables indicating the optimum amount of light required to perform various tasks in industry and in the home.

3.6 IEE Regulations Summary

If any circuit is used predominantly for discharge lighting, the neutral conductor must be of the same size as the phase conductor. Mineral-insulated cables should not be used for discharge lighting circuits unless surge arresters are used. The reason for this is that the inductive currents associated with such circuits produce high voltage surges, which could puncture the mineral insulation and earth the sheath. When ES lamp holders are used, the centre contact must always be connected to the phase conductor.

When bulkhead or well-glass luminaries are installed on the exterior wall of a building, they are regarded as being outside the equipotent zone (the earthing and bonding of all

metalwork in the building). Circuits supplying such luminaries must have a disconnection time of 0.4 second if an earth fault occurs. If the luminary is taken off from a circuit within the building, the disconnection time is also 0.4 second.

All insulated conductors taken into a bulkhead luminary must be sheathed with heat-resisting sleeving (this is because of the significant heat build-up inside the fitting).

When calculating the current taken by fluorescent luminaries, account must be taken of the fact that the associated circuits take more current than is indicated by the lamps' wattage, thus

$$I = (\text{Total wattage} \times 1.8) / \text{voltage}$$

According to this formula, we can calculate the current for our installation. As we will see, we used two fluorescent tubes with 40 W in the hall.

$$I = (80 \times 1.8) / 240 = 0.6 \text{ A.}$$

Where the factor of 1.8 includes such factors as the power factor of the circuit and the wattage loss in the choke (inductor).

Switches for fluorescent luminary circuits should be rated for inductive loads, if they are not, their rating must be reduced by a factor of 0.5.

3.7 Design Process

We will start to our design process from determination of the number of fittings and selection the type of lamp, which would be best, suited for the area.

In this illumination design, I used the following formulas:

- $N = E_{(s)} A_{(s)} / n F (LLF) UF_{(s)}$
- $R_1 = L W / H (L+W)$

$E_{(s)}$ = Average illuminance of the reference surface

$A_{(s)}$ = Area of the room surface

n = The number of tubes in a fitting

F = Total Flux of the tube

LLF = The light loss factor

$UF_{(s)}$ = The utilization factor of the surface area.

In calculations, I assumed to use LLF and $UF_{(s)}$ as one.

The light flux of the tube is 3000 lumens = 36 W Luminaries, 5800 lumens = 70 W.

In addition to, for average illuminance of hall, kitchen, and bedrooms I assumed this value as 350 lux.

As I assumed LLF and $UF_{(s)}$ as one, no need to calculate the room index.

Let us start to our calculations.

- **Kitchen**

$N= 350\ (6\times4.15\times2.4)\ /\ 1\times3000\times1\times1 = 2.9.$

From Table 3.1 we can choose, 2, 40-watt fluorescent lamps.

Table 3.1 The characteristics of some fluorescent lamps

The power of the lamp	Light Flux(lumen)
20	1200
40	3000
65	4900
18	1300

- **The Hall**

$N= 350\times\ (6\times4.95\times2.4)\ /\ 1\times5800\times1\times1= 4.30$

If we assume 70 W luminaries = 5800 lumens, instead of using 4 lamps with 70 W; I will use 1 lamp with 100 W.

- **The Toilet**

According to the Project Handbook of The Chamber of Electrical Engineering, I will use $E_{(s)}$ as 50 lux for toilet, stairs and corridors. Instead of 3000 lumens, I will use 300 lumens.

$N=50\times\ (2.5\times1\times2.4)\ /\ 1\times300\times1\times1=1$

We can use one incandescent lamp with 40 W.

- **The empty area in the first floor**

$N=350\times\ (6.75\times4.6\times2.4)\ /\ 1\times5800\times1\times1= 4.49$

With the conditions in the hall calculation, I will use one lamp with 100 W.

- **Bedroom 1**

N= N=350× (3×3.7×2.4) / 1×5800×1×1=1.60

We can use one incandescent lamp with 75 W

- **Bedroom 2**

N=350× (4.6×5.25×2.4) / 1×5800×1×1= 3.49

As in the hall calculation, I will use one 100 W incandescent lamp.

- **Bedroom 3**

N=350× (3.7×3.2×2.4) / 1×5800×1×1= 1.71

We can use one lamp with 75 W.

- **Bathroom**

N=350× (3.35×3.2 ×2.4) / 1×5800×1×1= 1.55

We can use one incandescent lamp with 75 W.

- **Balcony 1**

N=50× (6.2×1.55×2.4) / 1×1000×1×1= 1.15

This balcony is quite long so it is better to use two lamps with 40 W.

- **Balcony 2**

N=50× (3.3×3×2.4) / 1×1000×1×1= 1.18

In balcony 2, in the corridor, in the wind generator room and in the stairs I will use 40 W lamps.

3.8 Summary

The best lighting system provides the required amount and quality of light at the least cost, total installation and operating costs of the system must be considered when selecting a fixture type and lamp size. We chose the true lamps according to our necessity using the light formulas, IEE Regulations and TRNC electric standards. We saw a few kinds of lamps that are using today. We used in our design, two kinds of lamps: One of them is incandescent lamps, which are available to use for many purposes, and fluorescent lamps which are the most practical.

CHAPTER FOUR

WIND GENERATORS

4.1 Overview

The wind started to be important for human, since 1800s. Nowadays, we benefit from wind for producing electric in our roofs. The aim of this chapter to give some idea from techniques of installation a domestic usage wind generator and to explain briefly; why we prefer to design our home electric generator from wind rather than from sun.

4.2 Where does the wind come from?

Wind is the result of the heating and cooling of the earth by the sun. When we experience wind, we are feeling the movement of air from a region of high pressure to a region of low pressure. These pressure differences are a result of differing temperatures between one place and another.

Wind energy can be transformed into mechanical energy and electrical energy. It has been used for centuries as an energy source for sailing ships, pumping water and grinding grain. Wind pumps have been vital to the development of the livestock industry in the world. More recently wind has become an alternative source of electricity for remote sites not connected to the main electricity distribution grid.

Wind generators are used for battery charging, AC utility inertia, water or space heating and direct motor drive for water pumping. A typical system would have the wind generator on a tall tower (tilt-up, self-supporting, pipe or lattice), battery bank for storage, inverter to change DC to 120 volt AC. Depending on the type and size of inverter and wind system, the inverter can power all the loads, part of the loads or sell the surplus back to the utility company. Outputs will vary with wind speed, turbulence, blade diameter and generator size. An average wind speed of 8 mph or more is recommended for a battery charging system and 12 mph or more for a utility inertia system. Most wind generators will begin producing power at 7-10 mph and will reach full output at 25-30 mph. Air density will influence output. Hot temperatures or higher altitude lowers air density, which lowers power generated. Reduce expected output about 3% per 1000' above sea level. Wind generators are mounted at least 30' above nearby trees and buildings within a 300' radius. Tilt-up towers are nice because no climbing is needed. A wind generator, PV modules and Hydro electric unit can all be used to charge the same battery. The wind often blows on cloudy days when solar electric modules have low or no output.

