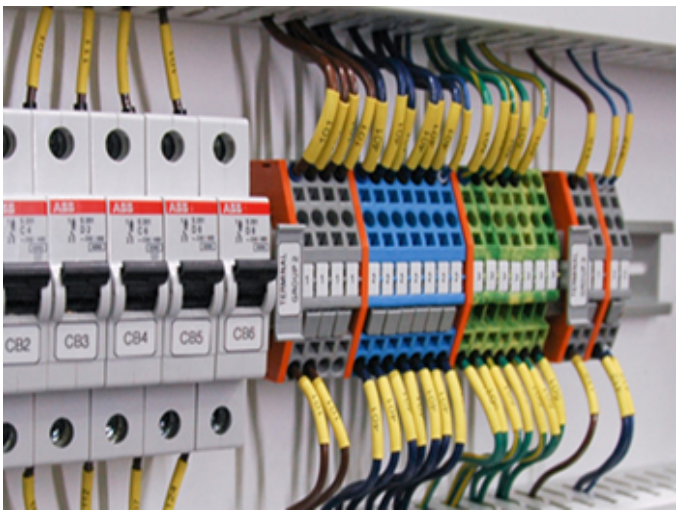
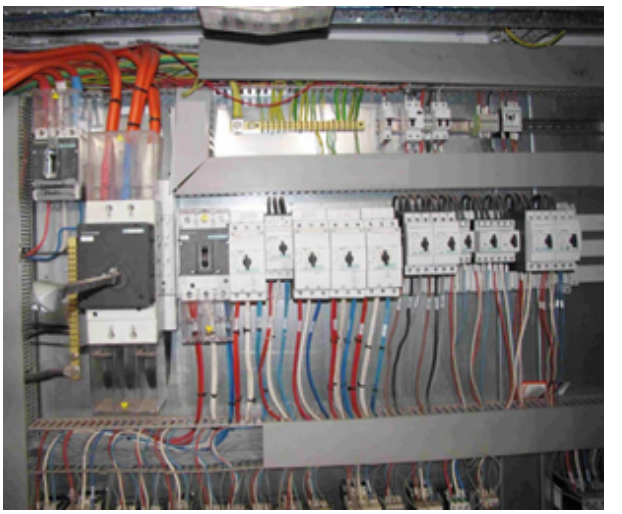
Textbook of
Industrial Electrician
Class-X





National Vocational & Technical Training Commission (NAVTTC)

Textbook of

Industrial Electrician

Grade – X

National Vocational and Technical Training Commission

H-9, Islamabad

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PREFACE

This book has been written to cater the needs of Matric-Tech to teach & train the students for the subject of Industrial Electrician. Matric-Tech is a new initiate of NAVTTC and Industrial Electrician trade is introduced first time and is highly suitable for present day needs. Key attempt has been made to make the book interesting and useful. All the chapters cover the basic details understandable to the students of Matric Tech. All chapters include assessment in form of MCQs, Short Questions & Long Questions. This book has been written to cover most of the topics to train the students in the field of Industrial Electrician. All the topics pertaining to theory & practical have been explained in a simple and convenient style. Safety practices, Introduction to drawing, communication skills have also been covered. Efforts have been made to cover all the practical aspects of the course.

The book is written to add the skills rather to learn theory only. It should be read conceptually. Perform all the activities and tasks to acquire hands on experience of the trade of Industrial electrician. Further improvement can be made on suggestions by the users.

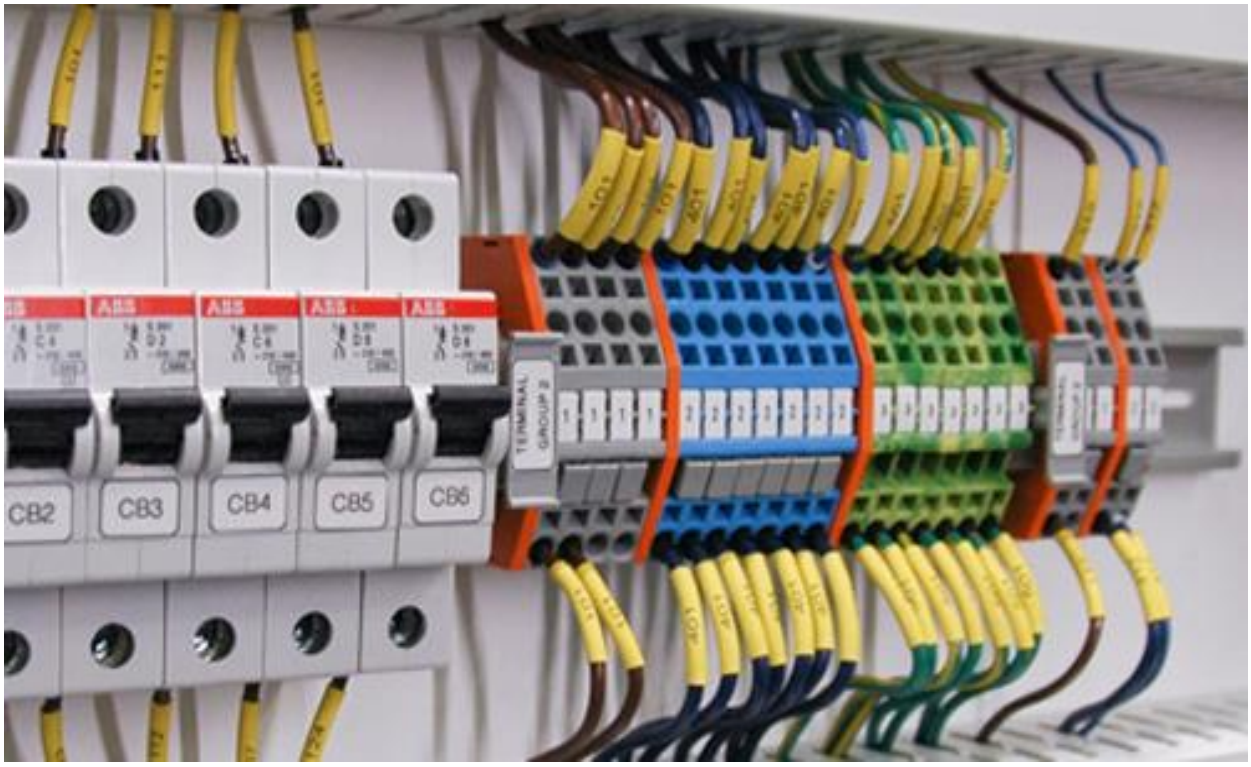
Any suggestions for the betterment of this book will be highly acknowledged. I am really thankful to NAVTTC Coordinator and evaluation tem for their cooperation & guidance.

Executive Director
National Vocational & Technical Training Commission
(NAVTTC)

Table of Contents

Chapter 1

Rules and Regulations for Wiring



Students Learning Outcomes

After studying this chapter you will be able to:

- describe all the IEE rules and regulations for electrical wiring.
- describe Pakistan electricity rules.

1.1 IEE (Institute of Electrical Engineers, London) Rules and Regulations for Electrical Wiring

Section-A

A-1: Control of Supply to Consumer's Installation.

Every consumer's installation shall be adequately controlled by switch gear readily accessible to the consumer which shall incorporate.

i. Means of Isolation
ii. Means of **Excess-Current Protection**.
iii. Means of **Earth-Leakage Protection**.

A-3: Excess Current Protection

The means of excess-current protection required by regulation A-1 (ii) shall comprise either a fuse inserted in each live conductor of the supply or a circuit-breaker having an excess-current release, fitted in each live conductor of the supply.

Exemption

The means of excess-current protection referred to in Regulation A-1 (ii) may be omitted provided that:

i. The rating of all cable connected between the supply undertaking's fuse or circuit-breaker and the consumer's sub-circuit fuses or circuit-breakers is not less than the rating of the supply undertaking's fuse or circuit-breaker, and
ii. The excess-current devices protecting all circuits controlled by the switchgear are located within the same enclosure as the switchgear or alternatively are fixed immediately adjacent to it.

A-26: Final Sub-circuits of rating exceeding 15 A

A final sub-circuit having a rating exceeding 15 amperes shall not supply more than one point except as specifically admitted in regulations A-27-29, or A-30-42, or A-43-55. For the purpose of this regulation, a cooker control unit incorporating a socket-outlet is regarded as one point.

Section-B

B-4: Type of Flexible Cables and Flexible Cords

Every flexible cable and flexible cord for use at low or medium voltage shall be selected from one of the following types and shall comply with the appropriate British Standard Specification referred to below so for as this is applicable. This regulation does not apply to a flexible cord forming part of a portable appliance which complies as a whole with a British Standard Cited in Section F of this regulation, or to special flexible cables and flexible cords for combined power and telecommunication wiring.

i. P.V.C insulate flexible cords (B.S.2004)
ii. Vulcanized rubber-insulated flexible cables and flexible cord (B.S.7).The cable may incorporate a flexible armor of galvanized steel or phosphor-bronze, or a screen of tinned copper-wire braid.
iii. Butyl-rubber insulated or ethylene-propylene rubber-insulated flexible cables and flexible cords (B.S.4180). The cable may incorporate a flexible armor of galvanized steel or phosphor-bronze, or a screen of tinned copper-wire braid.
iv. Varnished PTP fabric insulated flexible cables(B.S.3765)
v. Silicon-rubber insulated flexible cables and flexible cords (B.S.3258)
vi. Flexible cables and flexible cords insulated with varnished cambric and heat- resisting fiber (B.S.3249)
vii. Flexible cords insulated with glass fiber (B.S.4217)
viii. Trailing Cables (primarily for mining and/or quarrying) (B.S. 708 or B.S. 1116)
ix. Travelling Cable for lifts (B.S. 977)

B-12: Choice of Types of Insulation and Protective Covering of Flexible Conductor Sizes

Every flexible cable and flexible cord shall be one of the following types.

i. Braided circular
ii. Un-kinable
iii. Circular sheathed
iv. Flat-twin sheathed

v. Parallel twin; provided that this type shall be used only for wiring of fixed lighting fitting or where the cord ids not subject to abrasion or undue flexing.

vi. Twisted twin non-sheathed, insulated with rubber or general-purpose P.V.C; provided that this type shall be used only for fixed lighting fitting or for pendants which are wholly open to view, or for other applications where the cord is not subject to abrasion.

vii. Twisted twin non-sheathed, insulated with transparent P.V.C.; provided that this type shall be used only for pendants which are wholly open to view.

viii. Single-Core, twisted twin and three core, and circular twin and three core, insulated with glass fiber; provided that these types shall be used only in dry situations for lighting fittings or for other applications where the cord is not subject to abrasion or undue flexing.

