

**ADAMA SCIENCE AND
TECHNOLOGY UNIVERSITY**

*School Of Electrical Engineering and
Computing*

*Department Of Electrical &
Computer Engineering*

Electrical installation

Electrical regulations and standards

- ❧ The following references contain provisions which, through reference in this chapter constitute provisions of the Ethiopian Building Code Standards (EBCS-10 1995) on Electrical Installation of Buildings.
- ❧ IEC 364-1:1972 Electrical Installations of Building, Part 1, Scope, Object and Definitions.
- ❧ b) IEC 50:1982 : International Electrotechnical Vocabulary.
- ❧ c) BS 7671:1992: Requirements for Electrical Installations, IEE Wiring Regulations, Sixteenth Edition.
- ❧ d) C 22.1:1992: Canadian Electrical Code, Part I, Safety Standard for Electrical Installations. Sixteenth

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- ❧ (l) The following references contain provisions which, through reference in this chapter, constitute provisions of the Ethiopian Building Code Standards on Electrical Installation of Buildings.
 - ❧ (a) BS 8206: 1985 Part 1 - Lighting for Building.
 - ❧ (b) DIN 5035:1990 Part 1 - Artificial Lighting, Terminology and General Requirements.
 - ❧ (c) DIN 5035:1990 Part 2 - Artificial Lighting, Recommended Values for Lighting Parameters for Indoor and Outdoor Workplaces.
 - ❧ (d) DIN 5035:1988 Part 3 - Artificial Lighting of Interiors, Hospital Lighting.
 - ❧ (e) DIN 5035: 1983 Part 4 - Artificial Lighting of Interiors, Special Recommendations for Lighting Educational establishments
 - ❧ (f) DIN 5035:1987 Part 5 - Artificial



⌘ MARKING OF EQUIPMENT

⌘ General

- ⌘ (1) Each piece of electrical equipment shall bear such of the following markings as may be necessary to identify the equipment and ensure that it is suitable for the particular installation:
 - ⌘ a) The maker's name, trademark, or other recognized symbol of identification.
 - ⌘ b) Catalogue number or type.
 - ⌘ c) Voltage.
 - ⌘ d) Rated load amperes.
 - ⌘ e) Watts, volt-amperes, or horsepower.
 - ⌘ f) Whether for a.c., d.c., or both.
 - ⌘ g) Number of phases.
 - ⌘ h) Frequency in Hertz.
 - ⌘ i) Rated load speed in revolution per minute.
 - ⌘ J) Designation of terminals.
 - ⌘ k) Whether for continuous or intermittent duty.
 - ⌘ 1) Evidence of approval.
 - ⌘ m) Such other marking as may be necessary to ensure safe and proper operation.

Electrical installation materials: components and accessories

WIRE AND CABLE

In practice:-

- ∞ bare conductors, whether single or stranded together are termed as **Wire**.
- ❖ Conductors covered with insulation are termed as **cables**.

The necessary requirements of a cable are

- Conduct efficiently
- Cheap
- Safe



A Cable consists of three parts

1. **The conductor or core:**– the current carrying part of the metal.
2. **The insulation or dielectric:**– a covering of the conductor use to avoid leakage current from the conductor.
3. **The protective covering:**– for protection of insulation from mechanical damage.

2.2. CONDUCTOR MATERIALS USED IN CABLES

✧ The conductor is one of the important items as most of the capital outlay is invested for it. Therefore, proper choice of material and size of the conductor is of considerable importance.

The conductor material used for transmission and distribution of electric power should have the following properties

- ✧ (i) high electrical conductivity.
- ✧ (ii) high tensile strength in order to withstand mechanical stresses.
- ✧ (iii) low cost so that it can be used for long distances.
- ✧ (iv) low specific gravity so that weight per unit volume is small.
- ✧ All above requirements are not found in a single material. Therefore, while selecting a conductor material for a particular case, a compro

- 
- ☞ Commonly used conductor materials. The most commonly used conductor materials are *copper, aluminum, steel cored aluminum, galvanized steel and cadmium copper.*
 - ☞ The choice of a particular material will depend upon the cost, the required electrical and mechanical properties and the local conditions.
 - ☞ **1. Silver:** is the best conductor but due to its higher cost it is hardly used anywhere.

Cont....

- ⌘ **2.Copper.** Copper is an ideal material for overhead lines owing to its high electrical conductivity and greater tensile strength.
- ⌘ It is always used in the hard drawn form as stranded conductor.
- ⌘ It is mechanically strong, hard, extremely tough, durable and ductile. The electrical resistivity of pure copper at 20°C is $1.786 \times 10^{-8} \Omega\text{m}$
- ⌘ Although hard drawing decreases the electrical conductivity slightly yet it increases the tensile strength considerably.
- ⌘ Copper has high current density i.e., the current carrying capacity of copper per unit of crosssectional area is quite large. This leads to two advantages.
- ⌘ Firstly, smaller X-sectional area of conductor is required and
- ⌘ secondly, the area offered by the conductor to wind loads is reduced. Moreover, this metal is quite homogeneous, durable and has high scrap value.
- ⌘ There is hardly any doubt that copper is an ideal material for transmission and distribution of electric power.
- ⌘ However, due to its higher cost and non availability, it is rarely used for these purposes.

3. Aluminium

- ∞ Aluminium is cheap and light as compared to copper but it has much smaller conductivity and tensile strength. The relative comparison of the two materials is briefed below :
- ∞ (i) The conductivity of aluminium is 60% that of copper. The smaller conductivity of aluminium means that for any particular transmission efficiency, the sectional area of conductor must be larger in aluminium than in copper.
- ∞ For the same resistance, the diameter of aluminium conductor is about 1.26 times the diameter of copper conductor.
- ∞ The increased Xsection of aluminium exposes a greater surface to wind pressure and, therefore, supporting towers must be designed for greater transverse strength. This often requires the use of higher towers with consequence of greater sag.
- ∞ (ii) The specific gravity of aluminium (2.71 gm/cc) is lower than that of copper (8.9 gm/cc).
- ∞ Therefore, an aluminium conductor has almost $\frac{1}{2}$ the weight of equivalent copper conductor.

Cont...

- ❧ (iii) Aluminium conductor being light, is liable to greater swings and hence larger cross-arms are required.
- ❧ (iv) Due to lower tensile strength and higher coefficient of linear expansion of aluminum, the sag is greater in aluminium conductors.
- ❧ Considering the combined properties of cost, conductivity, tensile strength, weight etc., aluminium has an edge over copper.
- ❧ Therefore, it is being widely used as a conductor material.
- ❧ It is particularly profitable to use aluminum for heavy current transmission where the conductor size is large and its cost forms a major proportion of the total

2.3. INSULATING MATERIALS

- The insulation material must possess the following properties:
 - ❖ High resistivity
 - ❖ High flexibility
 - ❖ Non- inflammability
 - ❖ High resistivity to moisture, acids

∞ The various types of insulating materials used in cables are :-

1. **Rubber:-** Rubber may be natural or synthetic.

- . Its dielectric strength is above 30KV/mm.
- . Though it possesses high insulating qualities, it absorbs moisture readily, softens when heated to a temperature of 60°C to 70°C, swells under the action of mineral oils and ages when exposed to light.
- . Hence pure rubber cannot be used as insulating materials.

2. PVC (Polyvinyl chloride)

- :- is a man made thermo-plastic which is tough, non-inflammable and chemically unreactive.
- Its chief drawback is that it softens at a temperature above 80°C .
- It does not deteriorate with age and does not need to be renewed.
- PVC insulated cables are usually employed for low and medium voltage domestic and industrial lights and power installation



Rubber



PVC



3. **Vulcanized India Rubber:**– It is prepared by mixing India rubber with Minerals such as sulphur, zinc red lead.