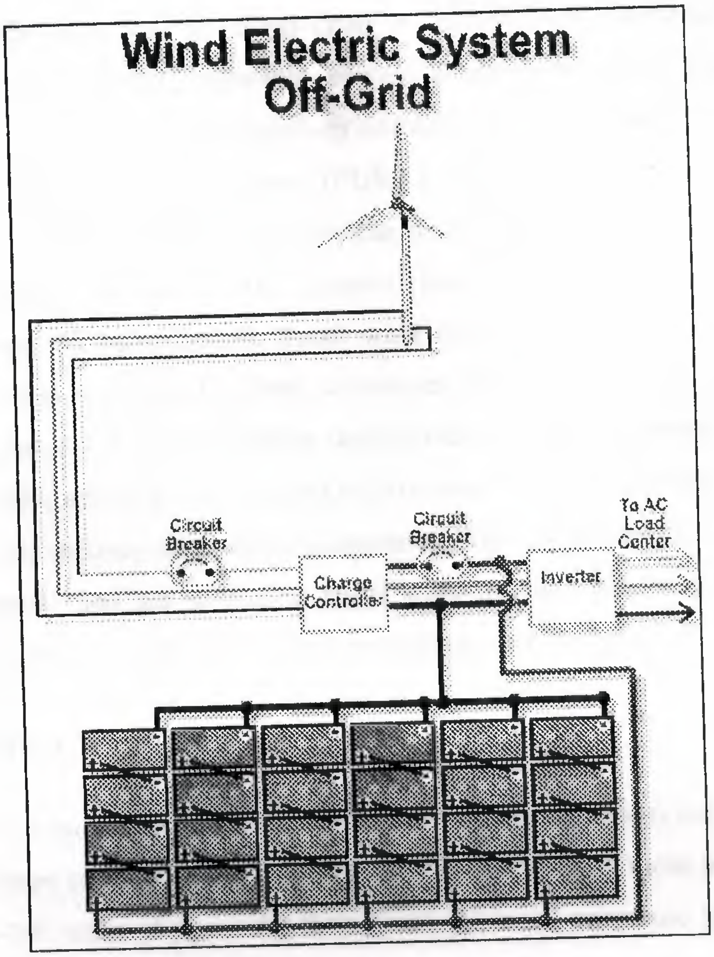


Figure 4.1 Wind Electric System

4.3 History

The wind has been an important source of energy in the U.S. for a long time. The mechanical windmill was one of the two "high-technology" inventions (the other was barbed wire) of the late 1800's that allowed us to develop much of our western frontier. Over 8 million mechanical windmills have been installed in the U.S. since the 1860's and some of these units have been in operation for more than a hundred years. Back in the 1920's and 1930's, before the REA began subsidizing rural electric coops and electric lines, farm families throughout the Midwest used 200-3,000 watt wind generators to power lights, radios, and kitchen appliances. The modest wind industry that had built up by the 1930's was literally driven out of business by government policies favoring the construction of utility lines and fossil fuel power plants. In the late 1970's and early 1980's intense interest was once again focused on wind energy as a possible solution to the energy crisis. As homeowners and farmers looked to various electricity producing renewable energy alternatives, small wind turbines emerged as the most cost effective technology capable of reducing their utility bills. Tax credits and favorable federal regulations (PURPA) made it possible for over 4,500 small, 1-25 kW, utility-intertied wind systems to be installed at individual homes between 1976-1985. Another 1,000 systems were installed in various remote applications during the same period. Small wind turbines were installed in all fifty States. None of the small wind turbine companies, however, were owned by large companies committed to long term market development, so when the federal tax credits expired in late 1985, and oil prices dropped to $10 a barrel two months later, most of the small wind turbine industry once again disappeared. The companies that survived this "market adjustment" and are producing small wind turbines today are those whose machines were the most reliable and whose reputations were the best.

4.4 The Cost Factor

Photovoltaic is an attractive technology in many ways, but cost is not one of them. Small wind turbines can be an attractive alternative, or addition, to those people needing more than 100-200 watts of power for their home, business, or remote facility. Unlike PV's, which stay at basically the same cost per watt independent of array size, wind turbines get less expensive with increasing system size. At the 50 watt size level, for example, a small wind turbine would cost about $8.00/watt compared to approximately $6.00/watt for a PV module. This is why, all things being equal, PV is less expensive for very small loads. As the system size gets larger, however, this "rule-of-thumb" reverses itself. At 300 watts the wind turbine costs are down to $2.50/watt ($1.50/watt in the case of the Southwest Wind power Air 403), while the PV costs are still at $6.00/watt. For a 1,500 watt wind system the cost is down to $2.00/watt and at 10,000 watts the cost of a wind generator (excluding electronics) is down to $1.50/watt. The cost of regulators and controls is essentially the same for PV and wind. Somewhat surprisingly, the cost of towers for the wind turbines is about the same as the cost of equivalent PV racks and trackers. The cost of wiring is usually higher for PV systems because of the large number of connections.

For homeowners connected to the utility grid, small wind turbines are usually the best "next step" after all the conservation and efficiency improvements have been made. A typical home consumes between 800-2,000 kWh of electricity per month and a 4-10 kW wind turbine or PV system is about the right size to meet this demand. At this size wind turbines are much less expensive.

4.5 Reliability

In the past reliability was the "Achilles Heel" of small wind turbine products. Small turbines designed in the late 1970's had a well deserved reputation for not being very reliable. Today's products, however, are technically advanced over these earlier units and they are substantially more reliable. Small turbines are now available that can operate 5 years or more, even at harsh sites, without need for maintenance or inspections and 5-year warranties are available. The reliability and cost of operation of these units is equal to that of photovoltaic systems.

4.6 Wind Energy

Wind energy is a form of solar energy produced by uneven heating of the Earth' surface. Wind resources are best along coastlines, on hills, and in the northern states, but usable wind resources can be found in most areas. As a power source wind energy is less predictable than solar energy, but it is also typically available for more hours in a given day. Wind resources are influenced by terrain and other factors that make it much more site specific than solar energy. In hilly terrain, for example, you and your neighbor are likely to have the exact same solar resource. But you could have a much better wind resource than your neighbor because your property is on top of the hill or it has a better exposure to the prevailing wind direction. Conversely, if your property is in a gully or on the leeward side of the hill, your wind resource could be substantially lower. In this regard, wind energy must be considered more carefully than solar energy. Wind energy follows seasonal patterns that provide the best performance in the winter months and the lowest performance in the summer months. This is just the opposite of solar energy. For this reason wind and solar systems work well together in hybrid systems. These hybrid systems provide a more consistent year-round output than either wind-only or PV-only systems. One of the most active market segments for small wind turbine manufacturers is PV-only system owners who are expanding their system with wind energy.

4.7 Wind Turbines

Most wind turbines are horizontal-axis propeller type systems. Vertical-axis systems, such as the egg-beater like Darrieus and S-rotor type Savonius type systems, have proven to be more expensive. A horizontal-axis wind turbine consists of a rotor, a generator, a mainframe, and, usually, a tail. The rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator. The rotor usually consists of two or three blades. A three blade unit can be a little more efficient and will run smoother than a two blade rotor, but they also cost more. The blades are usually made from either wood or fiberglass because these materials have the needed combination of strength and flexibility (and they don't interfere with television signals!). The generator is usually specifically designed for the wind turbine. Permanent magnet alternators are popular because they eliminate the need for field windings. A low speed direct drive generator is an important feature because systems that use gearboxes or belts have generally not been reliable. The mainframe is the structural backbone of the wind turbine and it includes the "slip-rings" that connect the rotating (as it points itself into changing wind directions) wind turbine and the fixed tower wiring. The tail aligns the rotor into the wind and can be a part of the overspeed protection.

A wind turbine is a deceptively difficult product to develop and many of the early units were not very reliable. A PV module is inherently reliable because it has no moving parts and, in general, one PV module is as reliable as the next. A wind turbine, on the other hand, must have moving parts and the reliability of a specific machine is determined by the level of skill used in its engineering and design. In other words, there can be a big difference in reliability, ruggedness, and life expectancy from one brand to the next. This is a lesson that often seems to escape dealers and customers who are used to working with solar modules.

4.8 Towers

A wind turbine must have a chance at the wind to perform efficiently. Turbulence, which reduces performance and "works" the turbine harder than smooth air, is highest close to the ground and diminishes with height. Also, wind speed increases with height above the ground. As a general rule of thumb, you should install a wind turbine on a tower such that it is at least 30 ft above any obstacles within 300 ft. Smaller turbines typically go on shorter towers than larger turbines. A 250 watt turbine is often, for example, installed on a 30-50 ft tower, while a 10 kW turbine will usually need a tower of 80-120 ft. We do not recommend mounting wind turbines to small buildings that people live in because of the inherent problems of turbulence, noise, and vibration. The least expensive tower type is the guyed-lattice tower, such as those commonly used for ham radio antennas. Smaller guyed towers are sometimes constructed with tubular sections or pipe. Self-supporting towers, either lattice or tubular in construction, take up less room and are more attractive but they are also more expensive. Telephone poles can be used for smaller wind turbines. Towers, particularly guyed towers, can be hinged at their base and suitably equipped to allow them to be tilted up or down using a winch or vehicle. This allows all work to be done at ground level.