Section-C

C-4: Selection for Situation

All apparatus shall be of a design appropriate to the situation in which it is to be used and its mode of installation shall take account of the conditions likely to be encountered. Apparatus intended to run unattended, shall be suitable for such operation having in mind the risk of excessive temperature rise.

C-6: Damp Situation

In damp situations, every item of apparatus shall be of the damp-and-dust proof type, and cable entries shall be provided with glands or bushings, or be suitable to receive screwed conduit. For lamp holders for a bayonet-cap lamp in any damp situation shall be earthed.

Section-D

D-1: Methods of Protection

Every item of apparatus and every conductor operating at a voltage exceeding extra-low voltage shall be effectively prevented, by one of the methods described in item i to iv below, from giving rise to danger from earth-leakage currents:

i. Enclosure in insulation which is durable and substantially continuous, i.e. “all-insulated” construction.

ii. For an appliance or a lighting fitting, double insulation where the use of this means is provided for in an appropriate British Standard.

iii. Earthing of exposed metal parts in accordance with the requirements of this section.

iv. Isolation of metal in such a way that is not liable to come into contact with live parts or with earthed metal.

Exemption

Regulation D-1 need not to be observed for apparatus and conductor which operate from a dc supply at a voltage not exceeding 110 volts, derived from a battery or dc generator, or from a double wound three phase transformer and rectifier with a suitable smoothing circuit.

D-22: Protection by Fuse and Current Circuit Breaker for Excess Current

Earth-leakage protection may be afforded by means of fuses or excess-current circuit-breakers provided that the earth fault current available to operate the protective device and so make the faulty circuit dead exceeds:

i. 3 times the current rating of any semi-enclosed fuse, or any cartridge fuse having a fusing factor exceeding 1.5, used to protect the circuit, or

ii. 2.4 times the rating of any cartridge fuse having a fusing factor exceeding 1.5, used to protect the circuit, or

iii. 1.5 times the tripping current of any excess-current circuit-breaker used to protect the circuit.

1.2 Pakistan Electricity Rules

Pakistan Electricity Rules 1937.

1) Condition of supply by licensee (Rule No. 25, 28, 29, 32, 40)

Rule No 25: Precaution against Leakage before Connection

i. A licensee shall not connect with his works the apparatus on the premises of any applicant for supply unless he is reasonable satisfied that the connection will not at the time of making the connection cause a leakage from that apparatus exceeding are five thousandth part of the maximum supply demand on the applicant's premises.

ii. If a licensee declines to make a connection in accordance with sub-rule (i), he shall serve upon the applicant a notice stating reason for so declining.

Rule No 28: Declared Pressures of Supply to Consumers

Before commencing to supply energy to a consumer, a licensee shall declare to the consumer the pressure at which he undertakes to supply energy and he shall not, without the written consent of the consumer or the precious sanction of the Provincial Government, permit the pressure to vary there from by more than 5 per cent in the case of low or medium pressure, or by more than 12 ½ per cent in the case of high pressure:

Provided that, for the purposes of testing or for any other purposes connected with the efficient working of the undertaking, the supply of the energy may be discontinued by the licensee for such period as may be necessary subject (expect in cases of emergency) to not less than twenty-four hours' notice being given by the licensee to all consumers likely to be affected by such discontinuance; and in the event of any such consumer objecting, the supply of energy shall not be discontinued (expect in cases of emergency) without the consent of the Provincial Government and subject to such conditions as it may impose.

Rule No 29: Declared Frequency of Supply to Consumer

From the time of commencing the supply of energy to a consumer by means declared frequency of supply to consumers by means of an alternating current a licensee shall declare to the consumer the frequency at which he undertakes to supply energy and the licensee shall not, without the written consent of the consumer or the previous sanction of the Provincial Government, permit the frequency to vary there from by more than 4 per cent.

Rule No 32: Limits of Errors in the Meters

The limits of error permissible, in a meter placed upon a consumer's premises in accordance with the section 26 are for the purpose of that sanction the following, namely:-

(a) Where the meter is of a type included the "British Standard Specification for Electricity Meters. No. 37" dated 1930, the limits of error laid down in the specification.

(b) Where the meter is of any other type, it shall not register more than 3 per cent, above or below absolute accuracy at tall loads in excess of one fifth of full load and up to full load.

(c) No meter shall register at no load.

Rule No 40: Cut-out (fuse) on Consumer's Premises

A licensee shall provide a suitable cut-out in each conductor of every service-line (other than an earthed neutral conductor or the earthed external conductor of a concentric cable) within a

consumer's premises, in an accessible position as close as possible to the point of entry. Such cut-out shall be contained within an adequately enclosed fire-proof receptacle:

Provided that where more than one consumer is supplied through a common service-line, each such consumer who so requires shall be provided with an independent cut-out at the point of junction to the common service.

Rule No 46: Instruction for Restoration of Persons Suffering from Electric Shock

(1) Instructions, both the English and in the vernacular (language) of the district, for the restoration of persons suffering from electric shock, shall be affixed by the owner in a conspicuous (visible) place in every generating station and sub-station, and in every factory as defined in clause (j) of section 2 of the Factories Act, 1934 (XXV) of 1934), in which electricity is used as the inspector may, by notice served on the owner, direct.

(2) Copies of the instructions shall be supplied on demand by every Inspector at the price to be fixed by the Provincial Government.

2) General precaution for safety of public (Rule 49, 51, 52, 58)

Rule No 49: Construction, Insulation and Earthing of Apparatus

(1) All apparatus shall be sufficient in power and size and of sufficient mechanical strength for the work it may be required to do, and so for as is practicable, shall be so constructed, installed, protected, worked and maintained as to prevent danger.

(2) All insulating material shall be chosen with special regard to the circumstances of its proposed use. It shall be of mechanical strength sufficient for its purpose, an so far as is practicable, shall be of such a character or so protected as fully to maintain its insulating properties under working conditions of temperature and moisture.

(3) No live parts shall be exposed as to be capable of being touched by persons not intended to have access to them.

(4) Every part of a system shall be kept efficiently insulting from earth expect that:-

(i) The neutral point of a ploy phase system may be earthed at one point only.

(ii) The mid-voltage point of any system, other than a concentric system, may be earthed at one point only.

Rule No 51: Identification of Earth and Earthed Neutral Conductors and Cutouts

In any case where the conductors include an earthed conductor of a two-wire system, or an earthed neutral conductor of multi-wire system or a conductor which is to be connected thereto, the supply of energy shall not be commenced until and unless the following provisions have been or are complied with namely:-

(1) An indication of a permanent neutral shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such conductor to be distinguished from any live conductor. Such indication shall be provided:

(a) Where the earthed or earthed neutral conductor is property of the licensee at or learned the point of commencement of supply.

(b) Where a conductor forming part of a consumer's system is to be connected to the licensee's earthed or earthed neutral conductor at the point where such connection is to be made; and

(c) In all other cases, at the point corresponding to the point of commencement of the supply or at such other point as may be approved by an inspector.

(2) No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed conductor and live conductor shall be inserted or remain inserted any earthed conductor of two-wire system or in any earthed neutral conductor of a multi-wire system or in any conductor connected thereto, with the following exceptions:

(i) A link for testing purposes, or

(ii) A switch for use in controlling a generator or transformer, or

(iii) A switch or link in the connection between the earthed conductor or the earthed neutral conductor and earth at a generating station or sub-station for use in the testing and emergencies only:

Provided that in the case of system in use prior to the 23rd December, 1932, no penalty shall attached to any breach of this Rule occurring before 23rd December, 1940.

Rule No 52: Crossing Metallic Substances

(1) Where an electric supply-line crosses, or is in proximity to, any metallic substance the owner of the supply-line shall take such precautions as an inspector may approve against the possibility of the metallic substance becoming charged.

(2) Where such metallic substance is introduced after the electric supply-line has been laid or erected, the cost incurred in taking such precautions shall be refunded to the owner of the electric supply-line by the owner of the metallic substance.

Rule No 57: Connection with earth of Frames of Generators, etc.

The frame of every generator, stationary motor, and so far as is practicable, portable motor, and the metallic parts (not intended as conductors) of all transformers and regulating of controlling apparatus connected with the supply, shall be earthed by the owner by two separate and distinct connection with earth.

Rule No 58: Connection with Earth of A Multi-Wire System

In every distributing system in which there is a neutral conductor, where the pressure between the neutral conductor and an outer or phase conductor exceeds 125 volts, the neutral conductor shall be connected with earth by two separate and distinct connections from the neutral bus-bar and in accordance with the following provisions, namely:

(a) The connection shall be made at one point only on each distinct system, namely, at the generating station or sub-station, or both as the case may be, and the insulation of the system shall be maintained at all other parts.

(b) The connection shall not be made by the aid of, nor shall it be in contact which any water-main, gas-main or similar main not belonging to the consent of the owner thereof, and of the inspector; a resistance, not exceeding 20 ohms may be inserted between the neutral bus-bar and earth, and if so inserted, it shall be of sufficient cross-sectional area to carry the current which would pass should an outer or phase conductor become accidentally connected with earth.

(c) The connection shall not be removed except for the purpose of testing in which case it shall be made good again as soon as such test is finished, and a record of any such disconnection shall be kept by the licensee or non-licensee, as the case may be;

(d) The connection shall not be removed in a licensee's system except between 1am to 3am and in a non-licensee's system, while the generator is in operation and energy is being used.

(e) The current from the neutral conductor to earth shall in the case of a licensee's direct current distributing system, be continuously recorded, and, if at any time it exceeds one-thousandth part of the maximum supply current, steps shall immediately be taken to improve the insulation of the system.

3) Electrical Supply Line and Apparatus (Rule 60, 62, 64)

Rule No 60: General Precautions Applicable to Supply at Medium or High Pressure

Where a licensee proposed to supply or use energy at medium or high pressure, he shall give notice to an inspector and shall not commence or continue the supply unless and until he has complied with the following provisions, namely:-

(a) All live parts of apparatus shall, unless accessible only to, and under the control of an authorized person, be protected by mechanically strong metal casings or metallic coverings securely fastened throughout.

(b) Suitable lined switch, of requisite capacity to carry and break the current, shall be inserted in each conductor, near the point of origin on the consumer's premises.

(c) Every conductor, unless accessible only to an authorized person shall be, as far as is practicable, completely enclosed in a mechanically strong metal casing or metallic covering, securely fastened throughout or fixed in such other manner as may be approved in writing by an inspector; and

(d) The supply to very apparatus shall be efficiently controlled by suitable linked switched, of requisite capacity to carry and break the current in each conductor, placed near the apparatus in such a position as to be readily handled by the operator, so that by their means all pressure can be cut-off from the apparatus concerned and from any device in connection therewith:

[Provided that this clause shall not supply in the case of transformers, motors and other apparatus where these are controlled by remotely operated switchgear and where suitable arrangements are made for preventing the remote switch from being closed while men are working on the transformer, motor or other apparatus controlled by the switch, or in cases where compliance with this clause would render inoperative the previsions of sub-rules (2) and (3) of Rule 62;]

(e) The word "Caution", both in English and in the vernacular, shall be affixed permanently in a conspicuous position, where possible, on every generator and every motor and every controlling, or regulating apparatus in connection with such generator or motor.