- It absorbs water, which reduces its insulation properties and becomes brittle with age.
- The use of VIR cables is limited to low voltage distribution and internal wiring. Insulated cables superseded them.

VIR



4. Impregnated Paper

- ✧ it is quite cheap, has low capacitance, high dielectric strength (30KV/mm), and high insulation resistivity (10Mohm-cm).
- ✧ The main advantage of paper insulated cable is that a cable of given size can be worked out at a higher current density than a VIR cable.
- ✧ Impregnated paper insulated cable on its own would be too fragile to be used unprotected, and a lead sheath is applied over the insulation.
- ✧ Paper insulated cables are used for conveying large power in transmission and distribution and particularly for distribution at low voltages in congested

Mechanical protection

- ✧ All the insulating materials used in the manufacturing of cables are mechanically weak, so
- ✧ some form of protection is required from mechanical injury.

2.4 TYPES OF CABLES USED IN INTERNAL WIRING

A. Based on number of cores

- single core
- twin core
- twin core with ECC (earth continuity conductor)

B. According to voltage grading

- 250/440 volt
- 650/1100-volt cable
- ⌘ AC cables are designed to be suitable for specific design voltages, which is called the "Voltage Grade" (or "Voltage Designation", "Voltage Class" or "Voltage Rating") of the cable.
- ⌘ The voltage grade is commonly expressed in the following form:
$$\frac{U_0}{U}$$
- ⌘ Where U_0 is the power frequency voltage between phase and earth (V rms)
- ⌘ U is the power frequency voltage between two phase conductors (V rms)
- ⌘ For example, some standard IEC voltage grades are 0.6/1kV, 1.9/3.3kV, 3.8/6.6kV, 6.35/11kV, 12.7/22kV, 19/33kV, etc.

C. Based on type of insulation

1. Vulcanized Indian Rubber (VIR) Cables : used for general conduit wiring.
2. Lead Sheathed Cables : Used for internal wiring where climatic condition has moisture.

∞ PVC

*Colour identification of
bare conductors and cable
cores (EEPCO's
Regulation)*

Function	Colour identification of core of rubber or PVC insulated cable.
Earthing	White
Live of a.c single-phase circuit	Green
Neutral of a.c single-phase or three-phase circuit	Black
Phase R of three-phase a.c. circuit	Green
Phase S of three-phase a.c. circuit	Yellow
Phase T of three-phase a.c. circuit	Red

General specification of cables

- *The size of the cable*
- *The type of conductor*
- *Number of cores*
- *Voltage grade*
- *Type of insulation*

2.5 CONDUITS

- The commonest method of installing cables is to draw them into a conduit.
- The conduit can be steel or plastic.
 - ❧ i) Light gauge steel-plain (unscrewed) conduit
 - ❧ ii) Heavy gauge steel-screwed conduit
 - ❧ iii) Flexible conduit



Conduit



Conduit Fittings

Conduit Accessories and Fittings

❖ Conduit Couplers:

- ✓ Couplers are used to join two lengths of conduit.
- ✓ screwed conduit are always threaded at both ends on the outer side.

Conduit accessories and fittings

A. Conduit couplers:-

- ✓ used to join two lengths of conduit.
- are threaded on both ends.

B. Bends elbows and tees: -are generally called conduit fittings.

- ✓ Bends are usually used for change in direction of conduit.
- ✓ This should never be sharp.
- ✓ The minimum allowable radius of curvature is 2.5 times the outside diameter of the conduit.
- ❖ Solid elbows and tees should be used only at the end of the conduit run.

Fig.

a. Tees



b. Elbow



❖ Bends, Elbows and Tees:

- ✓ In general conduit fittings include bends, elbows and tees.

❖ Conduit Boxes:

- ✓ Conduit boxes are used in surface conduit wiring as well as concealed conduit wiring.
- ✓ Conduit boxes are used in surface conduit wiring as well as concealed conduit wiring.
- ✓ Classified as:
 - ✓ Outlet boxes
 - ✓ Inspection boxes
 - ✓ Junction boxes



Lighting accessories and fittings



Plugs and socket outlets



Lamp holders



Different switches



One-way sw



Two-way sw



Intermediate sw



Gang sw





Lighting Accessories
and Fitting

Fuse and circuit breakers

Designed to interrupt the power to a circuit due to

- The current flow exceeds safe level.

Fuse :

It has narrow strip of metal which is designed to melt when current exceeds the rated value.

$$\text{Fusing Factor} = \frac{\text{minimum fusing current}}{\text{Current rating}} \geq 1$$

Two types of fuses

❧ Rewirable Fuses

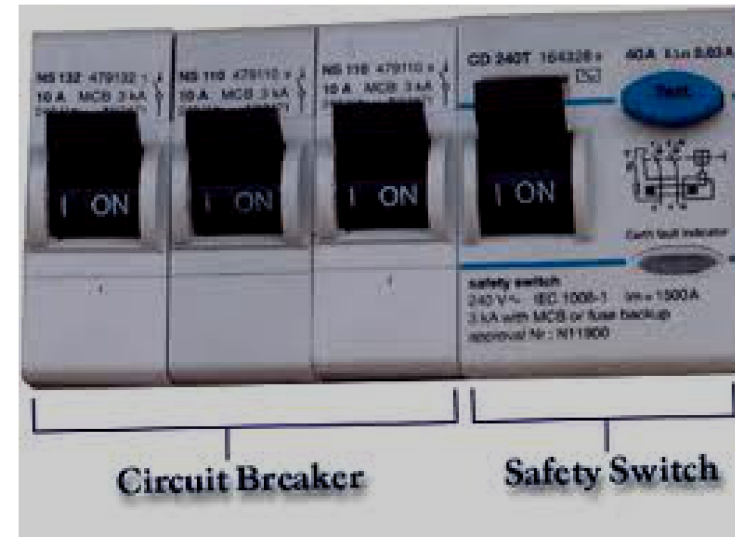
- consists of a porcelain bridge and base
- simple and relatively cheap
- Fusing factor about 2

❧ HRC

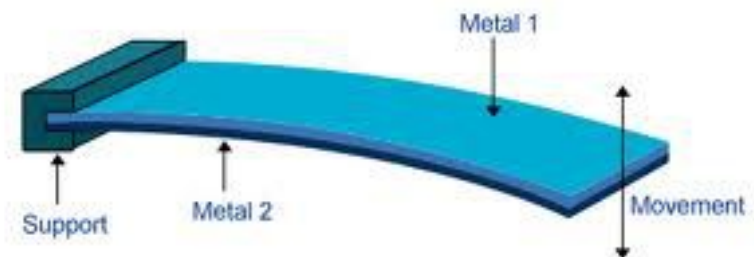
- high breaking capacity
- Fusing factor about 1.5
- Relatively expensive



Fuse



Circuit Breaker



Bi-Metallic Strip

Breakers

It is a mechanical devices, when the current flow through the breaker exceeds the rated value, a bimetallic strip heats up and bends. By bending it trips the latch.