Some towers and turbines can be easily erected by the purchaser, while others are best left to trained professionals. Anti-fall devices, consisting of a wire with a latching runner, are available and are highly recommended for any tower that will be climbed. Aluminum towers should be avoided because they are prone to developing cracks. Towers are usually offered by wind turbine manufacturers and purchasing one from them is the best way to ensure proper compatibility.

4.9 Remote Systems Equipment

The balance-of-systems equipment used with a small wind turbine in a remote application is essentially the same as used with a PV system. Most wind turbines designed for battery charging come with a regulator to prevent overcharge. The regulator is specifically designed to work with that particular turbine. PV regulators are generally not suitable for use with a small wind turbine because they are not designed to handle the voltage and current variations found with turbines. The output from the regulator is typically tied into a DC source center, which also serves as the connection point for other DC sources, loads and the batteries. For a hybrid system the PV and wind systems are connected to the DC source center through separate regulators, but no special controls are generally required. For small wind turbines a general rule-of-thumb is that the AH capacity of the battery bank should be at least six times the maximum renewable charging current, including any PV elements. The wind industry has had good experience using battery banks that are smaller than those typically recommended for PV applications.

4.10 Being Your Own Utility Company

The federal PURPA regulations passed in 1978 allow you to interconnect a suitable renewable energy powered generator to your house or business to reduce your consumption of utility supplied electricity. This same law requires utilities to purchase any excess electricity production at a price (avoided cost) usually below the retail cost of electricity. In about a half-dozen states with "net energy billing options" small systems are allowed to run the meter backwards, so they get the full retail rate for excess production. Because of the high overhead costs to the utilities for keeping a few special hand-processed customer accounts, net energy billing is actually less expensive for them.

These systems do not use batteries. The output of the wind turbine is made compatible with utility power using either a line-commutated inverter or an induction generator. The output is then connected to the household breaker panel on a dedicated breaker, just like a large appliance. When the wind turbine is not operating, or it is not putting out as much electricity as the house needs, the additional electricity needed is supplied by the utility. Likewise, if the turbine puts out more power than the house needs, the excess is instantaneously "sold" to the utility. In effect, the utility act as a very big battery bank and the utility "sees" the wind turbine as a negative load. After over 200 million hours of interconnected operation we now know that small utility-interconnected wind turbines are safe, do not interfere with either utility or customer equipment, and do not need any special safety equipment to operate successfully.

Hundreds of homeowners around the country who installed 4-12 kW wind turbines during the go-go tax credit days in the early 1980's now have everything paid for and enjoy monthly electrical bills of $8-30, while their neighbors have bills in the range of

$100-200 per month. The problem, of course, is that these tax credits are long gone and without them, most homeowners will find the cost of a suitable wind generator prohibitively expensive. A 10 kW turbine (the most common size for homes), for example, will typically cost $28,000-35,000 installed. For those paying 12 cents/kilowatt-hour or more for electricity in an area with an average wind speed of 10 mph or more (DOE Class 2), and with an acre or more of property (the turbines are big), a residential wind turbine is certainly worth considering. Payback periods will generally fall in the range of 8-16 years and some wind turbines are designed to last thirty years or more.

4.11 Performance

The rated power for a wind turbine is not a good basis for comparing one product to the next. This is because manufacturers are free to pick the wind speed at which they rate their turbines. If the rated wind speeds are not the same then comparing the two products is very misleading. Fortunately, the American Wind Energy Association has adopted a standard method of rating energy production performance. Manufacturers who follow the AWEA standard will give information on the Annual Energy Output (AEO) at various annual average wind speeds. These AEO figures are like the EPA Estimated Gas Mileage for your car, they allow you to compare products fairly, but they don't tell you just what your actual performance will be ("Your Performance May Vary").

As a rule of thumb wind energy should be considered if your average wind speed is above 8 mph (most, but not all, Class 1 and all other Classes) for a remote application and 10 mph (Class 2 or better) for a utility- intertied application. If you live in an area that is not too hilly then the DOE wind resource map can be used to fairly accurately calculate the expected performance of a wind turbine at your site. In complex terrain a judgment on the site's exposure must be made to adjust the average wind speed used for this calculation. In most situations it is not necessary to monitor the wind speed with a recording anemometer prior to installing a small wind turbine. But in some situations it is worth spending $300-1,000 and waiting a year to perform a wind survey. Manufacturers and equipment dealers can help sort out these questions

4.12 Advantages and Disadvantages of Wind Generators

4.12.1 Advantages

- Wind is a renewable energy resource. Wind patterns provide strong, steady trade winds in specific areas throughout most of the year.
- Used as a "fuel," wind is free and non-polluting, producing no emissions or chemical wastes.
- Use of wind power as a source of electricity will help reduce the state's almost complete dependence on imported fossil fuels.
- Wind power can be used with battery storage or pumped hydro-energy storage systems to provide a steady flow of energy.
- Wind farms can be combined with agricultural activities such as cattle grazing.
- Wind power is a proven technology and has been used to generate electricity for many years.
- Equipment for wind machines is commercially available.

4.12.2 Disadvantages

- Wind machines must be located where strong, dependable winds are available most of the time.
- Because winds do not blow strongly enough to produce power all the time, energy from wind machines is considered "intermittent," that is, it comes and goes. Therefore, electricity from wind machines must have a back-up supply from another source.
- As wind power is "intermittent," utility companies can use it for only part of their total energy needs.
- Wind towers and turbine blades are subject to damage from high winds and lighting. Rotating parts which are located high off the ground can be difficult and expensive to repair.
- Electricity produced by wind power sometimes fluctuates in voltage and power factor, which can cause difficulties in linking its power to a utility system.

4.13 Solar Electric

There are two forms of energy that we can use them for houses from the sun. One is thermal energy and the other is electric energy. Each one of us experiences thermal energy from the sun. The sun's infrared heat helps warm the planet, our bodies and our homes. The sun's heat can even be concentrated to power steam turbines to generate electricity. Besides thermal, we can directly convert sunlight into electricity using solar cells.

Solar cells or photovoltaic (PV) cells have been around since the age of the transistor, and through the years, they have become much more efficient. They have the ability to turn sunlight directly into electricity using a semiconductor material of silicon. Most everyone has seen a PV cell. They are commonly found in calculators, watches and some portable radios. Similar PV is when attached to each other form solar modules that can power much larger devices or batteries. A number of these modules then can be tied together to produce enough electricity to adequately power residential homes.

4.14 The Advantages and Disadvantages of Solar Electric

4.14.1 Advantages

- Compared to nonrenewable energy such as coal, gas, oil and nuclear, solar electric is totally nonpolluting.
- There are no moving parts in a solar electric system.
- There virtually maintenance is free.
- PV's will last for decades.

4.14.2 Disadvantages

- The most important disadvantage is the installation equipments are very big. Most of the roofs are not big enough for the design. Because the solar cells can just produce 1.372 W power in $1 m^2$.
- The sun does not always shine. Climates vary globally and no matter where you live, solar is only part of the answer to a renewable energy solution.

- In most cases, solar electric is still more expensive than nonrenewable energy. The gap is narrowing though and energy shortages are becoming more commonplace.