Provided that, where it is not possible to affix them on the generator motor, or apparatus, they shall be affixed as near as possible.

Provided also that, where the generator, motor, controlling or regulating apparatus, is within an enclosure accessible only to an authorized person, one notice affixed to the enclosure shall be sufficient for the purpose of this sub-rule.

Rule No 61: Main Switchboard

(not in new course)The owner of every main switchboard connected with a supply of energy at medium or high pressure shall comply with the following provisions, namely;

(a) A clear space of not less than 3 feet in width shall be provided in front of the switchboard.

(b) If there are attachments or bare connections at the back of the switchboard, the space (if any) behind the switchboard shall be either less than 9 or more than 30 inches in width, measured from the farthest outstanding part of nay attachment from conductor.

(c) If the space behind the switchboard exceeds 30 inches in width, there shall be passage-way clear to the height of not less than 6 feet, save as regards any horizontal supports of the switchboard, which may be placed at the height of not less than 4 feet 6 inches.

Rule No 62: Approval of High Pressure Supply

No licensee or non-licensee shall deliver a high pressure to any person, other than distributing licensee, except with the approval in writing of an inspector, and subject to such conditions (if any) as such inspector may think reasonable and proper in the circumstances, and the owner shall not bring the installation into use until it has been inspected by an inspector.

(3) A consumer supplied with energy at high pressure shall provide and maintain a locked weather-proof and fire-proof enclosure of agreed design and location for the purposes of housing the licensee's terminal high pressure apparatus and metering equipment. This enclosure should preferable be in a separate building to the consumer's sub-station or installation but where this is not feasible, the licensee's terminal high pressure apparatus and metering equipment shall be completely segregated from any other part of the consumer's apparatus by fireproof walls. The licensee shall, at all times, have access to the enclosure for the purposes of inspecting his apparatus.

Provided that in case of disagreement between the licensee and the consumer in regard to the design and the location of the enclosure party may appeal to the inspector.

Provided further that installations connected to the licensee's high pressure supply before the 4th December, 1943, not fulfilling the conditions of the sub-rule need not comply therewith before the 5th December, 1944.

(3) Where energy is proposed to be used at high tension be the owner or occupier not being a licensee at high pressure, he shall not bring the installation into use except with the approval, in writing, of the inspector, and such approval shall not be given until the following conditions have been complied with namely:-

(a) Every oil-field switch or switch-board, or static condenser or transformer having an oil capacity exceeding 50 gallons shall be segregated from all other apparatus by suitable fire-proof wall, and suitable oil drains and soak-pits shall be provided so as to prevent the spread of oil fires form any part to any other part of the installation.

(b) cable trenches inside sub-stations land containing cables shall be filled with sand, pebbles or similar non-inflammable materials or covered with non-inflammable slabs; and

(c) Such other conditions (if any) as the inspector may think fit to impose;

Provided that installations brought into use before the 4th December, 1943, and not fulfilling the conditions of this sub-rule, need not comply therewith before the 4th December, 1944.

(4) When the position of a high pressure motor or other apparatus is changed, notice shall forthwith be given to the inspector showing the extent and nature of the change of position.

(5) The owner of any high pressure installation (who makes any such alternation in or additions to the installation) as affect the supply shall not utilize the alternations or additions for the purposes of supply unless and until they have been approved by the inspector.

Rule No 64: High Pressure Electric Supply-Lines And Apparatus Placed Above Ground.

(1) All owners of high pressure apparatus, including every portion of anything pressure electric supply-line) other than an aerial line) placed above the surface of the ground, unless it is in a sub-station, or in a compartment specially arranged for the purpose and accessible only to authorized persons, shall ensure that is completely enclosed in, or protected by a mechanically strong metal casing or metallic covering securely fastened throughout.

Provided that this sub-rule shall not apply to neon-signs and X-rays apparatus which are operated in accordance with instructions issued by the inspector.

(2) All owners of circuits and apparatus connected with any high pressure apparatus to which sub-rule (1) is applicable shall ensure that they are marked at frequency intervals with the

word “Caution” both in English and in the Urdu. All supports of high pressure aerial lines shall be similarly marked at frequent intervals.

Key points

- Every consumer’s installation shall be adequately controlled by switch gear readily accessible to the consumer which shall incorporate.

i. Means of Isolation

ii. Means of Excess-Current Protection

iii. Means of Earth-Leakage Protection

- The means of excess-current protection required by regulation shall comprise either a fuse inserted in each live conductor of the supply or a circuit-breaker having an excess-current release, fitted in each live conductor of the supply.
- A final sub-circuit having a rating exceeding 15 amperes shall not supply more than one point except as specifically admitted in regulations
- The rating of all cable connected between the supply undertaking’s fuse or circuit-breaker and the consumer’s sub-circuit fuses or circuit-breakers is not less than the rating of the supply undertaking’s fuse or circuit-breaker.
- Earth-leakage protection may be afforded by means of fuses or excess-current circuit-breakers provided that the earth fault current available to operate the protective device and so make the faulty circuit dead. For this purpose
    - **a.** 3 times the current rating of any semi-enclosed fuse, or any cartridge fuse having a fusing factor exceeding 1.5, used to protect the circuit, or
    - **b.** 2.4 times the rating of any cartridge fuse having a fusing factor exceeding 1.5, used to protect the circuit, or
    - **c.** 1.5 times the tripping current of any excess-current circuit-breaker used to protect the circuit.

iii. A licensee shall not connect with his works the apparatus on the premises of any applicant for supply unless he is reasonable satisfied that the connection will not at the time of making the connection cause a leakage from that apparatus exceeding are five thousandth part of the maximum supply demand on the applicant’s premises.

Multiple Choice Questions

Select the most appropriate option (✓)

1. The IEE regulation A-3 speaks about
   a. Control of supply to consumer's installation
   b. Rating of final sub circuit
   c. Excess current protection
   d. Types of flexible cords and cables
2. According to the IEE regulation No A-26, a final sub circuit whose current rating exceeds 15 A, shall not supply more than.
   a. One point
   b. Two points
   c. Ten Points
   d. 15 points
3. According to the IEE regulation No A-1, every consumer installation shall be controlled by switch gear having
   a. Means of isolation
   b. Means of excess current protection
   c. Means of earth leakage protection
   d. All these
4. According to IEE regulation B-23, the limit of voltage drop from consumer's point to any load point is
   a. 2.5 % of the supply voltage
   b. 2.5V
   c. 5%
   d. 4%
5. This flexible cable shall be used only for pendant, and should be open to eye
   a. Single core non-flexible
   b. Braided circular
   c. Twisted twin non-sheathed
   d. Any of these
6. According to IEE regulation, electrical apparatus operating above extra low voltage shall be protected against leakage current by this method
   a. By enclosing it in durable insulation
   b. By providing double insulation
   c. By Earthing the exposed metal parts
   d. All these
7. Pakistan electricity rules apply on
   a. Power producing public companies
   b. Power producing private companies
   c. Persons related to electricity
   d. All these
8. Electricity rules do not apply on
   a. Power producing public companies
   b. Power producing private companies
   c. Persons related to electricity
   d.None of these

9. According to Pakistan electricity rules, this job can be completed without licence holder contractor
   a. Installing a new wiring
   b. Make changes in existing wiring
   c. Change any switch or fuse in wiring
   d. None of these
10. According to Pakistan electricity rules, max allowable change in high voltage of the declared voltage is
   a. 2.5% b. 5% c. 10% d. 12.5%
11. According to Pakistan electricity rules, electrical equipment should be made in such a way that
   a. All the consumers could buy them easily
   b. Their insulation should be strong and non-absorbent of moisture and heat
   c. Their live parts should not be bare and should be non-touchable
   d. Both b & c
12. According to electricity rule ,this voltage & higher is called "high voltage"
   a. 220V b. 440V c. 650V d. 1100V
13. For testing purpose or in case of emergency, supply company can shut down the supply
   a. At any time
   b. On 24 Hrs. Notice
   c. With the permission of government
   d. Both b & c
14. According to Pakistan electricity rules, these lines must be protect from lighting
   a. Guard wires
   b. Arial line (Overhead Lines)
   c. Barrier wires
   d. All these

ANSWER KEY

1	**c**	2	**a**	3	**d**	4	**a**
5	**c**	6	**d**	7	**d**	8	**d**
9	**c**	10	**a**	11	**d**	12	**C**
13	**d**	14	**d**				

Short Questions

Give Short Answer of the following questions.

1. What does IEE Regulation A-1 speaks about?
2. About what IEE Regulation A-3 speaks about?
3. Write IEE Regulation A-1.
4. Write IEE Regulation A-3.
5. Write IEE Regulation A-26.
6. What does IEE Regulation B-4 speaks about?
7. What does IEE Regulation B-12 speaks about?
8. What does the section "C-4" of IEE Regulations speaks about?
9. What does the IEE Regulations No C-6 speaks about?
10. What does the IEE Regulations No D-22 speaks about?
11. Write the IEE Regulation No C-4.
12. When Pakistan electricity rules were imposed and to which these are applicable?
13. Write Pakistan electricity rule No. 25
14. Write Pakistan electricity rule No. 28
15. Write Pakistan electricity rule No. 40

Long Questions

Answer the following questions in detail.

1. Describe IEE Regulation B-4
2. Explain briefly the IEE Regulation No B-12
3. Write four methods of protection against leakage current given in the IEE regulation D-1.
4. What type of instructions has been given in Pakistan electricity rule No.46?

Practical Activity

1. Observe Pakistan electricity rules and regulation in any organization and prepare a report.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Chapter 2

Estimation for Electrician Works

Students Learning Outcomes

After studying this Chapter students will be able to:

- recognize the electrical symbols as per drawing.
- explain the electrical drawing/ diagram
- interpret the electrical drawing/ diagram
- describe measuring techniques for marking of accurate location of Installations as per drawing.
- describe the importance of planning and estimation.
- explain interpretation of drawing as per job.
- explain the work planning procedure.
- calculate:
    a. material cost estimation
    b. labour cost estimation
    c. time(hours) estimation
- present estimation to the client or supervisor for agreement.
- explain the procedure for necessary adjustment, if required.