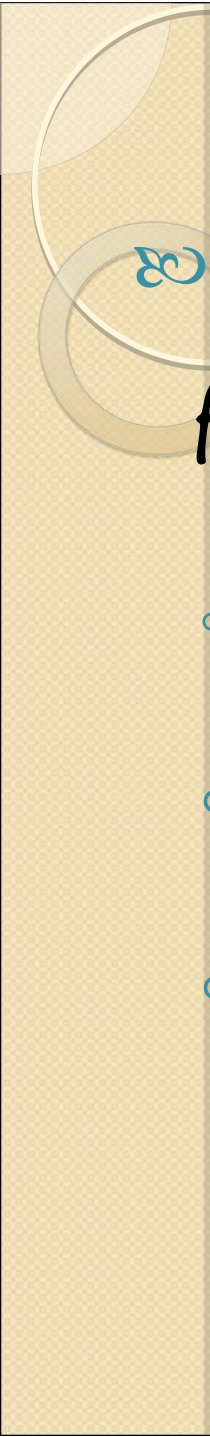
Most breakers will carry

- 150% of their rated load for 1 min
- 200% for about 20 sec
- 300% for about 5 sec

Standard Rating

6, 10, 16, 20, 25, 35, 50, 63, 80, 100,
125, 160, 224, 250, 300, and large sizes.

Rating of cables : 1.5 2.5 4 6 10 16 25 35
50 70 95 120 150 185 240 300 400
500 630 800



∞ Fuse has higher risk of causing a fire than circuit breaker due to

- loosely screw
- contact corroding
- wrong size



A circuit breaker has several advantages over any type of fuse

- All the poles are simultaneously disconnected
- The time can be adjusted
- Can be closed again quickly

Distribution board

Is an assemblage of parts for the distribution of electrical energy to the final circuits.

It includes

- fuses
- circuit breakers
- main switches
- frame
- bus-bar





Electrical Installation design

- ☐ *wiring design criteria*
- ☐ *Design procedures*
- ☐ *Branch circuit design*
- ☐ *Load tabulation*
- ☐ *Design current*
- ☐ *Cable size design procedures*
- ☐ *Voltage drop calculation*
- ☐ *Service entrance*
- ☐ *Diversity factor*

Wiring Design Criteria

- ❖ **Flexibility**:- Able to change to suit new conditions or situations for the provision for expansion.
- ❖ **Reliability**:- that can be trusted to do something well or without interrupting the system
- ❖ **Safety**:- be constantly attentive to an initial safe electrical installation and such factors as electrical hazards caused by misuse of equipment or by equipment failure after installation.
- ❖ **Energy saving and control consideration**:- limiting voltage drops, power factor correction, use of switches for control, etc
- ❖ **Economic cost** :- initial cost and operating cost.
- ❖ **Space allocation**:- concerned with maintenance ease, ventilation, expandability, centrality, limitation of access, and noise, in addition to the

Design procedures

- steps involved in the electrical wiring design of any facility.
 - A. Determine the type and rating of all client furnished equipments.
 - B. If the designer could not get the exact electrical ratings, determine their ratings from other **consultant**.
 - C. Make an **electrical load estimation** based on the collected data.

Load Estimation:- estimating total electric loads the building uses after completing the design.

The electrical loads which can be estimated are,

- (i) **Lighting.**
- (ii) **Miscellaneous power, which includes convenience outlets and small motors.**
- (iii) **Heating, ventilating, and air conditioning.**
- (iv) **house water pump, air compressors,**
- (v) **elevators, moving stairs,**
- (vi) **Kitchen equipments**

Cont...

- D. decide the point of service entrance:- type of service run, service voltage, metering location, and building utilization voltage.
- E. Determine the location and estimate the size of all required electric equipment spaces including switchboard rooms, emergency equipment spaces, and so forth
- F. Design the lighting for the facility
- G. In your plan **Locate** all electrical apparatus including receptacles, switches, motors, and other power consuming apparatus and **signal** apparatus such as

Cont...

- H. Make drawing showing all lightings, devices, and power equipments circuit connection to the appropriate panel board.
- I. Prepare the panel schedule (table). This table shows the **load distribution over the three phases and the type of load which is connected on each circuit..**
- J. From the panel schedule (table) compute panel loads, and make connection rearrangement so that you will be able to **an optimum power balance** over the three phases **R**, **S** and **T**.
- K. Prepare the riser diagram. This includes design of **distribution panels, switchboards, a service equipment.**
- L. **Compute feeder sizes and all protective equipment ratings.**
- M. Check the preceding work.

Branch Circuit Design

- ✓ **Branch circuits** are circuits that supplies power from the distribution **board(DB)**
- **Protective devices**:- Fuses, MCBs, Main switch,
- **Main cables**:- carry total current of the installation
- **Sub main cables** carry current to sections of large installation to SMDB
- **Final circuit** feeds one type of circuit. It can range from a pair of 1.5 mm² cables feeding a light to a very heavy three- core cable feeding a large motor from a CB or switch at the main DB. Each circuit should have its own protective fuse or CB. the **rating of the protective device must not be less than the designed load current** of the circuit.

The **final circuits** can be

Lighting circuits 10A, general purpose socket outlets 16A, socket outlets for water heater 3kw 16A, s.o for cooker 20/25A, power outlets for feeding motor 16A, bell circuits 6A etc.

Cont...

□ Residential wiring system Guidelines

- a. The NEC requires to supply a load of 3w/sq ft in the building, excluding unfinished spaces such as porches, garages, and basements.
- b. The NEC requires a minimum of two 20-amp appliance branch circuits to feed all the small appliance outlets in the kitchen, pantry, dining room, family room etc.
- c. The NEC requires that at least one 20-amp circuit supply to be set for laundry outlets
- d. Do not combine *receptacles and switches into a single outlet* except where convenience of use dictates high mounting of *receptacles*
- e. Circuit the lighting and receptacles so that each room has parts of at least two

Cont...

- f. Supply at least one receptacle in the bathroom and one outside the house
- g. *Provide switch control for closet lights.*
- h. In bedrooms supply **two duplex outlets** at each side of the bed location.
- i. Kitchens should have a duplex appliance outlet every 36 in. of counter space, but no less than two in addition to the normal wall outlets
- j. *A disconnecting means, readily accessible,*

Cont...

Non-residential wiring Guidelines

(a) Schools:-

- ❖ Lecture Hall
- ❖ Laboratory
- ❖ Shop
- ❖ Assembly
- ❖ Office
- ❖ Gymnasium
- ❖ Swimming Pools
- ❖ Photographic Labs

Cont...

so it is not possible to generalize on branch circuit design considerations except for the following

- i. To accommodate the opaque and film projectors frequently used in the classroom, **20-amp outlets wired two receptacles** on a circuit are placed at the front and back of each such room.
- ii. **Light switching should be provide:**

*High-low levels for energy conservation and to permit low-level lighting for film viewing. And With fluorescent lighting this can be accomplished by alternate **ballast wiring** and switching, thus avoiding the high cost of dimming equipment. And also Separate switching of the lights on the window side of the room, which is often lighted sufficiently by daylight*

Cont...

- iii) Provide appropriate outlets for all special equipment in labs, shops, cooking rooms, and the like.
- iv) Use heavy-duty devices and key operated switches for public area lighting (corridors, etc.), plastic instead of glass in fixtures, and vandal-proof equipment wherever possible. All panels must be locked and should be in locked closets.
- v) The NEC requires sufficient branch circuitry to provide a minimum of 3 w/sq ft for general lighting in schools..
- vi) Keep lighting and receptacles completely separate when circuiting.

(b) Office Space

- i. In **small office spaces** (less than 400 sq ft) provide either **one outlet** for every 40 sq ft, or **one outlet for every** 10 linear ft of wall space, In **larger office spaces**, provide one outlet every 100 to 125 sq ft.
- ii. Corridors should have a 20-amp, 220-v outlet every 50 ft, to supply cleaning and waxing machines.
- iii. As with all non-residential buildings, convenience receptacles are figured at 180 w each.