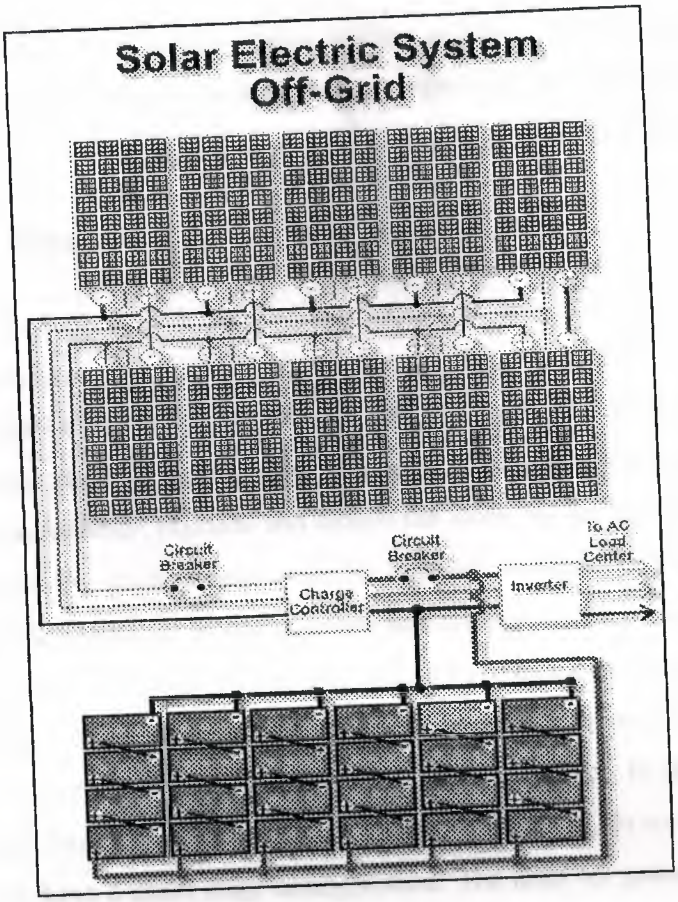


Figure 4.2 Solar Electric System

As we saw above when we pay attention to advantage and disadvantages, we can use wind generator in our project, because our house is quite small (10×11). The wind generator gives us 18 times bigger energy than solar cells.

4.15 Summary

We saw two popular renewable energy sources; wind and sun. When we pay attention to advantage and the disadvantages, which explained above, for a house that has a small roof, it is not a true idea to install the photovoltaic cells. So, we installed to our house a small wind generator that has a charger, inverter and a battery.

CHAPTER FIVE

PUMP BASICS

5.1 Overview

In this chapter, we will see the basics of the mechanism of the centrifugal pumps and their working. It mentioned the most famous types that used for domestic purposes. In addition, we will see the parameters that effect our choosing to the pump type.

5.2 Centrifugal Pumps

A centrifugal pump is of a very simple design. It only has one moving part, an impeller that attached to as haft and driven by the motor. The two main parts of the pump are the impeller and the diffuser. Impellers can be made of bronze, polycarbonate, cast iron, stainless steel as well as other materials. The diffuser (sometimes called a volute) houses the impeller, captures and directs the water off the impeller. Water enters the eye (center) of the impeller and exits the impeller via centrifugal force. As water leaves the eye of the impeller, a low-pressure area created, causing more water to flow into the eye. Atmospheric pressure and centrifugal force cause this to happen. Velocity developed as the water flows through the impeller while it spins at high speed. The water velocity collected by the diffuser and converted to pressure, by specially designed passageways that direct the flow to the discharge of the pump, or to the next impeller should the pump have a multi-stage configuration. The head (or pressure) that a pump will develop is in direct relationship to the impeller diameter, the number of impellers, the size of impeller eye, and shaft speed. Capacity is determined by the exit width of the impeller. All of these factors affect the horsepower size of the motor to be used. The more water to be pumped, the more energy is required. A centrifugal is not positive acting. The greater the depth to the water, the less the pump will pump. In addition, when it pumps against increasing pressure, the less it will pump. For these reasons, it is important to select a centrifugal pump that is designed to do a particular job. For higher pressure or greater lifts, two or more impellers are commonly used; or, a jet ejector is added to assist the impellers in raising pressure.

5.3 Choosing the water pump type

Before we install a new water system, we will need to do a complete assessment of our water usage, such as how many bathrooms our house has, how many spigots are in the yard, or is there any land that we may want to irrigate. All areas where we need water must be taken into account. A good contractor should be able to assess our needs and design a suitable water system

The first important step in planning a sufficient and economical water supply is to estimate the actual capacity required. It is a common mistake to under-estimate the real need. Dissatisfaction and higher cost usually occur because of "doing the job over". Proper planning can eliminate this. A general average for each member of a household, for all purposes, including kitchen, laundry, bath, and toilet (but not including yard fixtures), is 75 gallons per day per person. It is suggested that the total requirement of a 24-hour day be pumped in two (2) hours for two basic reasons:

- To take adequate care of the peak period demand such as several outlets on at one time, and
- To provide an economical pump selection. Added to the normal daily household requirement should be the demand required for any special requirement, such as sprinkling systems, livestock, etc.

In this project I assumed, five people would live in the house.

5 Family members @ 75 gpd = 375 gpd

- Gallons per day divided by 2 = Pump capacity.

375 divided by 2 = 187.5 Gallons per hour or 3.125 gallons per minute.

Using this situation as an example, we will need a pump capable of delivering 3.125 gallons per minute. A competent dealer should be able to recommend which one of the pumps will fit our needs. From Table 5.1 we chose our pump.

Table 5.1 Properties of Centrifugal water pump- series C

WATER PUMP TYPE	POWER		PERFORMANCE			
Single Phase	hp	KW	Capacity l/min	Head meters	inlet	Outlet
C 50	0.6	0.45	10-77	22-10	11/4’	1’
C 70	0.75	0.55	10-90	25-10	11/4’	1’
C 90	0.9	0.67	10-120	27-12	11/4’	1’
C 110	1	0.75	10-123	36-12	11/4’	1’
C 150	1.5	1.1	10-140	38-13	11/4’	1’
C 200	2	1.5	10-150	40-14	11/4’	1’

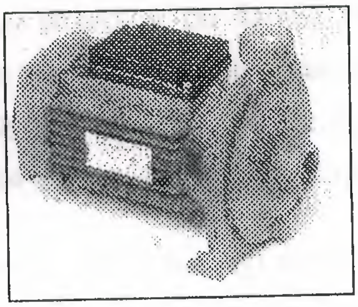


Figure 5.1 Centrifugal Water Pump(C 90)

The current rating of cables feeding a motor should be based on the full-load current taken by the motor. A conductor carries a current

Maximum permissible voltage drop = 4 % of 240 V = 9.6 V.

If we assume the cables are to be single-core, with 85°C insulation. The ambient temperature is taken as 60 °C. Protection is by MCB.

The current of 1 HP motor is 6.7 A.

Rating of protective device (I_n) = 30 A

Current rating of conductor (I_z) $= \dfrac{I_n}{Correction\ \ factor\ \ for\ 60\ °C}\quad amps$

$Correction\ \ factor\ \ for\ 60\ °C = 0.67$

$\therefore I_z = \frac{30}{0.67} = 44.7\ A$

The required rating of conductor is 6 mm^2

The total volt drop is $\frac{VD/A/m = I_B \times length\ of\ run}{1000} = \frac{7.7 \times 6.7 \times 38}{1000} = 6.44$

Thus, the conductor size of 6 mm^2 is suitable for the load in the conditions specified.

In the first working of the water pump, it will use the current 6 times bigger than the normal current because of this reason we choose instead of 1 mm^2 cable 2.5 mm^2 cable.

5.4 Control gear

Small squirrel-cage motors, starting on light load, can be switched direct-on-line, but to comply with the IEE Regulations the starters are fitted with isolator, and overcurrent and under-voltage protection. On starting, the motor, if switched direct, takes a current of up to seven times its normal full load current, which decreases as full speed is reached. The supply authorities require that the magnitude and duration of these starting surges be limited and use is often made of special starting gear.

Starling equipment for wound-rotor (slip-ring) motors comprises two parts: a stator switch, which contains the protective devices, and a graded rotor resistance which is cut out as the motor speeds up.

- **Direct-on-line starting**. This can be a hand-operated switch, but more use is now being made of the push-button operated contactor starter. Figure 5.2 shows the circuit diagram of a simple contactor starter.