2.1 Electrical Symbols as per Drawing

Wiring diagrams use many special symbols that represent various circuit elements like, switches, bulbs, electric outlets, breakers, smoke detectors, and many more. The following table lists the most important symbols along with their names. Other than these 20 symbols, there are some lighting, electrical and telecom, and wall, shell or structure symbols that are involved in a house wiring diagram.

Elements	Symbols	Elements	Symbols
Electrical switchbox		Light bar	
Single pole switch	S	Junction Box	
Three-way switch	S_3	Lamp Holder	
1P switch		Water Heater	
2P switch		Electrical Panel	
1DP switch		Battery	
2DP switch		Fire alarm	
Water tap		Doorbell	
Wall light		Smoke detector	
Circuit breaker		Ground	

2.2 Electrical Drawing/ Diagram

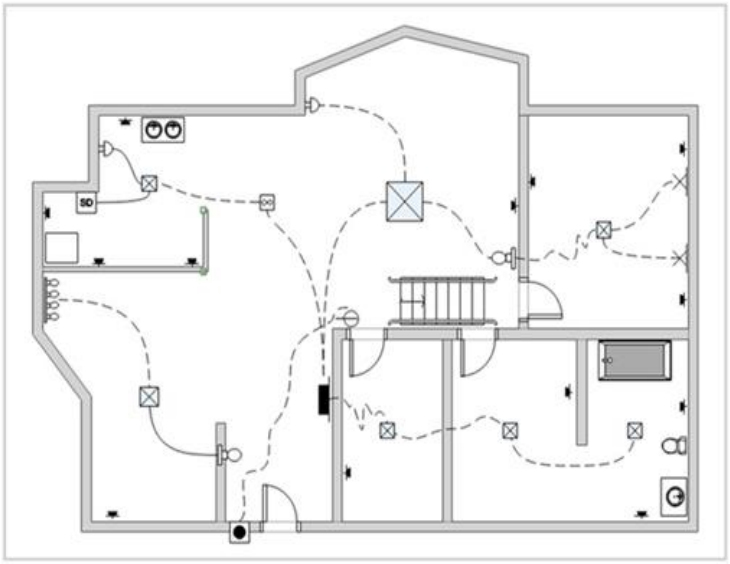


Fig. 2.1 Electrical Wiring Diagram of a House

A wiring diagram is a pictorial representation of an electric circuit, in which various elements, their connections and power source are shown in simplified shapes.

A house wiring diagram is thus, a wiring diagram of a house. It is the visual representation or design of the entire electrical wiring system or circuitry of a house (or a room) that helps in creating the system so as to distribute energy that can be used to power the various equipment and appliances around the house through proper installation and operation of the different elements included in the design such as electrical outlets, meter base, switches and breakers etc. A sample wiring diagram is shown in Fig 2.1.

2.3 Interpretation of Electrical Drawing/ Diagram

While creating a house wiring diagram, one must always keep in mind the following principles.

i. Understand the basic policy of electricity, how it flows and the positive and negative terminals of a battery and as such the circuit.
ii. Try to use CAD software such as AutoCAD and Solid Works to draw and design the diagram. It makes it easy and quick to draw up the planning.
iii. Know what the standard voltages are (220V/ 50Hz)
iv. Understand the meanings of the various symbols and place them accurately in your diagram.
v. Specify the length and make of the wires to be used.

These are just a few of the principles associated with House Wiring. A typical house wiring diagram is shown in figure below.

In this section, we are going to take a look at the example of house wiring diagram, comprising of bedroom, bathroom, and study room and living room of a house.

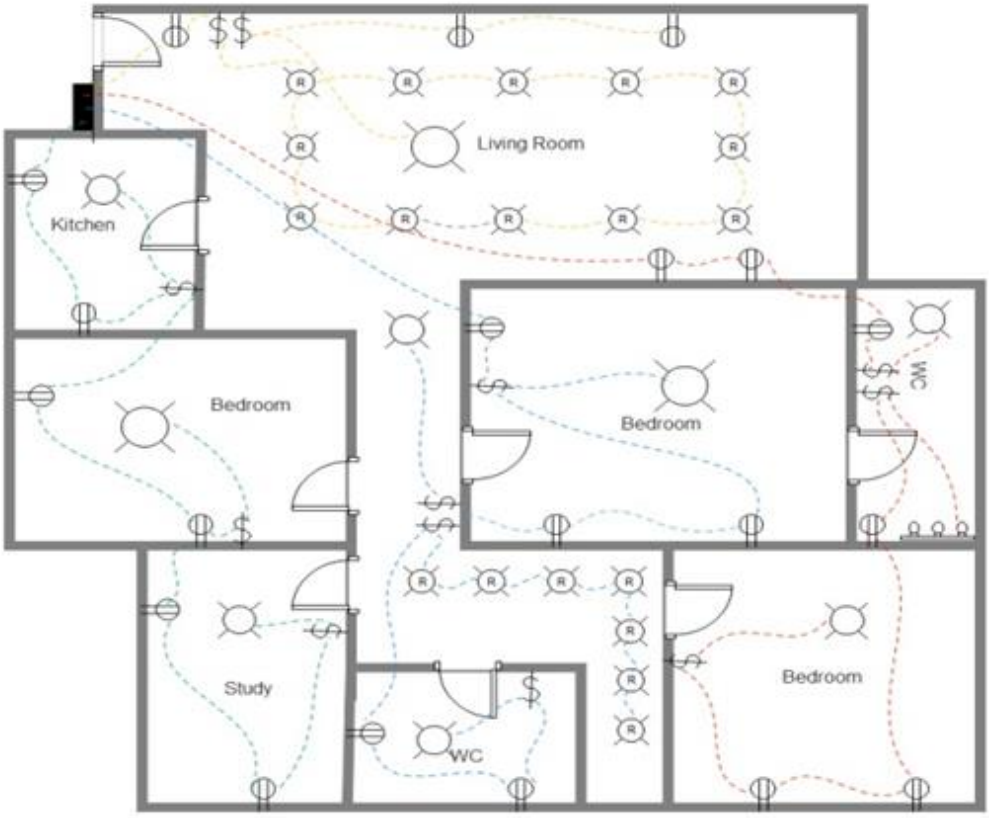


Fig. 2.2 Example of House Wiring

Activity 2.1
Identify the electrical symbols as per drawing.
Components/Instruments
Get Various Electrical Drawings (Building Electrician)
Step 1: Arrange the class in small groups Say 05 Students in each Group) Step 2: Assign them how to read the drawing and understand drawing legends. Step 3: Students should make manual sketching and practicing. Step 4: Same practice can be related to any advanced electrical system.

2.4 Measuring Techniques for Marking of Accurate Location of Installations as Per Drawing

Many types of tools are used to make a cost estimation of an electrical project. All the tools and instruments which are used to make estimates for an electrical project are called estimating tools. Generally, an electrical drawing is required to prepare an estimate of the project. Few tools are required to facilitate estimating and considering their utility, the cost of these tools is justified. The importance of such tools depends upon the ability of the estimator. These tools save time and ensure accuracy in the estimates for electrical circuits.

The Commonly used tools in electrical estimating are as follows.

i. Map Measure

It is the most valuable tool used by the estimators of electrical estimating. It resembles closely with an ordinary pocket watch. It is used to measure feeder and branch circuit runs. It is approximately 1.75 inches in diameter and 0.5625 inches in thickness. It has a reset pin on the top and a contact wheel on the bottom. There are three dials on the face (one large and two small), Each of the dials has an indicating hand. The large hand indicates inches and the two small hands indicate feet. One small dial is marked for 0 to 10 ft and the other one indicates for 0 to 100 ft.

Fig. 2.3 Dial type (a) and digital map measurer (b)

The contact wheel has small gear like grooves to prevent slipping. The small pin-type stem helps to prevent accidental resetting. Crystals are recommended to be unbreakable. New, as well as used instruments, should also be checked. The hands may become loose or slightly shifted if the tool is dropped.

While taking measurements (when large quantities are taken off for each reading) it is not necessary to reduce the instrument readings to inches. The indicated feet can be read directly as plant feet. For every instrument, foot readings can be 50 plan feel for 0.25-inch scale, 100 plan feet for 0.125 inch scale, and 200 plan feet for 0.0625-inch scale. That will introduce approximately 5% overrun, which will compensate for shrinkage.

ii. Tape Measure

Some estimators prefer the tape measurements to the map measure. There are 0.1875 inch steel tapes available in the market, which have foot markings for direct readings.

The special marking is on each foot of the tape. A 0.25 inch scale has a "48 ft" marking at the 12 inch point, a "96 ft" marking at the 24-inch point, and so on. Other markings are at 0.25 inch intervals. In the same way, the 0.125-inch scale tape has "96 ft," "192 ft," and similar markings at 12 inch intervals with intermediate markings at 0.125 inch intervals.

Fig. 2.4 Tape Measure of 5 meter length

iii. Architect's Scale

The scale has to be set to make the layout plan of very large sized buildings on a drawing sheet. This is because it becomes difficult to display a large drawing on a drawing sheet without setting a scale. For example, a length of 1 meter can be displayed on a drawing sheet by 1 cm. For this, there are cards of different scales called Architect Scale.

Fig. 2.5 Architects Scale

iv. The Tally

A tally is a mechanical, electronic, or software device that is used for accounting or adding. Electronic or digital tile counters are now widely available. A mechanical tile counter has an iron or a plastic cylindrical body.

Fig. 2..6: Electronic (a), Mechanical (b) and hand tally counters (c)

Any estimate that involves a large number of items, justifies the use of a tally. Examples are the inclusion of light fixtures, light plugs, power plugs in a multi-story building. The estimator uses the tally to record the count so that one can stop at the appropriate time to study the details or make notes. One should take-of only limited quantities at a time and make use of tally to double-check the manual count.

v. C-Clamps

An ordinary 3 inch size flexible C-Clamps may be used for clamping large sets of plans to the end of the estimating tables. It helps to organize the workplace for an estimator within the minimum space. That also reduces the space taken up by plans to a minimum, and as the sheets are turned over, their weight will not pull the set off the table. It is often necessary to tum sheets back and forth for reference purposes. It is much easier to handle them with clamps on the table than it is to have to fold them under.

Fig. 2.7: C-Clamp

vi. Slide Rule

The slide rule is a mechanical type measuring tool that is very helpful in basic mathematical operations like addition, subtraction, division, and multiplication. Its also known as a mechanical based mathematical machine that can further perform LCM, trigonometric and logarithmic functions. The slide rules have uniform scales.