(c) Stores.

In stores, good practice requires at least one convenience outlet receptacle for **every 300 sq ft in** addition to outlets required for loads such as lamps, show windows,

Load Tabulation

- Arranging facts or figures of loads.
- While circuiting the loads, a panel schedule is drawn up which lists:
 - ❑ The circuit numbers
 - ❑ Load description (the type of the load)
 - ❑ Wattage (actually in volt-amperes)
 - ❑ The current ratings
 - ❑ Number of poles of the circuit-protective device feeding each circuit and the like
 - ❑ *Spare circuits* are included to the extent that the designer considers them necessary and consonant with economy, but normally no less than 20% of

Cont...

In calculating panel loads,

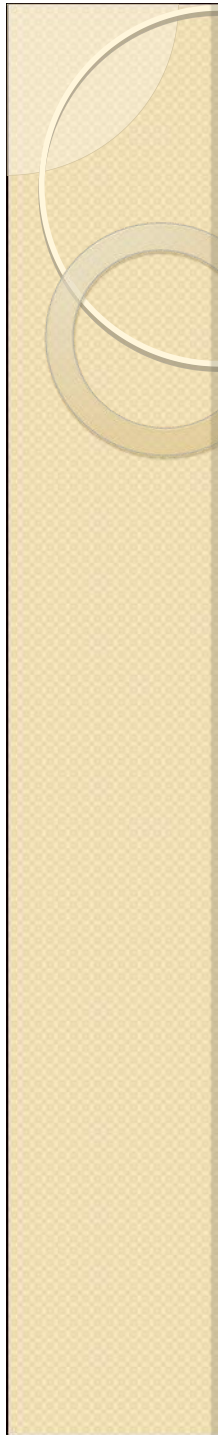
- (a) Each specific appliance, device, lighting fixture , or other load is taken at its nameplate rating
- (b) Each convenience outlet, is counted as 16 amp (180 W).
- (c) Spare circuits are figured at approximately the same load as the average active circuits

Schedule for lighting panel

Elect. Panel		220/380 3 ϕ			
No.	Services	Load in watts			
		R	S	T	
1	Lighting	1050			
2	Lighting		1050		
3	Lighting-corridor			700	
4	Lighting	1050			
5	Lighting			800	
6	Receptacles			900	
7	Receptacles-corridor(single pole)		900		
8	Receptacles			900	
9	Spare	1050			
10	Spare		1050		
	Phase total	3150	3000	3300	
	Panel total	9450			
	Max.phase current	15 A			
Main breaker _____					
Feeder size _____					
Diversity factor _____					

RECOMMENDED ILLUMINATION LEVELS

SERVICE	Illumination level (Lux)
Building Areas	
- Circulation areas, corridors	100
- Stairways, Escalators	150
- Cloak rooms, Toilets	150
Assembly Shops	
- Rough work: Heavy machinery assembly	300
- Medium work: Engine, Vehicle body assembly	500
	750
- Fine work: Electronic and Office machinery assembly	
Offices	
- General offices, Typing, Computer rooms -	500
Deep-Plan general offices	750



Schools	
- Class rooms, Lecture theatres	300
- Laboratories, Libraries, Reading rooms and Art rooms	300
Shops, Stores and Exhibition Areas	
- Conventional Shops	300
- Self-service Shops	500
- Supermarkets	750
Museums and Art galleries	
- Light - Sensitive exhibit	150
- Exhibits insensitive to light	300
Public Buildings	
- Cinemas	50
- Auditoriums	150
Theatres and Concert Halls	
- Auditorium	100
- Foyer	200
Dwelling Houses	
- <i>Bed rooms:</i> -	50
- General	200
- Bed-Head	
Nursery	150

Example

Assume a single floor of an office building 10 m X 20 m.
Calculate the required number of panels, circuits for lighting.

Solution

Office space – illumination=300lux from table (EBCS-10)

$$N = \frac{E * A}{n * \Phi * CU * MF}$$

Where **cu**=coefficient of utilization=0.55,

MF=maintenance factor=0.9

$n * \Phi$ shows luminous flux produced per lamp.

∞ Let's select **single fluorescent lamp**($n=1$), **wattage =40w** which has **efficiency of 60**.

∞ Flux lumen=lumenus efficiency *watt

∞ =So $60*40 =$ **2400 lumens** flux per lamp

Cont...

$$\text{So, } N = \frac{300 \times 200}{40 \times 60 \times 0.55 \times 0.9} = 51 \text{ single fluorescent lamps}$$

$$\text{Total wattage} = 51 \times 40 = 2040 \text{ W}$$

Assuming that each lightening branch circuit is $\frac{2040}{1300}$ **1300 W** rated.

$$\therefore \text{Number of branch circuit for lightening} = 1.5 \sim \mathbf{2 \text{ ckt}}$$

Cont...

Receptacles:

we simply take into account the furniture, electronic equipments that located in that room and the functions of rooms. Let's take total number of receptacles = 6 (mostly 6 receptacles supplying from one branch ckt) So, one branch ckt for socket is required.

Total wattage of
receptacles = $6 \times 200 = 1200W$ (Each
socket outlet point has wattage of 200

Cont...

The total no. of circuits for lighting plus receptacles
is $2 + 1 = 3$ ckts

Spares is = 20% of total circuits

$$3 * 20\% = 3 * 0.2 = 0.6 \sim 1 \text{ckt} \sim 1200\text{W}$$

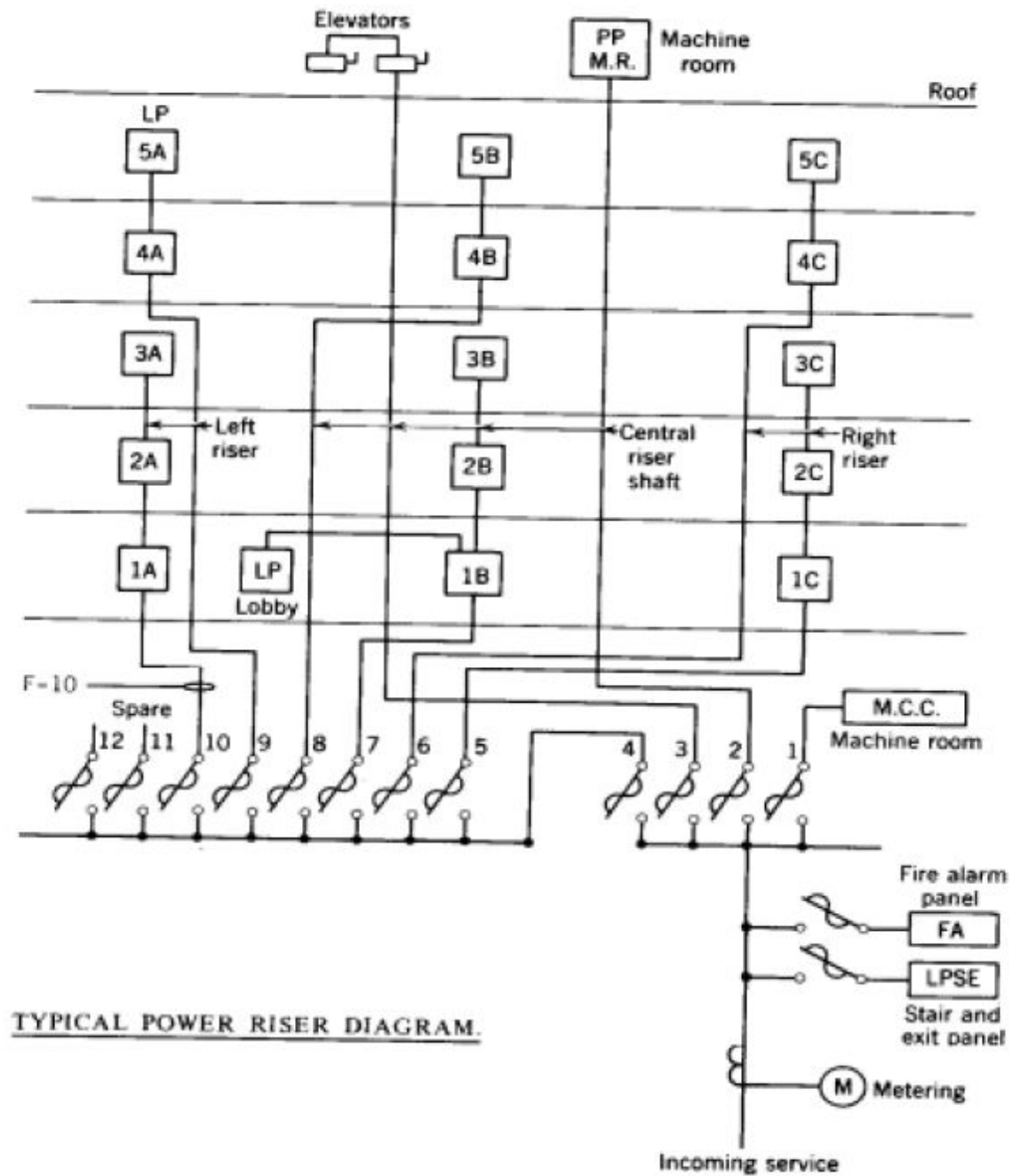
Total of 4 ckts.