The start button, when pressed, completes the contactor circuit and closes the three-phase switch establishing the supply to the stator. The motor current passes through the overload coils and if the current becomes excessive, the overcurrent solenoid operates the trip coil and breaks the contactor circuit. Under voltage, protection is inherent, as failure of the supply causes the contactor, which is operated from the supply, to drop out. The stop-button is wired in series with the overload contacts to break the circuit. An isolating switch is mounted in, or near to, the starter so that the circuit can be isolated, and if necessary, this can be locked off for safety during motor maintenance.

If a hand-operated starter is used the overcurrent device actuates the mechanical linkage of the starter. In this case, the under voltage coil is energized from two of the supply terminals and actuates the mechanical linkage if the supply fails. However our installations are one phase we wanted to show the circuit diagram of a contactor starter for three phase circuit.

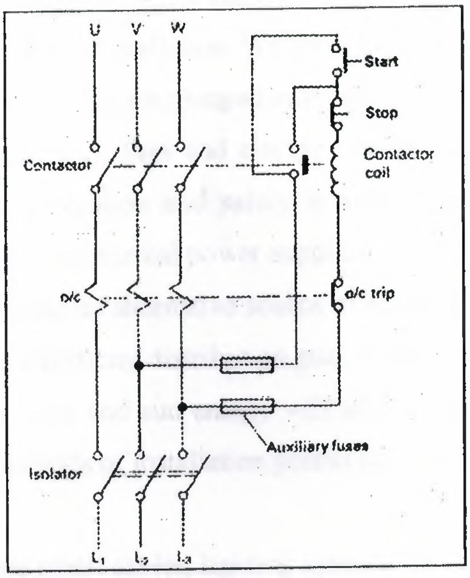


Figure 5.2 circuit diagram of a contactor starter

5.5 Summary

Centrifugal water pumps are ideal for domestic usage. It has a simple design. However, for every specific job we have to choose a special kind of pump. To decide what kind of pump we choose, our water usage needs to do a complete assessment of how many people will live in the house, how many bedrooms we have. We can calculate the pump capacity from how many gallons of water are using per day.

CONCLUSION

Electrical installations require some techniques and rules. Final circuits made up the greatest part of the electrical installation. We used two lighting circuits for one stair, when one circuit fails; the house is not plunged into darkness.

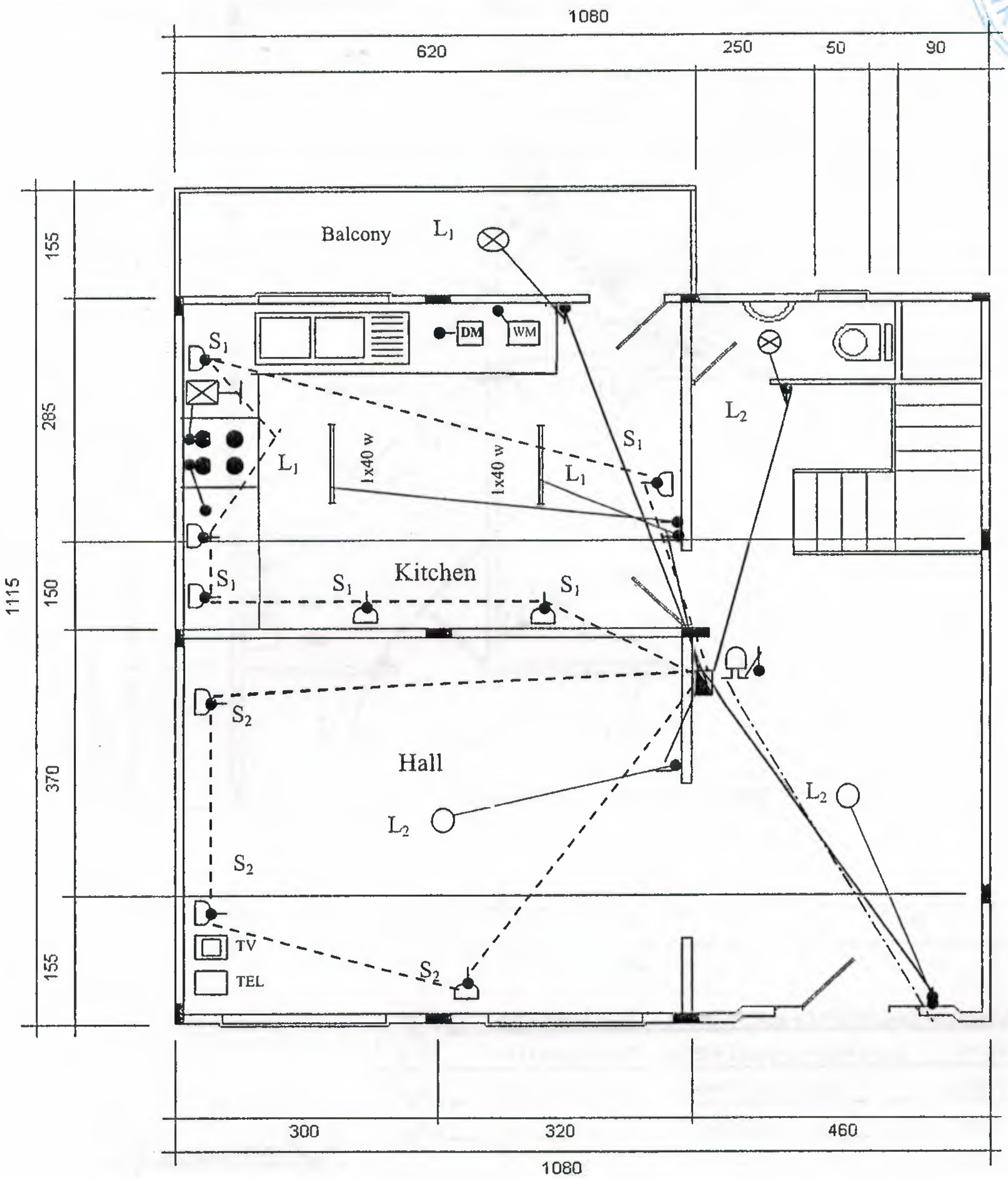
The hazards from electricity, fires and electric shocks are mostly the result of the bad electrical installation protection and safety is very important point in electrical installation and distribution of electrical power supplies.

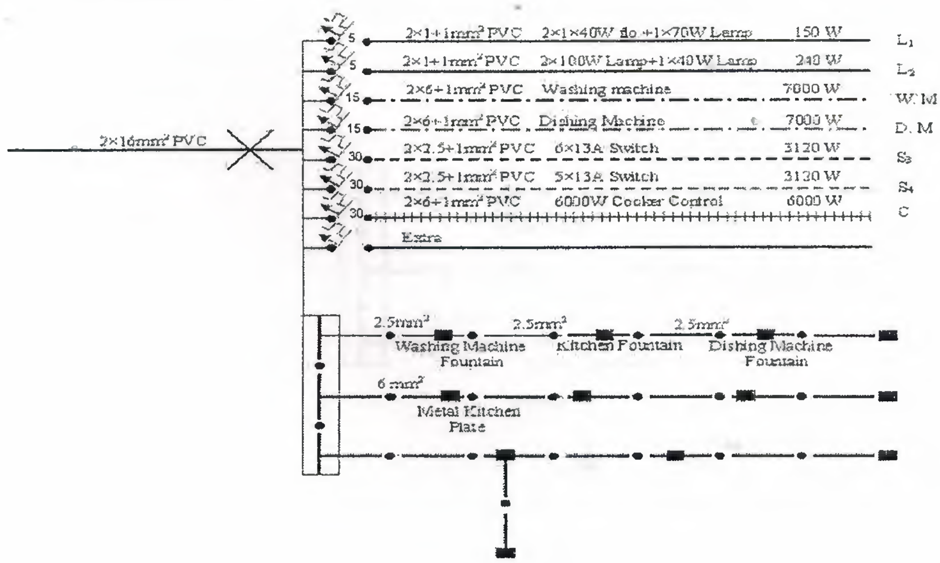
Wind energy has become an alternative source of electricity remote sides, which is not connected to the main electricity distribution grid. Photovoltaic cells need large area for installation. In future wind and sun energy will take much more effective place in our life. The developed methods of installation permit to reduce the hazardous effects of electricity.