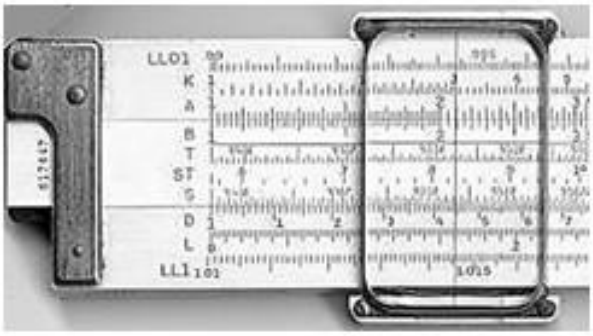


Fig. 2.8: Slide Rule

vii. Drawing Board and Related Instruments

The drawing sheet is fixed on a wooden board for drawing is known as a drawing board. The drawing sheets are fixed on these drawing boards firmly with transparent tape. There are advanced level drawing tables and drafting tables that have a facility of sheet fixation and rules to draw lineshorizontally, vertically, or at any angle very precisely.

Fig. 2.9: Modern day drawing table

viii. Colored Pencils & Chalk

The different colored pencils are used in electrical out plans to distinguish the different wiring circuits. These color pencils must be soft enough so that they can be erased with the help of an eraser or with cleaning liquid used for cleaning purposes. The crayons are also used for making drawings on the boards.

ix. Plan Cleaning Fluids

To modify the drawing on a drawing sheet, there is always a need for cleaning liquids. There are so many cleaning liquids available in the market such as Benzine, Naphtha, or Carbon Tatra-chloride used to clean the marks of colored pencils.

2.5 Planning and Estimation

Planning

The process of thinking about the activities required to achieve a desired goal is called planning. It is the first and foremost activity to achieve desired results. Without Planning it is impossible to complete any project.

For example Electrical wiring design for a specific building begins with an analysis of the type of building, electrical load and source of supply. Consideration must be taken of the activities performed in the building and the nature of electrical usage by the occupants.

Activity 2.2
Perform the measurement for accurate location of installation as per the drawing.
Components/Instruments
Get Various Electrical Drawings (Building Electrician), Measuring Instrument
Step 1: Arrange the class in small groups Say 05 Students in each Group) Step 2: Assign them how to read the drawing, locate the specific installation and make measurement. Step 3: Practice for various objects and make the record. Step 4: Same practice can be related to any advanced electrical system drawing.

Estimation

Estimation means determining the quantities of various items required to execute a job and to assess the cost of the execution. The cost is determined by consulting the price catalog and schedule of labor rates.

The various steps for estimation are:

i. Chalk out a list of items and quantities required.
ii. Consult the rate catalogs for pricing the various items.
iii. Assess the exact number of workmen required to complete the job. After consulting the schedule of labor rates add the labor cost to the estimate under preparation.
iv. It should be noted that the number of workmen required is dependent upon the time limit fixed to complete the service.
v. Add supervision charges and executor's profit.

Importance of Planning and Estimation

Planning and estimation of electrical system of any building or outdoor area is to install conductors and other appliances in such a way that electric current should be delivered to all lamps, motors and other appliances in safe and effective manner. Planning and estimation will help the designer while preparing design of electrical system.

The Electrical Design will be having complete wiring diagram, single-line diagram, Isometric Drawing, sketches and detailed drawing etc.

Drawbacks of Starting Project without Planning

Staring project without Planning is never ever tolerable. It will effect project badly. Some drawbacks are:

i. Project is most likely to be cost overrun.
ii. Project deadlines will be missed.
iii. Frustration in team members due to non-sequential activities.
iv. Scope expectations will be missed.
v. Quality will be compromised

2.6 Work Planning Procedure

Necessary Steps to be considered for Planning of residential building wiring can be as follows.

i. Selection of Wiring System

This is necessary step to select suitable wiring system. It depends on operating condition of building. For example Batten wiring can be used for residential building, but it will not serve purpose if it is used in steel/iron mills where high temperature can damage the insulation of cables.

ii. Distribution of Electrical System in different Circuits

Keeping the load in mind, it is necessary to distribute electrical system in different circuits while planning electrical system.

iii. Estimation of Load

To calculate load, the loads of main, sub main cable, fuse, lamps, sockets and fixed appliances to be added. Sometimes full load is consumed at a time, but mostly 70% of the load is not used at a time.

iv. Selection of Cable size

Size of the cable is the main factor while designing electrical system. As load of each circuit is different, so cable size should be selected based on following points Current carrying capacity of conductor

a. Voltage drop.
b. Minimum permissible cable size

v. Selection of Switchgear size

Switchgear size will be based on maximum current of the load in any installation. In large buildings, as the load is expected to be increased in future; so switchgear size is taken as 1.2 times of the total load current. It will help in case of loading on switchgear; there will not be any damage to switchgear.

vi. Selection of Fuse Wire

Fuse rating is based on the current rating of the minimum sized cable in the sub circuit.

vii. Availability of Accessories

While planning, it should be checked whether these materials are available in local market or not?

viii. Present Load and Future Capacity

Installation design should bear all present loads and also if load is increased, it should allow to this increased load.

ix. Standard Voltage for Equipment

Standard Voltage should be checked before installation of any equipment and also which voltage is provided by Supply Company? Therefore, Transformer, Switchgear and other electrical equipment's should have same standard voltage.

x. Safety Precautions

Safety precautions should be kept in mind while designing electrical Installations. These should be designed based on National Electrical Safety Code. Safety precautions could be different for different equipments.

xi. Flexibility

A good design should be flexible. It should allow for transfer for any motor, panel board etc. from one place to other.

xii. Reliability

A good design should be reliable. It should work in every circumstance like natural disasters (Rain, Thunder storm, Earthquake etc.)

2.7 Electrical Project Cost Estimation

It is very important to determine the estimation of the total cost of an electrical project before starts. Cost estimation is a fundamental need because it is not possible to assign a contract for the electrical project without cost estimation.

An electrical project without proper estimation suffers from so many difficulties and it will become impossible to complete it right on time and project will become over budget. The total expenditures of an electrical project include:

a. Material Cost
b. Labor Cost
c. Time (Hours)

Material Cost

It is very important to estimate the cost of material used for an electrical project. The cost of material depends on the quality of the material. To determine the cost of a material, it is important to prepare a list of materials used in the project with its complete specifications. The per-unit cost of the material is taken from the market so that the total cost of the material can be easily calculated. A similar procedure is adopted for all types of materials. There are so many other factors that can affect the cost of material such as quality of material, variation in market rates and change in the specification and brand.

Labor Cost

In order to complete a major power project, the salaries of all the people involved in the project are included in the labor cost. In small electrical projects, for example, the labor cost of a building's electrification involves the labor of an electrician and his helper. The labor cost depends on the nature of the project, the nature of the work, and the labor market.

Determination of Labor Cost

The labor cost for an electrical project can be determined by three methods.

i. Labor cost/point
ii. Per day labor cost of skilled and semi-skilled labor
iii. Percentage of total cost of material

In the first method, labor cost is given according to the per-point installation in the building. The per-point labor also depends upon the type of wiring. The ceiling fan, lamp or light point, and

socket with its control switch are considered one point. The switchboard is considered as two points. In a concealed wiring, a bell push button from the main gate to the location where the doorbell is installed, considered as six points. Similarly, all points in the wiring are multiplied with the fixed labor cost per point to calculate the total labor cost.

In the second method, all the workers including electricians engaged in the work are paid according to their fixed wage per day. The per day wages of the workers vary according to the skill and type of their work.

In the third method, the labor cost is considered 15% to 20% of the total material cost. The labor cost depends upon the size of the project. In small electrical projects, there is only a need for an electrician whereas in large electrical projects all kinds of staff including designers, supervisors, and engineers are also required. So labor cost depends upon the size of the electrical project, type of electrical work, weather conditions of the workplace place availability of the skilled labor, and their wages.

Time (Hours)

Normally a time frame is given to the electrical contractor for electrical installations. In case the civil works are associated with the electrical works, the contactor have to be in proper coordination with civil contractor or main contractor for the execution of his electrical jobs.

Activity 2.4:
Prepare the list of the materials as per job specifications and drawing.
Components/Instruments :
Get Various Electrical Drawings (Building Electrician), Writing Material
Step 1: Arrange the class in small groups Step 2: Read the drawing and perform estimation of material required in a project Step 3: Prepare the list of material as per job specification

2.8 Presenting estimation to the client or Supervisor for Agreement

Estimation is a system of compiling information to facilitate competitive tendering and is seen as the technical process of predicting the cost of the project. It will involve the studying of contract documents, drawing and specification etc. in order to assess the material and labor necessary for carrying out the project. As a first step information regarding the project is collected from the competent authority to prepare an estimate of the job. Assuming that all the standard procedures for checking the suitability of an inquiry has been implemented regarding the following information.

i. Type of work.
ii. Period of tender.
iii. Competition.
iv. Proposed program of work.
v. Fulfill legal requirements if any.

After acquiring the basic information, the estimator needs to follow the following steps for the preparation of cost or the price of whole job.

i. Contract conditions checklist.
ii. Segregate the project into identifiable sections.
iii. Send out written inquiries to suppliers/sub-contractors for specified material,
iv. Lift off quantities.
v. Cost sheets and labor running times.
vi. Section summary sheet.
vii. Labor hourly rates.
viii. Preliminary sheets
ix. Complete section summary sheet.
x. Complete tender summary sheet.

2.9 Procedure for Necessary Adjustment (If Required)

At the completion of the project, the drawing is modified as per the changes which have been finally implemented. The necessary adjustments are incorporated in the drawing and this drawing is called in built drawing.