The feeder current is

$$I = \frac{2040 + 1200 + 1200}{220} = 20.18\text{A}$$

Riser Diagrams

- ⌘ This diagram is an electrical version of a vertical section taken through the building.
- ⌘ The **main switchboard** shown in the figure below constitutes a combination of **service equipment** and **feeder switchboard**. The service equipment portion of the board comprises the **metering** and the 4 main switches feeding risers, **motor control center (MCC)**, **roof**, **machine room**, and



Cable Size Design procedure

The correct choice of **cable size** for any installation is dependent upon

- ❖ Environmental conditions and characteristics of protection, **PVC, weather proof, VIR, LSC**
- ❖ Current-carrying capacity of the cable and
- ❖ Voltage drops of the cable.



Steps for selection of cable size

1. Determine the design current I_b .
2. Select the rating of the protection I_n (rating of protective device)
3. Select the relevant correction factors (CFs).
4. Divide I_n by the relevant CFs to give cable current-carrying capacity (I_z)
5. Choose a cable size to suit I_z
6. Check the voltage drop
7. Check for shock risk constraints
8. Check for thermal constraints.

Design current

In many installations, the design current I_b is quoted by the manufacturer, but there are times when it has been calculated.

➤ Single phase

➤ Three phases:

Single phase: $I_b = P/V$

Three phase: $I_b = P/(\sqrt{3} V)$

If an item of equipment has a pf and eff, it will have been taken into account. Hence:

∞ Single phase: $I_b = (P/(V*PF* eff))$

∞ Three phase: $I_b = (P/(\sqrt{3}*V L*PF* eff))$

Cont...

Nominal setting of protection:

- **$I_n > I_b$** . This value may be taken from IEE regulations.
- **Standard ratings:** both fuse and circuit breakers are available in standard ratings of 6, 10, 16, 20, 25, 35, 50, 63, 80, 100, 125, 160, 224, 250, 300, and large sizes

Correction factors

When a cable carries its full load current, it can become warm.

other influences are

- ❑ **high ambient temperature:-**
- ❑ **cable grouped together closely**
- ❑ **uncleared over currents and**
- ❑ **contact with thermal insulation.**

Because of the high fusing factor of BS 3036 fuses, the rating of the fuse I_n , should be less than or equal to $0.725 I_z$. Hence **0.725** is the

Images of BS 3036 fuses



Cont...

Current carrying capacity of conductor = $I_z = I_n / (\text{relevant CFs})$

Or

$$I_z = \frac{I_n}{c_g \times c_a \times c_i}$$

c_i

- ∞ IEE Regulation gives these factors for situations when thermal insulation touches one side of a cable. However, if a cable is totally surrounded by thermal insulation for more than 0.5 m, a factor of 0.5 must be applied to the tabulated clipped direct ratings. For less than 0.5 m, derating factors should be applied.

- **Choice of cable size**

Having established I_z of the cable to be used, it now remains to choose a cable to suit that value.

The IEE regulation also lists all

- ✓ Cable Sizes,
- ✓ Current Carrying Capacity
- ✓ Voltage Drops Of Various Types Of Cables.

Voltage drop

It is the voltage difference between the voltage measured at DB and the voltage reaching the load.

The conductor has, $R = \rho l/A$

And also, $R_T = R_O (1 + \alpha \Delta T)$

Where, R_T = resistance at the required temperature

$R_O = \rho l/A$ resistance at room temperature

α -Expansion coefficient

ΔT - Change in temperature

∞ V_d = voltage drop

∞ mV = voltage drop in mV per ampere per meter obtained from IEE table

∞ I_b = design current

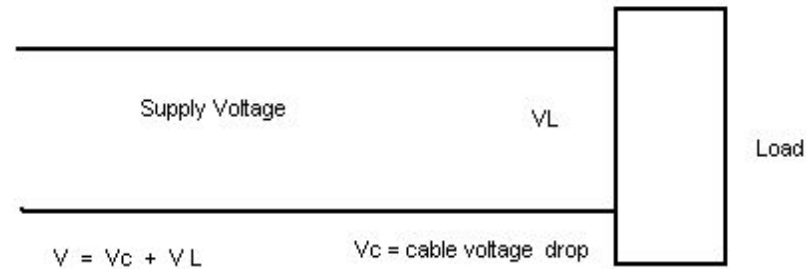
∞ L = total length of the cable

Then, According to IEE regulations,

$$V_d = mV/Am * I_b * L$$

Cont....

- ⌘ The resistance of a conductor increases as the length increases and / or the cross sectional area decreases.
- ⌘ Associated with an increased resistance is drop in voltage, which means that a load at the end of along thin cable will not have the full supply voltage available.



- ❧ The IEE regulation require that the voltage drop V_c shouldn't be so excessive that equipment doesn't function safely.
- ❧ The drop of not more than 4% (IEE)
- ❧ Therefore for single phase 220v , the drop should not exceed 4% of 220v = 8.8V
- ❧ For three phase 380V, the voltage drop should not exceed 4% of 380v = 15.2V
- ❧ The drop of not more than 2.5% (EEPCCO)
- ❧ Single phase It should be less than 2.5% of 220v = 5.5v
- ❧ Three phase It should be less than 2.5% of 380v = 9.5v

$$\Delta V = V - V_L =$$

$$R_i = \rho L / A$$

ρ - resistivity of
conductor material

Where L - length from source
to load

A - cross-sectional area
of the conductor

R_i - resistivity per unit
length $\Delta V = \frac{2\rho x L x I_L}{A} \cos \phi$