In future, we may see smart cables, lighting systems and small electrical devices.

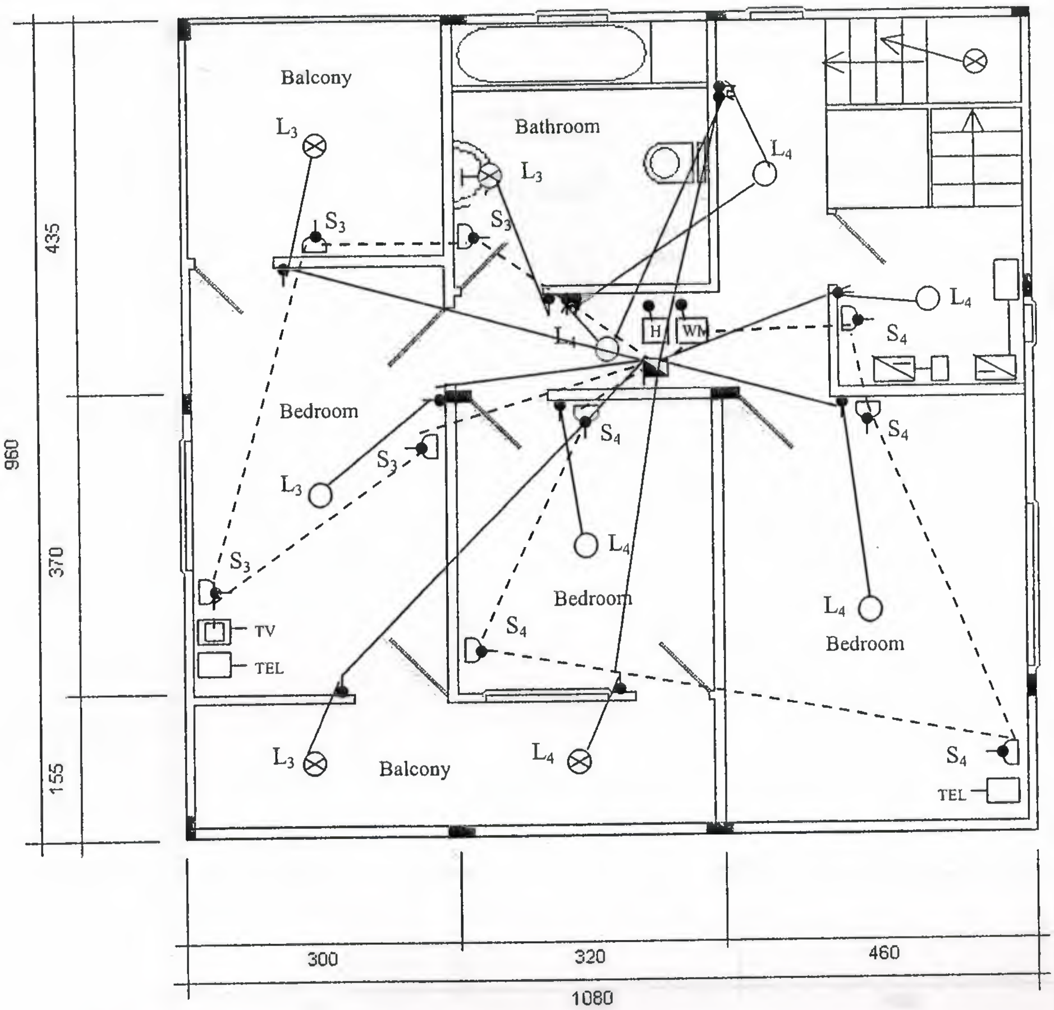
APPENDIX A

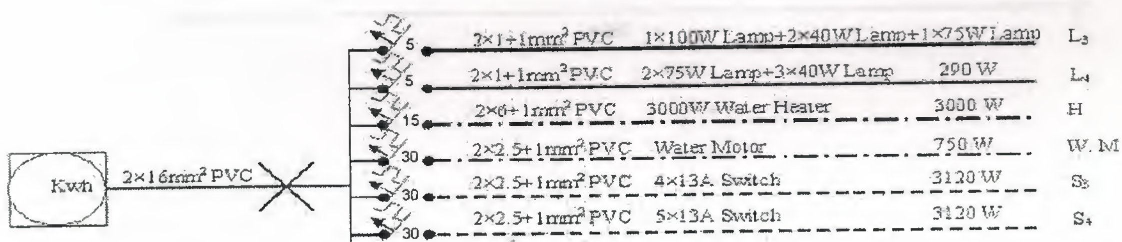
Electrical installation of the first floor

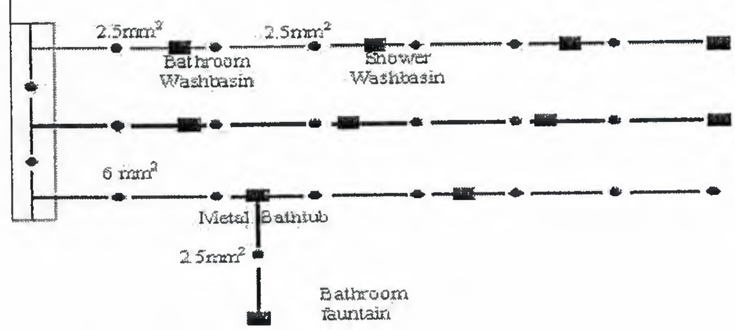




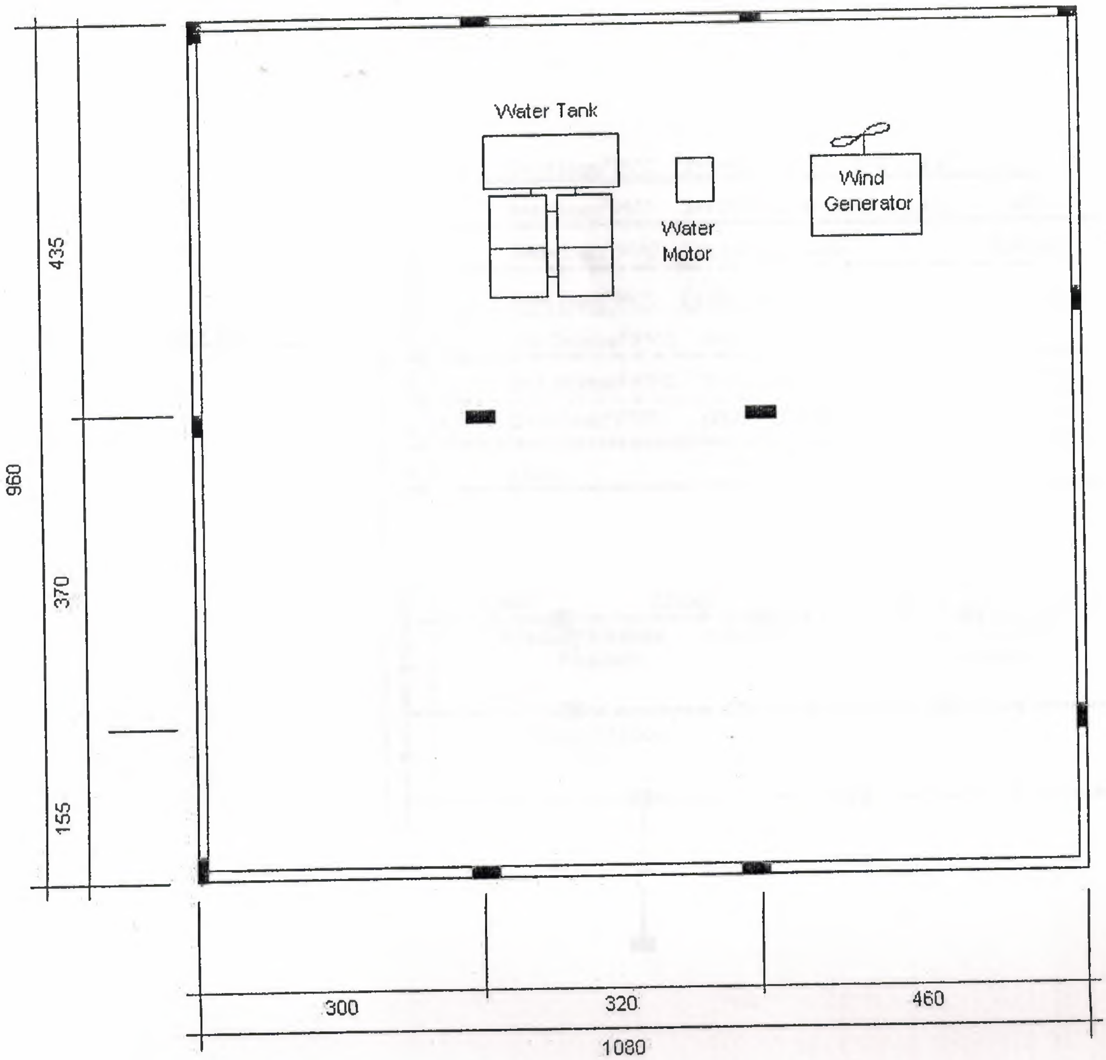
Electrical installation of the second floor