Activity 2.5:
Make necessary adjustment as per the requirement of client.
Components/Instruments :
Initial drawings, client demand and specification
Step 1: Understand client requirement Step 2: Modify the drawing as per client requirement Step 3: Finalize work

Key points

1. Wiring diagrams use many special symbols that represent various circuit elements like, switches, bulbs, electric outlets, breakers, smoke detectors, and many more.
2. A wiring diagram is a pictorial representation of an electric circuit, in which various elements, their connections and power source are shown in simplified shapes.
3. Many types of tools are used to make a cost estimation of an electrical project. All the tools and instruments which are used to make estimates for an electrical project are called estimating tools. These are map tape, measuring tape, Architect scale, The Tally & C-Clamp etc.
4. The process of thinking about the activities required to achieve a desired goal is called **Planning.** It is the first and foremost activity to achieve desired results.
5. **Estimating** means determining the quantities of various items required to execute a job and to assess the cost of the execution. The cost is determined by him by consulting the price catalog and schedule of labor rates.
6. Electrical Project Cost Estimation is very important to determine the estimation of the total cost of an electrical project before its start. In a contract situation, cost estimation is a fundamental need because it is not possible to assign a contract for the electrical project without cost estimation.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Exercise

Select the most appropriate option (✓)

1. A pictorial representation for an electric circuit in which various elements, their connection and power source are shown is called:

a. Wiring diagram b. Wiring plan c. Wiring BOQ d. Wiring Schedule

2. The most valuable tool used by the estimators for electrical estimation is ----------

a. Tape Measure b. Map Measure c. Architect Scale d. Tally

3. A mechanical type measuring tool that is very helpful in basic mathematical operations like addition, subtraction, division, and multiplication is:

a. Simple Ruler b. Slide Rule c. Vernier Caliper d. Micrometer Screw Gauge

4. The process of thinking about the activities required to achieve a desired goal is called **:**

a. Planning b. Estimation c. Execution d. Implementation

5. Procedure of determining the quantities of various items required to execute a job and to assess the cost of the execution.

a. Planning b. Estimation c. Review d. Installation

Answer Key

1.a	2.b	3.b	4.a	5.b

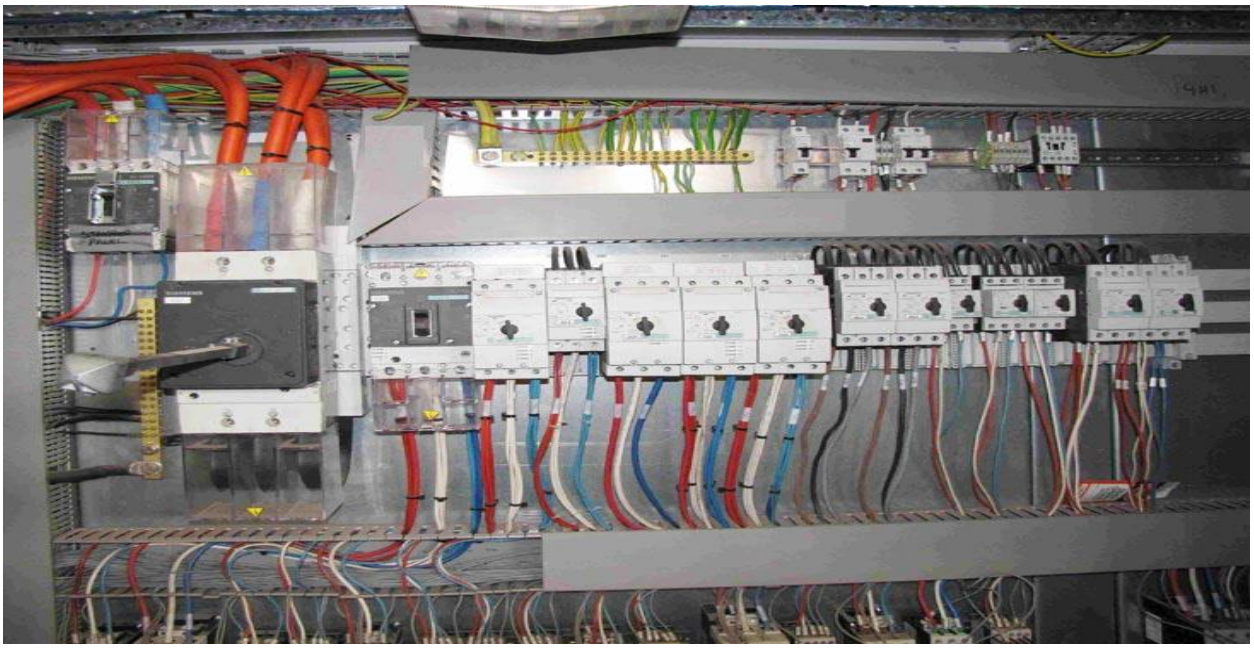
Give Short answer to the following questions.

1. What is a wiring diagram?
2. Enlist few points while creating a house wiring diagram.
3. Describe the use of C-Clamp.
4. What is a tape measure?
5. Define map measure.
6. Define Estimation.
7. Define planning.
8. What do you mean by labor cost?
9. Enlist three steps for work planning procedure.
10. What is a necessary adjustment?

Answer the following questions in detail.

1. Enlist the measuring techniques for marking of accurate location installations as per the drawing and explain any two of them.
2. Define estimation and enlist various steps for estimation.
3. Describe the work planning procedure in detail.

Chapter 3: Industrial Wiring



Students Learning Outcomes

After studying this chapter you will be able to

- explain the devices/fixtures consider for load calculations.
- describe specifications of the devices.
- describe the procedure and formulae for load calculations.
- explain load distribution techniques in industrial wiring
- explain 3 phase industrial wiring.
- explain industrial wiring layout diagram.
- describe interpretation of the drawing for three phase wiring.

3.1 Devices / Fixtures for Load Calculations with their Specifications

1. Switches

These are used to make or break the electric circuit (or to change the direction of current flow) manually.

a. **Types of switches with respect to poles**
   Single pole (SP), Double pole (DP), Triple pole (TP), Four pole (TP&N).
b. **Types of switches with respect to materials**
   Iron clad (for TP and TP& N), Bakelite, Bakelite with porcelain base.
c. **Types of switches with respect to throw**
   Single throw and double throw. Simple piano type switch fitted in your room to control the fan is an example of single throw switch while change over switch is an example of double throw switch.
d. **Types of switches with respect to ways**
   One way, two way and intermediate (4 way in USA).
e. **Space between switch contacts on opening for 230V** 6mm
f. **Working voltage:** 250V and 500V.
g. **Current Rating:** Variable (mA-A)
h. **Main Switch**

As the name indicates this switch is used to switch "ON or "OFF" the main supply. In other words these switches are used to control the whole supply for a house, office and machine. In single-phase circuit I.C.D.P. main switches are used, whereas in three-phase circuits I.C.T.P. main switches are used to control the supply. The main switches are of the following type

i. **Bakelite DP main switch:** Bakelite Double Pole main switches are used to control single-phase supply at homes and shops. These are available in 15 Amp and 30 Amp current ratings. These are used to make and break phase and neutral wires at the same time.
ii. **I.C.D.P. Switch:** Iron Clad Double Pole main switch is used in single-phase supply circuits. These are available in 15 Amp, 30 Amp, 60 Amps and 100 amperes current rating. In these switches, either two numbers of fuse links are provided or a fuse link and a neutral link is provided. The neutral wire is directly connected with the neutral link and phase wire is

connected with the fuse link. Normally 15 Amp current rating main switches are made of plastic molding instead of iron.

iii. **I.C.T.P Switch**: Iron Clad Triple Pole main switches are used to control the three phase supply circuit. These are available in 15 Amp, 30 Amp, 60 Amp, 100 Amp, 150 Amp, 200 Amp, 250Amp and 300Amp current rating. Generally these switches are also known as 3 phase 4 wires main switches. In these switches, three fuses and a neutral link is available. The neutral wire is directly connected with the neutral link and phase wires are connected with these fuse links.

2. Socket Outlets

These are fitted in wiring to give supply to the portable appliances by inserting a plug in the receptacles (tubes) of the sockets. Their proper quantity installed in the building reduces the extra use of loose wires which may lead to any accident.

Every socket outlet should be controlled by a separate switch. Switch sockets have a switch fitted in the socket body. These may be three pin five pin or universal type. Three pin 30A switch socket is called power socket. Socket above 30 A should not be used.

Types of Socket outlets with respect to pins: Two pins and three pins

a. Shape of pins: flat or round.

b. Current rating

Two pin 2A, 5A, 13A and 15A, Industrial: 16, 30, 32, 63and 125A.

c. Working voltage: 250V

d. Materials: Bakelite, Bakelite with porcelain base for higher ratings.

e. Fitting: Surface type or flush type.

3. Plugs

Plug is connected at the end of the flexible cord (supply lead) of portable electrical appliances. It is then inserted into the socket tubes to get supply for that appliance. Plugs may have two or three (straight flat, straight round) pins. These pins are made of phosphor bronze or hard drawn brass either solid or slotted. Slotted pins form the spring to make better contact with socket tubes.

A fused plug has a cartridge fuse in it. The three pins of three pin fused plugs are clearly marked L (for line), N (for Neutral) and E (for earth). Male and female plugs are just like socket and plug. Ratings are similar to sockets.

Around the world, different types of plugs are used. Their names are:

Type A,Type B,Type C,Type D,Type E,Type F,Type G,Type H,Type I,Type J,Type K,Type L,Type M,Type N,Type O.

In Pakistan, Type C, Type D, Type G and Type M plugs are used.

The Type C Plug has only two pins (phase and neutral) and current rating of2.5A, voltage range of 220-240V.The pins of the Type C Plug (& Socket) have a diameter of .16"-.19" (4-4.8 mm), length of 0.75"(19 mm), and are fitted with a .39"(10 mm) insulating sleeve. The two pins are set .69"-.73" (17.5-18.6 mm) apart.

4. Fuses

It is the most common and important type of safety device used for domestic and commercial installations. These fuses are of kit-Kat type and are also known as cut-out. These cut-outs are made of porcelain in current rating of 15 to 300 amperes. The material used as a fuse wire is tin, lead, silver, antimony, copper and aluminum etc. Copper or lead, tin alloy is mostly used in ordinary fuse wire.

i. **Rewire able type fuse** also called kit Kat fuse. An old and cheap type. It is semi enclosed type fuse and not very reliable. Its fusing factor is 2. Standard Current rating of tinned wire rewire able fuse is3,5,10,15, 20, 25, 30, 45, 60,80 and 100A. Voltage rating: 250 and 500V

ii. **Cartridge type Fuse:** Cartridge fuses are totally enclosed type fuse. Glass body is used for low currents and ceramic body for high current. Standard Current Ratings of Cartridge type fuse are as under: Fraction of an ampere to 600A. Voltage rating: 250 and 500V and above

iii. **HBC** (old name HRC) **type fuse**. Blade Type and Bolted Type
Standard Current Ratings of HBC fuse are as under:2,4,6,10,15,20,25,30,35,40,60,80,100,125,160,200,250,300A

Voltage rating: 250V

Body material

i. Rewire able fuses: Bakelite or ceramic
ii. Cartridge fuses: Glass or porcelain
iii. HBC fuses: Quartz or porcelain

5. Distribution Box/Board

The term distribution Box/ Board It is used to distribute electrical energy to final sub circuits or to other sub distribution boards in the installation. It is usually made with sheet steel. It has some protective devices (fuses, MCCBs or MCBs), line, earth and neutral bus bar, installed in it. Phase indicator lights, voltmeter, ampere meter and volt & am meter selector switch ore optional. No. of sub circuits through holes in the body. These are called "ways". Number of ways may be from 2, 3, 4, 5, 6, 8, 10, 12…….. to 42

Fig. 3.1 Distribution Board

Current rating may be from few amperes to thousands ampere and voltage 250V and 500V or above.