for pure

resistive load $\Delta V = \frac{2 x I_L x P}{VA} \cos \phi$

for

For three phase ,

$$\Delta V = \frac{L \times \rho \times P}{V}$$

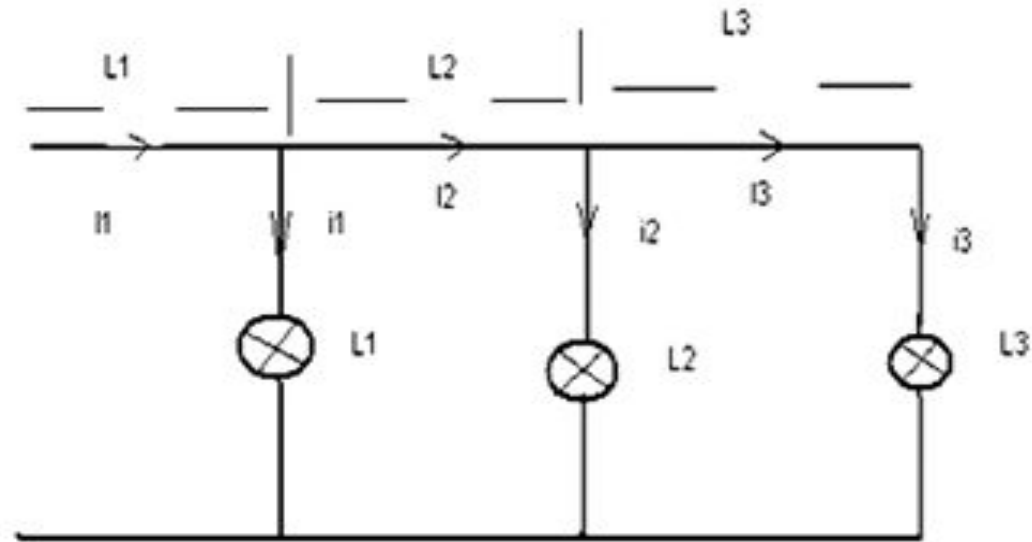
$V = 380V$

$A \times V$

The above formula can be summarized as follows:

Voltage Drop	For dc or single phase, power factor= $\cos\theta$	For 3-phase ac with power factor= $\cos\theta$
When the current I is known	$\Delta V = \frac{2 \times \rho \times L \times I_L \times \cos\theta}{A}$	$\Delta V = \frac{1.73 \rho \times L \times I_L \times \cos\theta}{A}$
When the power P is known	$\Delta V = \frac{2 \times \rho \times L \times P}{A \times V}$	$\Delta V = \frac{\rho \times L \times P}{A \times V}$

Example-1- Consider the installation circuit consisting of three lighting points:

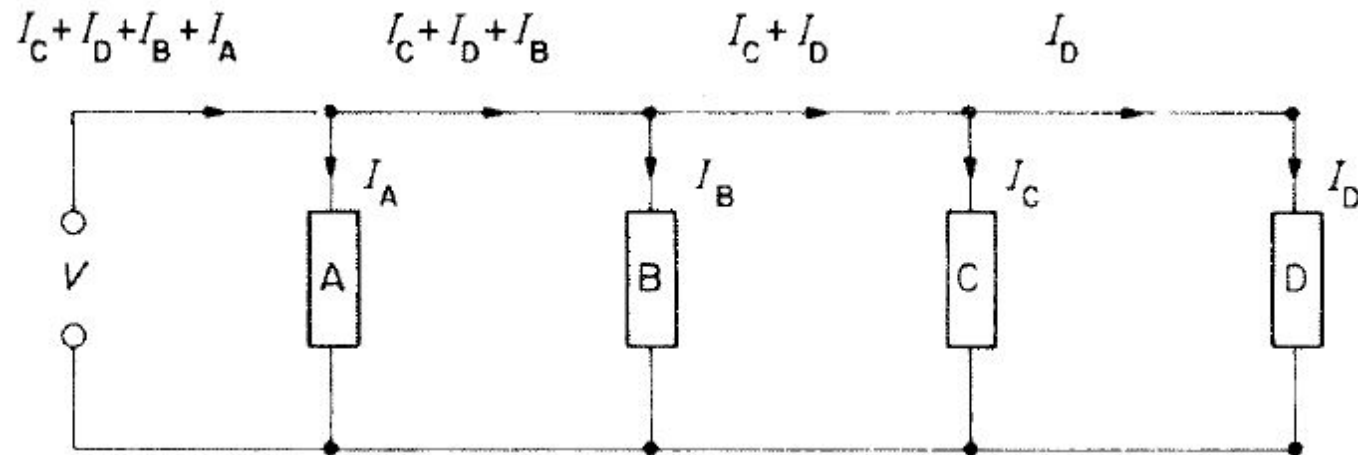


$I_1 = I_1 + I_2 + I_3$, voltage drop will be :

$$\Delta V = I_1 \left(\frac{2\rho L_1}{A} \right) + I_2 \left(\frac{2\rho L_2}{A} \right) + I_3 \left(\frac{2\rho L_3}{A} \right)$$

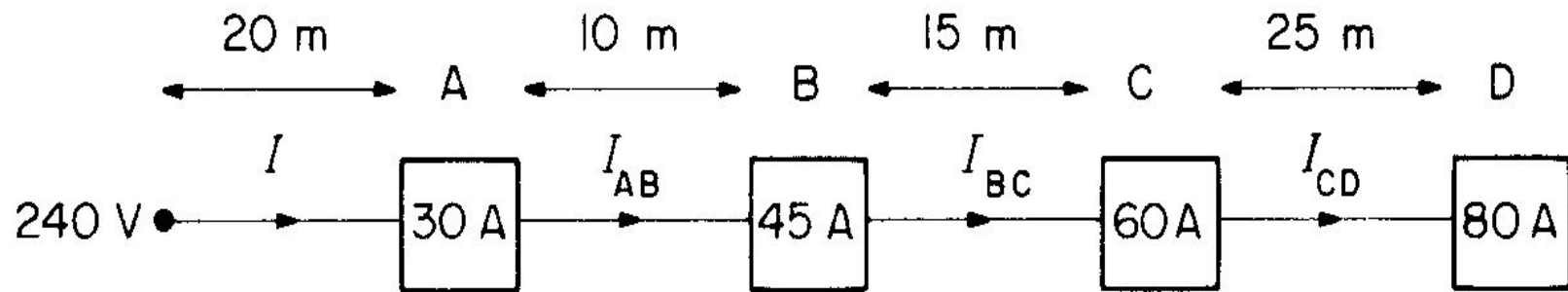
$$\Delta V = \frac{2\rho}{A} (I_1 L_1 + I_2 L_2 + I_3 L_3)$$

In practice the highest voltage drop is calculated for the most distant load



Example

1. A 240 V radial distributor is 70 m long and has a resistance of 0.0008 per metre supply and return. Four loads A, B, C and D rated at 30 A, 45 A, 60 A and 80 A are fed from the cable at distances of 20 m, 10 m, 15 m and 25 m respectively. Calculate the total current drawn from the supply, the current in the cable between each of the loads, and the voltage at load D if all the loads are connected.