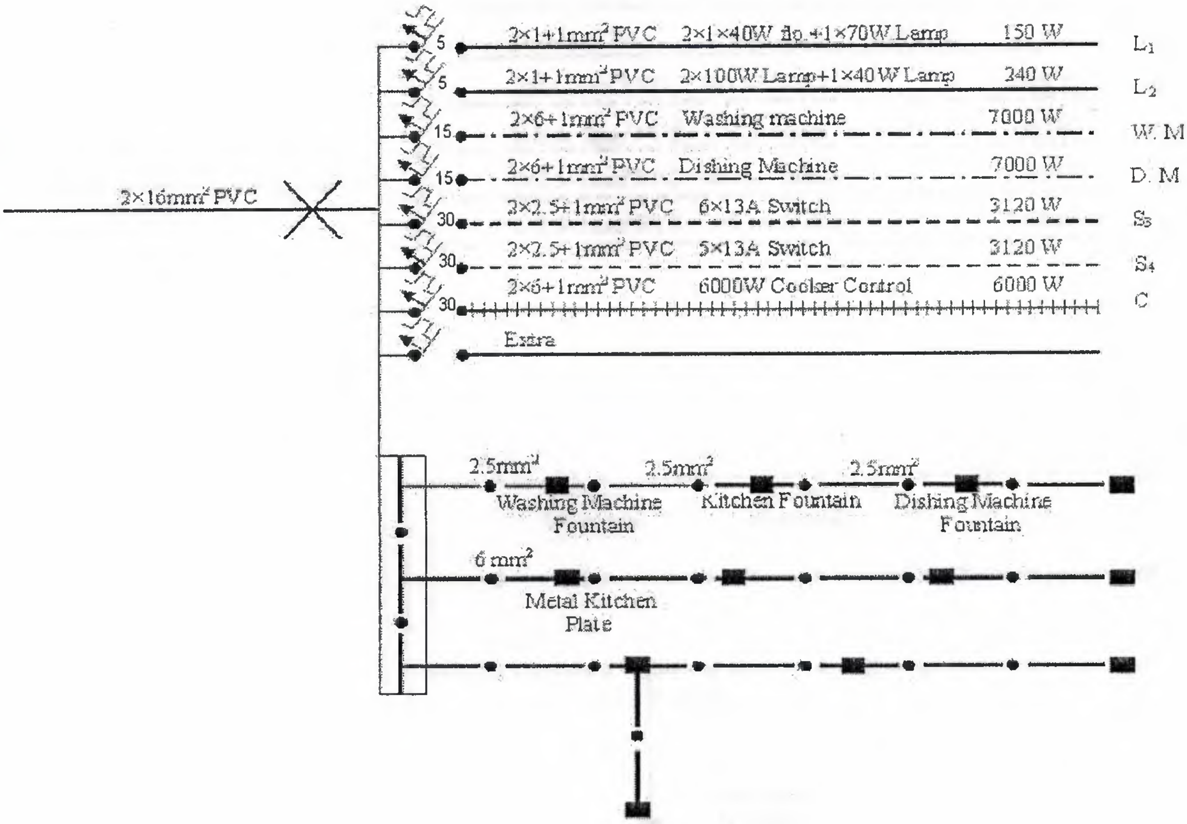




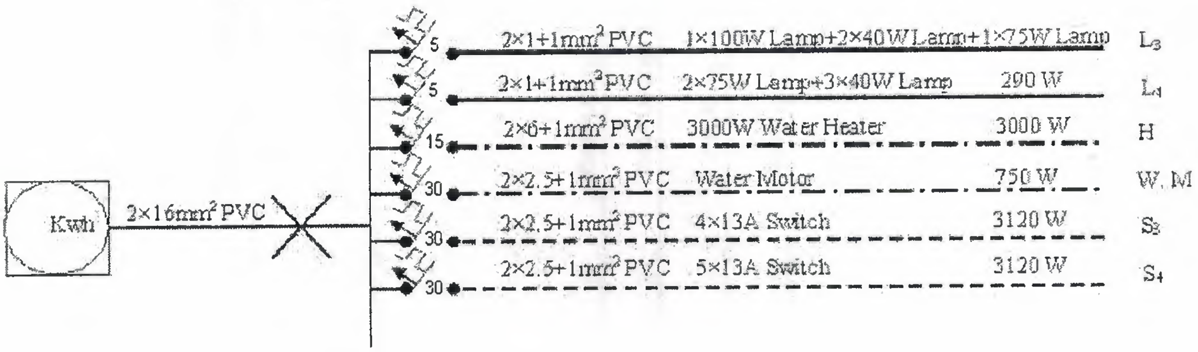
The Roof Plan

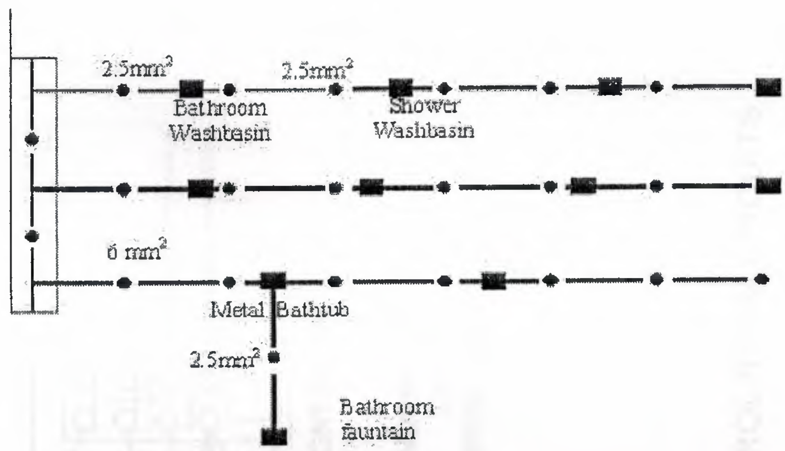


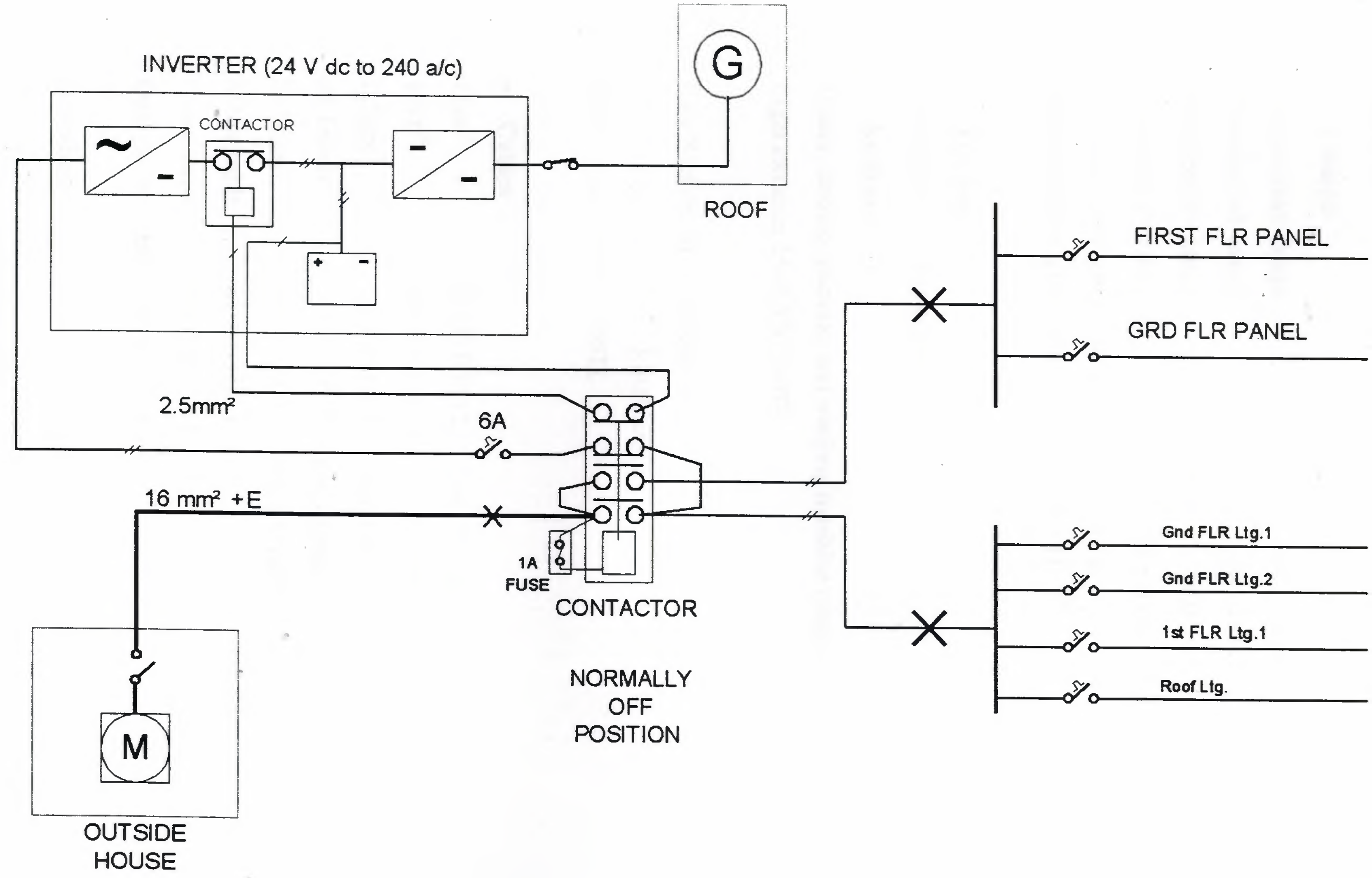
Grounding connections conductor of the first floor



Grounding connections conductor of the second floor







CONTROL ROOM CIRCUITS

APPENDIX B

Price List

- **Lamps**

Incandescent lamps	6× 40 W	2.400.000TL
Incandescent lamps	4×75 W	3.000.000TL
Incandescent lamps	3×100 W	2.100.000TL
Fluoresant Lamps 1×40	15.800.000TL+ 4.000.000TL	
Bathroom Glob glass – lamp	17.000.000 TL	
Garden balcony glass –lamp	10.000.000 TL	

- **The Bell**

19.000.000 TL+ 4.000.000TL

- **Switches**