Two types are:

- **a.** Main distribution box/board(MDB)
- **b.** Sub distribution box/board (SDB)

6. MCCB & MCB

A circuit breaker is a protective device used to make and break the electric circuit both in normal (manually) or abnormal (automatically) conditions. Moulded case circuit breakers are usually used as main circuit breaker and miniature circuit breakers are used as branch circuit breakers.

Current Ratings:

0.5,1,1.5,2,3,4,5,67,8,10,15,16,20,25,30,32,35,40,50,63,80,100,125,1510,175,200,225,250,300,350,400,500,630,800A

Working Voltage*:* 250,380,400,500,660V

7. Light Fixtures

Different light fittings are used for illumination purpose starting from 5-80 Watts.

Fig. 3.2 Light Fitting

8. Ceiling Fans

Power consumption: 60-120 Watts

9. Electric Refrigerators

Power Consumption = 140 Watts-400 Watts

10. Air Fryer

Power Consumption = 1000 Watts

Fig. 3.3 Air Fryer

11. Hot Water Immersion Heater

Power Consumption = 3000Watts

12. Air Conditioner

Power Consumption = 1000-4000 Watts

13. Inverter AC

Power Consumption = 1300-1800 Watts

14. Exhaust Fan

Power Consumption = 200 Watts

15. Electric Oven

Power Consumption = 2200 Watts

16. Electric Iron

Power Consumption = 1000 Watts

17. Electric Kettle

Power Consumption = 1200-3000 Watts

18. LED TV

Power Consumption = 60-140 Watts

19. Automatic Washing Machine

Power Consumption = 300-1500 Watts

3.2 Procedure and Formula for Load Calculations

The understanding capacity and load becomes necessary if we are planning the electrical service for a new home.

Understanding the load needs will let you choose an electrical service with an appropriate capacity. In older homes, it's extremely common for the existing service to be badly undersized for the needs of all the modern appliances and features now in use.

Fig. 3.4 Load Calculations

The term "Electrical Load Capacity" refers to the total amount of power provided by the main source of electricity for use by your home's branch circuits and the lights, outlets, and appliances connected to them.

Total electrical capacity of an electrical service is measured in amperage (amps).It may vary from few amperes to several amperes, depending upon the size of house.

Understanding Electrical Capacity

Calculating how much power your home needs is a matter of calculating the amperage load of all the various appliances and fixtures, then building in a margin of safety. Generally, it's recommended that the load should never exceed 80 percent of the electrical service's capacity.

To evaluate the load you need to understand the relationship between watts, volts, and amps. These three common electrical terms have a mathematical relationship that can be expressed as follows:

- Volts x Amps = Watts
- Amps = Watts/Volts

These formulas can be used to calculate the capacity and loads of individual circuits, as well as for the entire electrical service. For example, a 20-amp, 120-volt branch circuit has a total capacity of 2,400 watts (20 amps x 120 volts). Since the standard recommendation is for the load to total no more than 80 percent of the capacity, this means that the 20-amp circuit has a realistic capacity of 1920 watts. So to avoid the danger of circuit overloads, all the light fixtures and plug-in appliances together on this circuit should consume no more than 1,920 watts of power.

It is fairly easy to read the wattage ratings of the light bulbs, television sets, and other appliances on the circuit to determine if a circuit is likely to overload. For example, if you routinely plug a 1500-watt space heater into a circuit, and run several light fixtures or lamps with 100-watt bulbs on the same circuit, you have already used up-most of the safe watt capacity.

For a load of 100 amperes, the same formula can be used to determine the capacity of the house's overall electrical service. Because a home's main service is 220 volts, the math looks like this:

- 220 volts x 100 amps = 22,000 watts
- 80 percent of 22,000 watts = 17,600 Watts

In other words, a 100-amp electrical service should be expected to provide no more than 17,600 watts of power load at any given time.

Load Calculation

After you know the capacity of individual circuits and of the home's full electrical service, you can then compare this with the load, which you can calculate simply by adding up the wattage ratings of all the various fixtures and appliances that will be drawing power at the same time.

You might think this involves adding up the wattage of all the light fixture light bulbs, all the plug-in appliances, and all the hard-wired appliances, and then comparing this to the total capacity. But it is rare for all electrical appliances and fixtures to run at the same time. Electricians suggest a simple rule-of-thumb as follows:

- 100-amp service is generally large enough to power a small- to moderate-sized home's general branch circuits, plus one or two electric appliances, such as a range, water heater, or clothes dryer. This service may be sufficient for a home under 2,500 square feet if the heating appliances run on gas.
- 200-amp service will handle the same load as 100-amp service, plus electric appliances and electric heating/cooling equipment in homes up to about 3,000 square feet in size.
- 300- or 400-amp service is recommended for large homes (more than 3,500 square feet) with all-electric appliances and electric heating/cooling equipment. This service size is recommended where the expected electric heat load is over 20,000 watts. A 300- or 400-amp service is usually provided by installing two service panels—one providing 200 amps and a second providing another 100 or 200 amps.

Plan for the Future

It is generally a good idea to oversize an electrical service to make future expansion possible. In the same way that 100-amp service quickly became undersized when electric appliances become common, today's 200-amp service may someday seem badly undersized when you find yourself recharging two or three electric cars. An oversized electrical service will also make it possible to run a sub-panel out to your garage or shed if you someday choose to take up woodworking, welding, pottery, or another hobby requiring lots of power.

Activity 3.1 Calculate load of the classroom/workshop with the given fixtures/devices.
Components/Instruments Fixtures and devices, Calculator and Writing Material
Step 1: Identify the devices/fixtures available in the target area Step 2: Identify power consumption of each fixture/device Step 3: Calculate total load/power for the classroom/workshop

3.3 3-Phase Industrial Wiring

A single phase system consists of just two conductors (wires). One is called the phase (sometimes line, live or hot), through which the current flows and the other is called neutral, which acts as a return path to complete the circuit.

In a three – phase system, we have a minimum of three conductors or wires carrying AC voltages. It is more economical to transmit power using a 3 – phase power supply when compared to a single phase power supply as a three – phase supply can transmit three times the power with just three conductors when compared to a two – conductor single – phase power supply.

Hence, most of the power generated and distributed is actually a 3 – phase power (but majority of households will receive a single phase supply).

The need for three-phase supply or service occurs when heavy equipment are present such as large motors (beyond 5 HP motors), because such large equipment need high starting and running currents. Large buildings, plants and offices have greater power requirements than the power used in domestic installations. Therefore, generally they are often installed with three phase wiring or three-phase supply.

The three-phase power service is generally used for high power rated equipment such as large air conditioners, high rated pump sets, air compressors and high torque motors. Therefore, it is rarely used for domestic installations, but commonly used in commercial buildings, offices and industrial installations.

Activity 3.2 Identify 2-phase and 3-phase electrical wiring system.
Components/Instruments Distribution Board/Panel, 2-phase and 3-phase devices.
Step 1: Locate distribution board within your premises. Step 2: Identify 2-phase and 3-phase electrical devices.

3.4 Three Phase AC Supply

Three-phase AC power is generated by a three-phase alternator (also called as AC generators) in the power plants. In the alternator, three stator windings (or say three independent coils) typically separated by some number of degree of rotation and hence the current produced by that coils is also separated by some degrees of rotation, which is typically 120 degrees. This three phase power from the alternators is further transmitted to the distribution end through transmission lines.

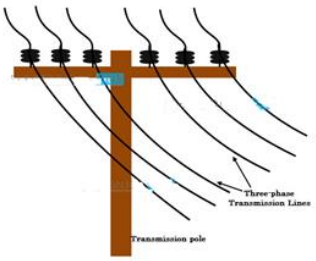


Fig. 3.5 three fase AC Supply

The three phase supply from the distribution line transformer is given to the home or building's point of service. Most industrial and commercial services consists of three phase systems that are operated typically at 415V phase to phase and 230V phase to neutral.

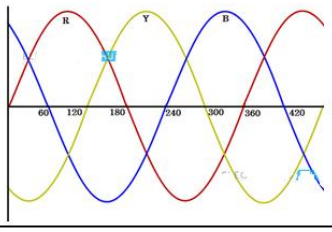


Fig. 3.6 waveform three phase Ac supply

Three phase system consists of three conductors unlike single conductor in single phase system excluding neutral conductor. In addition to the three phases, additional neutral conductor is required for three-phase four wire system.

Three-phase systems can be three-phase three wire or three-phase four wire systems. Three-phase 3 line connection consist of three phase conductors and is employed only where there is no requirement for connecting phase to neutral loads. These connections can be star or delta depending on the secondary of the distribution transformer.

Three-phase 4 wire system is most commonly used connection that consists of three phase conductors and one neutral conductor. In this three phase wiring, lighting, small-appliance loads

and receptacles are often connected between phase and neutral while larger equipment such as air conditioners and electric heaters are connected between two phases (i.e., phase to phase).

Mostly three-phase 4 wire star connection is preferred for connecting both single phase and three phase loads efficiently and in a balanced manner.

This connection allows phase to neutral connection for small loads. Three phase 4 wire delta connection used only where the phase to neutral load is very small compared with three phase load.

Three phase circuits can provide square root of 3 (1.732) times more power compared to single phase power with same current. Thus the three phase system saves electrical installation cost by reducing cable size and size of associated electrical devices.

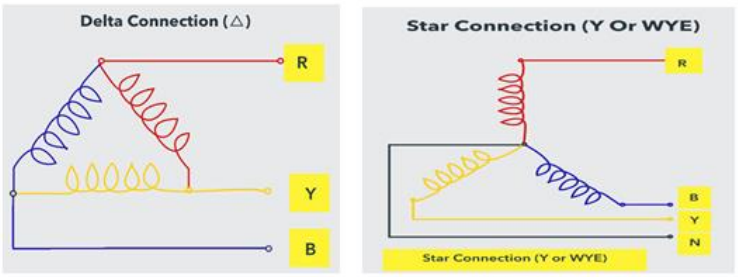


Fig. 3.7 Star Delta Connection Three phase AC Supply

We can easily observe three phase circuits by looking at power line while travelling on roads. Even for a large power transmission system, they are three phase transmission lines unless they are of DC.

Large hotels, restaurants, most factories, office buildings, and grocery stores with heavy refrigeration systems have three phase services.

Comparison between Star and Delta Connections

Let us understand more about these connections by using the following Comparison between Star and Delta Connections.