$$\begin{aligned}\text{Total load } I &= 30 + 45 + 60 + 80 \\ &= 215 \text{ A}\end{aligned}$$

$$I_{CD} = 80 \text{ A}$$

$$\begin{aligned}I_{BC} &= 60 + 80 \\ &= 140 \text{ A}\end{aligned}$$

$$\begin{aligned}I_{AB} &= 45 + 60 + 80 \\ &= 185 \text{ A}\end{aligned}$$

$$\begin{aligned}\text{Resistance between supply and A} &= 20 \times 0.0008 \\ &= 0.016 \Omega\end{aligned}$$

$$\begin{aligned}\therefore \text{Voltage drop between supply and A} &= 0.016 \times I \\ &= 0.016 \times 215 \\ &= 3.44 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Resistance between A and B} &= 10 \times 0.0008 \\ &= 0.008 \Omega\end{aligned}$$


$$\begin{aligned}\therefore \text{Voltage drop between A and B} &= 0.008 \times I_{AB} \\ &= 0.008 \times 185 \\ &= 1.48 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Resistance between B and C} &= 15 \times 0.0008 \\ &= 0.012 \, \Omega\end{aligned}$$

$$\begin{aligned}\therefore \text{Voltage drop between B and C} &= 0.012 \times I_{BC} \\ &= 0.012 \times 140 \\ &= 1.68 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Resistance between C and D} &= 25 \times 0.0008 \\ &= 0.02 \, \Omega\end{aligned}$$

$$\begin{aligned}\therefore \text{Voltage drop between C and D} &= 0.02 \times I_{CD} \\ &= 0.02 \times 80 \\ &= 1.6 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Total voltage drop} &= 3.44 + 1.48 + 1.68 + 1.6 \\ &= 8.2 \text{ V}\end{aligned}$$

$$\begin{aligned}\therefore \text{Voltage at load D} &= 240 - 8.2 \\ &= 231.8 \text{ V}\end{aligned}$$

Examples

1. Mr Tadele wants to install an electric iron of 12kw, 220v, 50Hz in the kitchen which is 20m far away from the distribution board by using PVC insulated non-armored, copper conductors multi core cables clipped directly to the wall at an ambient temperature of 35°C and protection is by MCB. If only one side of cable is in contact with thermal insulation.

Determine:

- ∞ Design current
- ∞ The nominal setting of protection(I_n)
- ∞ The correction factor current(I_z)
- ∞ The size of cable and
- ∞ Check for the voltage drop

Cont...

2. A 16kw, 400V, 50Hz, three-phase industrial process heater is to be installed in a factory using a PVC insulated, non-armored, copper conductors multi core cables. Length of run is 25m enclosed in a conduit . Assume a maximum ambient temperature of 45°C , no. of circuits is 4 and protection is by MCB.

- ✧ Design current

- ✧ The nominal setting of protection(I_n)

- ✧ The correction factor current(I_z)

- ✧ The size of cable and

- ✧ Check for the voltage drop

2. what length of two core 1.5mm^2 copper cable be used to supply a current to a combined load of 25 lamps of 80W each on a 220V supply and at the same time not to exceeding the allowable voltage drop of 1EE ⁸¹

Cont....

❧ **EXAMPLE 4** A circuit is to be installed using 2.5 mm², 1.5 mm² twin and earth 70°C thermoplastic cables, it is 32 metres long and protected by a BS 88 fuse. The load to be supplied is a 4.2kW, the circuit is to be installed in trunking containing one other circuit at an ambient temperature of 35°C. Maximum permissible volt drop is 7 V.

SERVICE ENTRANCE

- ⌘ Power is transmitted by means of transmission lines. And further distributed by means of distributing lines.
- ⌘ The consumers are supplied with power by taking connections (tapping's) from distributing lines.
- ⌘ The **conductors** and **equipment** used for delivering electric energy from the supply system to the wiring system of the premises is called the **service**.

Cont...

Service lines are of two types

- 1) **Overhead service lines** :- the service cables are connected to the line conductors by means of mechanical connectors called line-taps .
- 2) **Underground Cable Service Lines**:- used when the power to be supplied to the consumer is large (say above 25kw).

Diversity Factor

- ❖ The ratio of the maximum demand of a load to the total connected load.
- ❖ it is factor of power utilization
- ∞ the application of the diversity factor should be decided by the engineer.
- ∞ There are some final circuits fed from wiring to which diversity factor applies:

Cont...

- ❑ lighting 0.7- 0.9
- ❑ heating:- water heaters (0.2-3) , stoves (0.2) , electric iron(0.3) ,
- ❑ cooking appliances which are permanently connected 0.3
- ❑ motors (other than lifting motors) 0.7-0.9
- ❑ instantaneous-type water heater 0.2
- ❑ thermostatically controlled water heater 0.2
- ❑ floor-warming installation
- ❑ thermal-storage space-heating installation 0.2
- ❑ 13A fused socket outlets and appliance fed there from and
- ❑ Other *socket outlets such as 16A sockets.* 0.2-0.5

Example

From EBCS-10. Table B.1, select cables of suitable current-carrying capacity for the following loads and conditions (p.v.c. cables to BS 6004 into screwed conduit).

- (a) 240 V single-phase sub-mains of lighting load totaling 10.5 kW. Length of run 10 m. Average ambient temperature 25°C, diversity 66%
- (b) 400 V balanced 3-phase power circuit. Load 18.65 kW, efficiency, 80%, power factor 0.69. Average temperature 30°C. Length of runs 100 m.

Solutions

a)
Given

Power = 10.5kw

single phase Voltage = 240V

Length of cable run = 10 m = L

Average ambient temperature of 25°C

diversity factor = 0.66

Required

➤ selecting suitable cable size

Cont...

Then,

Current taken by load = Power / Voltage = $10.5\text{kw} / 240\text{v} = 43.75\text{ A} = I_b$

maximum current through cables = $43.75 * 0.66 = 28.88$
A (using D.F)

From table, If BS 88 32-A circuit breaker is chosen for protection, **32 A rated circuit breaker** can be selected ,

Then, **$I_n = 32\text{ Amp}$**

The correction factor for ambient temperature from Table A.4 for 25°C is **1.04**.

∞ Therefore the required cable capacity rating:

∞ **$I_z = I_n / C_a = 32 / 1.04 = 30.77\text{ A}$**

From Table B.1, choose **a 4 mm^2** conductor which carries 32A.

Cont...

$$\infty \text{ Voltage drop} = \text{mV/Am} * I_b * L$$

From table B.2 voltage drop for 4mm² conductor size
= 11mV/Am

$$\blacksquare V_d \text{ on cable} = 11 \text{ mV/Am} * 28.8 \text{ A} * 10 \text{ m} = 3.168 \text{ V}$$

Maximum allowable voltage drop(MVd) = 2.5% of 240

$$MV_d = 2.5 * 240 / 100 = 6V.$$

Since the actual voltage drop(V_d) < MV_d , 4 mm² can be
the correct size selected

Cont...

If **BS 3036 fuse** is chosen for protection, this fuse type requires a correction factor of **0.725**.

$$I_z = I_n / CF$$

$$C_a = 1.06, \quad C_f = 0.725$$

$$I_z = I_n / C_a * C_f = 32 / 1.06 * 0.725 = 41.64 \text{ Amp.}$$

From [Table B.1](#), a 6mm² conductor carries 41 A. And a 10mm² conductor carries 57 A.

Take 10mm² diameter conductor.

$$\text{Voltage drop} = (\text{mV/Am}) * I_b * L$$

From [table B.2](#) voltage drop for 10mm² conductor size = 4.4mV/Am

$$\text{Voltage drop on cable} = 4.4 \text{ mV/Am} * 28.8 \text{ A} * 10 \text{ m} = 1.27 \text{ V}$$

Maximum allowable voltage drop = 2.5% of 240 V = 6V.

Since the actual voltage drop is less than from the allowable maximum voltage drop,

selected size is **10mm²**.

Cont...

$$b) \quad \text{eff.} = \frac{\text{output}}{\text{input}} = \frac{kw}{\sqrt{3}VI \cos \theta}$$
$$\Rightarrow I = \frac{18.65kw}{\sqrt{3} \times 400 \times 0.8 \times 0.69} = 48.77 A$$

From table 9.1, 50 A circuit-breaker of type BS 3871 can use for protection.

then, $I_n = 50 \text{ Amp}$

Load current will be :

$$\rightarrow I_z = I_n / CF : = \underline{Ca = 1}$$

Then,

$$\rightarrow I_z = 50 A$$

Choose 16 mm² cable which is capable of carrying 50 A

Cont...