Heater, dishing machine, and washing machine switches 3 ×8.500.000TL

Light switches 15×2.300.000TL

Plug Sockets 20×4.000.000TL

TV & Telphone socket 3.800.000TL

Motor price 160.000.000TL

- **Cables**

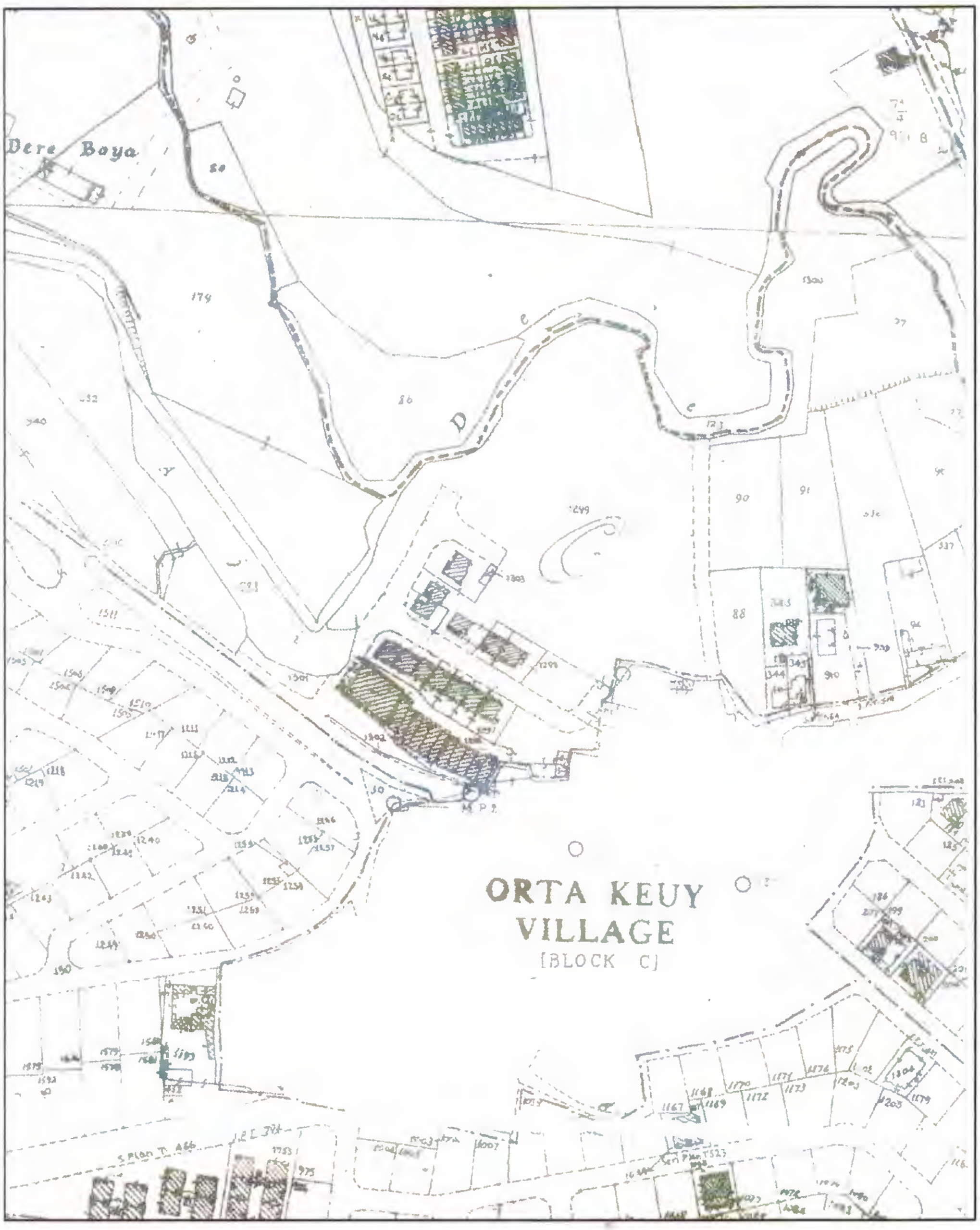
1mm^2	8.200.000 TL	per 100 meter
6mm^2	45.000.000 TL	per 100 meter (for grounding)
2.5mm^2	19.500.000 TL	per 100 meter (for grounding)
2× 16mm^2	3.800.000 TL	per 1 meter
2×1 mm^2	32.500.000 TL	per 100 meter
Motor cable	61.500.000 TL	
Heater cable	146.000.000 TL	
Dual rozans cable	5.000.000 TL	

grounding rod 30.000.000TL

We couldn't find the wind generator prices.

APPENDIX C

Map of the area



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