Testing for Voltage drop:

∞ Maximum voltage drop = 2.5% of 400 V = $2.5 \times 400 / 100 = 10\text{V}$.

∞ Voltage drop on the cable = $(\text{mV/Am}) * I_b * L$

$$= 2.3 * 48.77 * 100$$

= 11.22 V which is beyond the allowable voltage drop.

So, choose the next cable size, which is **25mm²**.

$$\text{Voltage drop for } 25 \text{ mm}^2 = 1.7 * 48.77 * 100 = 8.29 \text{ V}$$

Therefore selected size is **25 mm²**.

i.e. voltage drop becomes the main determining Factor

Cont...

when, **50 A BS 3036** fuse can used for protection from table 9.1

→ $I_n = 50 \text{ A}$

→ Correction factor for the fuse is $C_f = 0.725$

→ Load current $I_z = I_n / C_f = I_n / C_f$

→ $I_z = 50 \text{ A} / 0.725 = 68.966 \text{ A}$

From table B.3 select 25mm^2 cable which carries 97 A

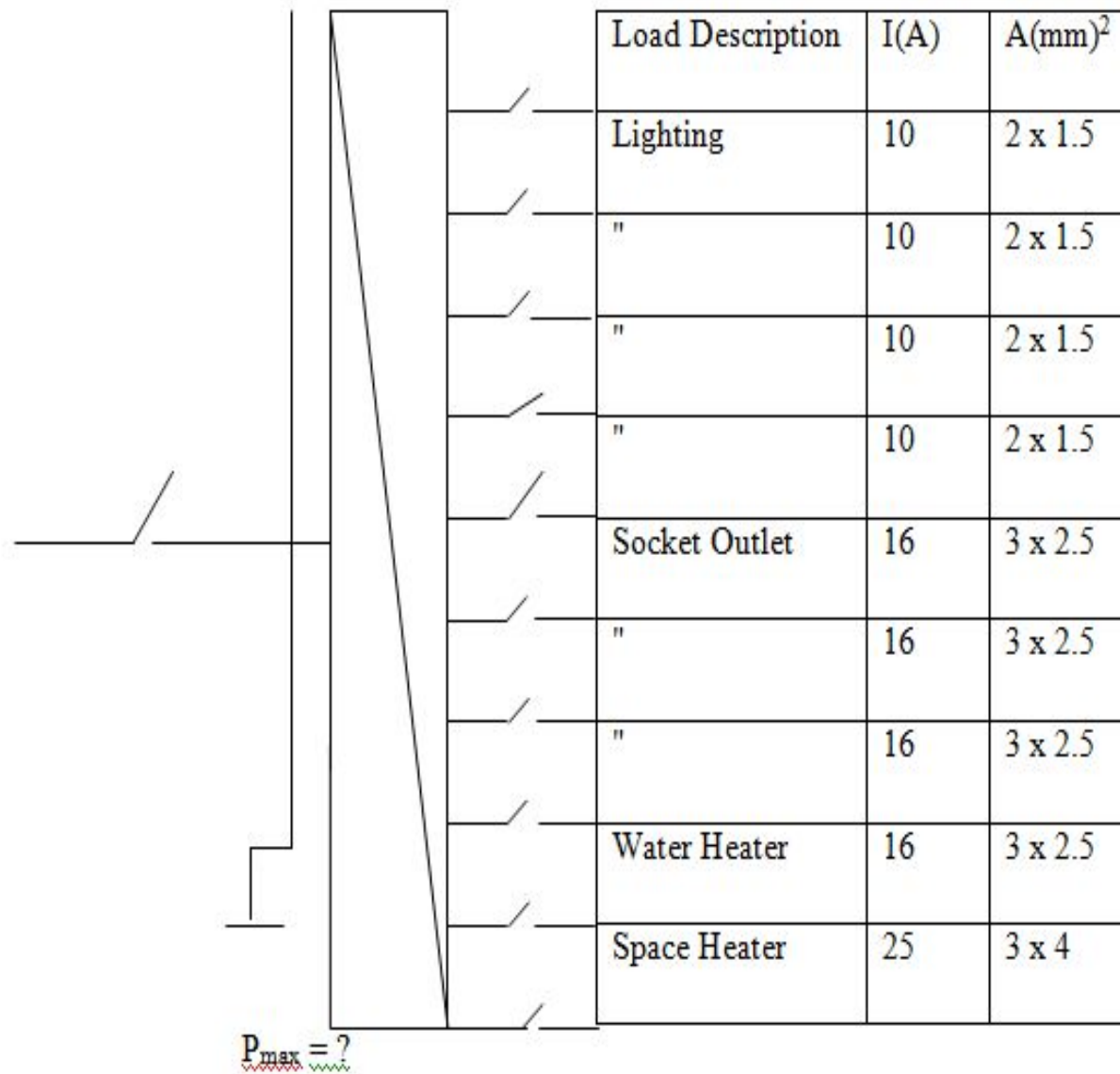
Testing for Voltage drop:

Voltage drop on the cable = $(\text{mV}/\text{Am}) * I_b * L$

Voltage drop for $25 \text{ mm}^2 = 1.7 \times 48.77 \times 100 = 8.29 \text{ V}$

Therefore selected size is 25 mm^2 conductor sizes.

Example. Consider the SDIS shown below.



- ⌘ No. of light points (lamps) per lighting circuit = 4
- ⌘ No. of sockets per circuit = 3
- ⌘ No. of space heater = 1
- ⌘ No. of water heater = 1

Determine

- ⌘ a) The estimate of maximum power demand, P_{max}
- ⌘ the rating of the main switch
- ⌘ the size of the feeder cable

Solution:

⌘ a. <u>Circuit</u>	<u>Power with DF</u>	<u>Power</u>
<u>without DF</u>		
⌘ Lighting $4 \times 220 \times 10 = 8800W$ $8800 = 6160W$		$0.7 \times$
⌘ Socket outlet $3 \times 220 \times 16 = 10560W$ $\times 10560 = 2112W$		0.2
⌘ Water heater $220 \times 16 = 3520W$ $0.2 \times 3520 = 704W$		
⌘ Space heater $220 \times 25 = 5500W$ $\times 5500 = 1100W$		0.2
⌘	28380	$P_{max} = 10076W$

$$b. \quad P = \sqrt{3} V_L I_L \cos \phi$$

$$\rightarrow I_L = \frac{P}{\sqrt{3} V_L \cos \phi}; \cos \phi \approx 1 \text{ because most of the loads are resistive}$$

$$= \frac{10076}{\sqrt{3} \times 380} = \underline{15.3A}$$

∞ Rating of main switch (MCB) is 32 A

∞ Assuming that the copper cable is enclosed in conduit, choose cable size of $A = \underline{4 \times 6\text{mm}^2}$.

∞ Standard Ratings for fuses and CBs:

6, 10, 16, 20, 25, 35, 50, 63, 80, 100, 125, 160, 224, 250, 300, etc.

∞ Maximum load estimate = $\frac{10,676 \text{ VA}}{(\cos \phi \approx 1)}$

$$I_L = \frac{10,676}{\sqrt{3} \times 380 \times 1} = 16.2A$$

$$I_n = \underline{32A}$$

$$A = 4 \times 6\text{mm}^2$$

∞



The End