Star Connection (Y or Wye)	Delta Connection (Δ)
A Star Connection is a 4 – wire connection (4th wire is optional in some cases)	A Delta Connection is a 3 – wire connection.
Two types of Star Connection systems are possible: 4 – wire 3 – phase system and 3 – wire 3 phase system.	In Delta Connection, only 3 – wire 3 phase system is possible.
Out of the 4 wires, 3 wires are the phases and 1 wire is the neutral (which is the common point of the 3 wires).	All the 3 wires are phases in a Delta Connection.
In a Star Connection, one end of all the three wires are connected to a common point in the shape of Y, such that all the three open ends of the three wires form the three phases and the common point forms the neutral.	In a Delta Connection, every wire is connected to two adjacent wires in the form of a triangle (Δ) and all the three common points of the connection form the three phases.
The Common point of the Star Connection is called Neutral or Star Point.	There is no neutral in Delta Connection
Line Voltage (voltage between any two phases) and Phase Voltage (voltage between any of the phase and neutral) is different.	Line Voltage and Phase Voltage are same.
Line Voltage is root three times phase voltage i.e. VL = √3 VP. Here, VL is Line Voltage and VP is Phase Voltage.	Line Voltage is equal to Phase Voltage i.e. VL = VP.
With a Star Connection, you can use two different voltages as VL and VP are different. For example, in a 230V/400V system, the voltage between any of the phase wire and neutral wire is 230V and the voltage between any two phases is 400V.	In a Delta Connection, we get only a single voltage magnitude.
Line Current and Phase Current are same.	Line current is root three times the phase current.

In Star Connection, IL = IP. Here, IL is line current and IP is phase current.	In Delta connection, IL = √3 IP
Total three phase Power in a Star Connection can be calculated using the following formulae. P = 3 x VP x IP x Cos(Φ) or P = √3 x VL x IL x Cos(Φ)	Total three phase Power in a Delta Connection can be calculated using the following formulae. P = 3 x VP x IP x Cos(Φ) or P = √3 x VL x IL x Cos(Φ)
Since Line Voltage and Phase Voltage are different (VL = √3 VP), the insulation required for each phase is less in a Star Connection.	In a Delta Connection, the Line and Phase Voltages are same and hence, more insulation is required for individual phases.
Usually, Star Connection is used in both transmission and distribution networks (with either single phase supply or three – phase.	Delta Connection is generally used in distribution networks.
Since insulation required is less, Star Connection can be used for long distances.	Delta Connections are used for shorter distances.
Star Connections are often used in application which require less starting current	Delta Connections are often used in applications which require high starting torque.

Activity 3.3 Connect 3-phase AC motor in both configurations (star/delta) with power supply.
Components/Instruments 3-Phase AC Power Supply, 3-Phase AC Electrical Motor, Electrical Toolkit.
Step 1: Follow health and safety instructions. Step 2: Connect the Motor with AC power supply in star and delta configurations separately. Step 3: Perform test run.

3.5 Load Distribution Technique in Industrial Wiring

Industries or factories are installed with three phase power in order to connect heavy machineries and equipment. Busbars carries this three phase power and from which individual connections are brought out, to individual loads, through cables. The Fig.3.8 shows schematic diagram for industrial three phase wiring.

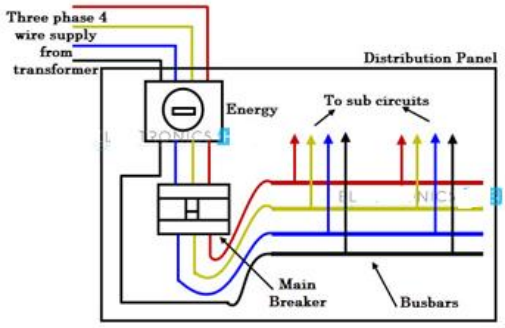


Fig. 3.8 Load Distribution in industrial wing

Three phase power from the utilities is connected to the main breaker through three-phase energy meter. The power in the main breaker is then given to various bus bars.

This panel is also included with metering arrangement to display parameters like current, voltage, energy and power.

Fig 3.9 shows the power distribution from main panel to machinery and lighting loads. Power from the main distribution board is distributed to heavy machinery equipment as well as to lighting boards with power sockets. The power distributed through single and three phase sub-meters is shown in Fig.3.10.

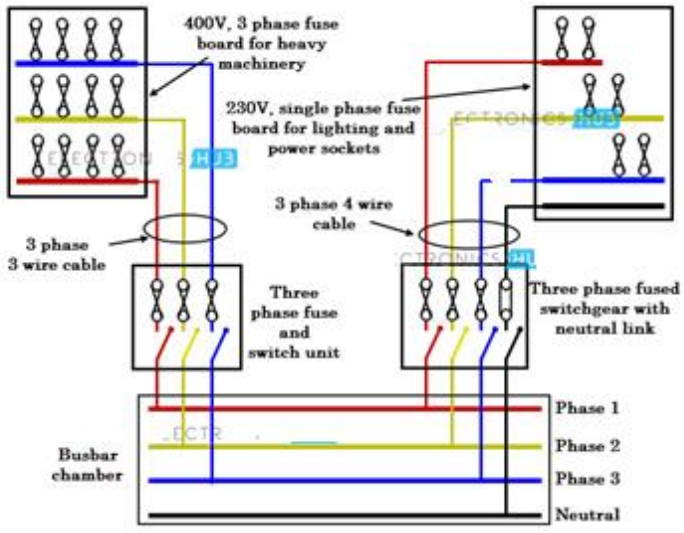


Fig. 3.9 Load Distribution in 3-Phase with four wire output

The three phase power distribution to homes or offices is necessary if the load requirement cannot be handled by a single phase supply. The efficient usage of three phase power depends on balancing load distribution on each phase of the three phase supply. So the single phase loads in the offices or homes must be connected to each phase such that maximum possible load balancing will be achieved. The main components in the three-phase wiring to home or building or office premises are shown in Fig3.10.

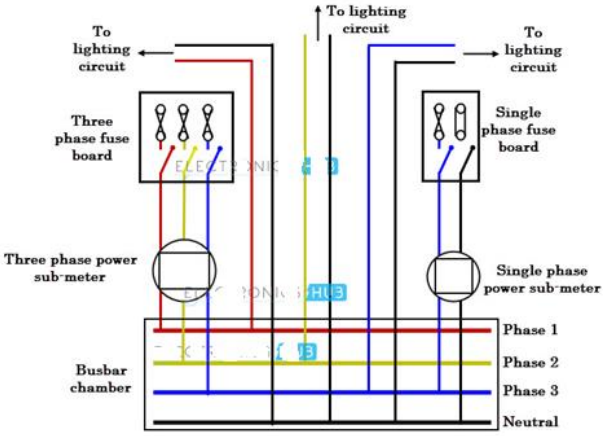


Fig. 3.10 Three Phase distribution with energy meters

In this, the service entrance conductors are connected to a three phase entrance panel. This panel has a three phase main breaker or sometimes it has three separate cartridge fuses. This three phase breaker consists of three input lugs to energize three vertical busbars. This main breaker has single handle such that all the loads are powered down simultaneously and also in case of electrical faults, it trips or opens all loads simultaneously. The power from this main panel is connected to the branch circuits. The main panel may consists of single pole or double pole or triple pole breakers for these branch circuits where phase to ground, phase to phase or three phase loads are connected.

In the above figure power from the utility pole is connected to sub-circuits via three phase energy meter, three phase breaker (3-pole 60A), double pole RCD, double pole MCB and single pole MCBs.

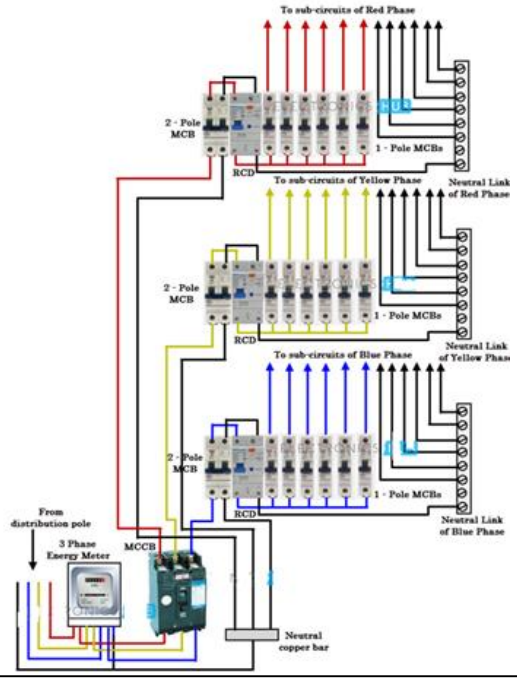


Fig. 3.11 Three Phase distribution with Breakers

Activity 3.4 Calculate load distribution of load as per desired fixtures/devices.
Components/Instruments Electrical fixtures/devices, Calculator, Writing Material.
Step 1: Locate electrical fixtures/devices. Step 2: Check the power rating of the electrical fixtures/devices. Step 3: Distribute the load fairly on the 3-phases.

Interpretation of Industrial Wiring Layout Diagram

Single phase and three phase loads connection to three phase power supply is shown in Fig3.12. We can connect the single phase loads to three phase sub-circuits via switches or MCBs.

But for three phase loads like motors have to be connected to three phase supply via contactor or breaker arrangement.

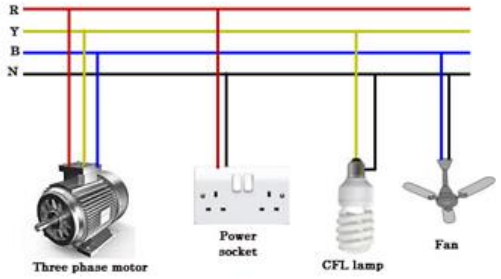


Fig. 3.12 Connection of single & three phase devices

A three pole breaker with an appropriate current rating is used for connecting a three phase motor. Proper care should be taken while connecting three phase wires to the motor because the direction of rotation can be reversed simply by reversing any of the two wires of three phase system.

The wiring diagram for connecting thee phase motor to the supply along with control wiring is shown in Fig3.13. This is a start-stop push button control schematic which includes contactor (M), overload relay, control transformer, and push buttons.

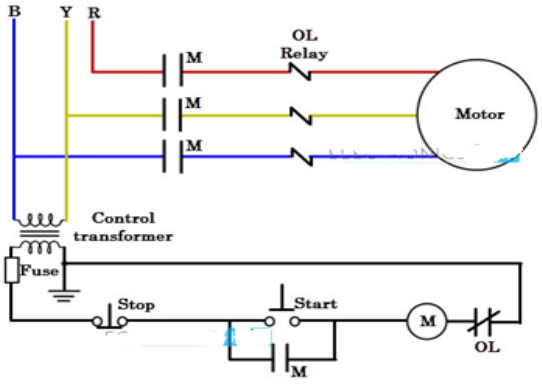


Fig. 3.13 Connection of three phase Motors

The contactor contains large load contacts that are intend to handle large amount of current. The overload relays protect the motor from overload condition by disconnecting power to the coil of the contactor.

The above mentioned information and diagrams illustrated only for giving basic understanding of three phase power supply distribution to homes and industries.

KEY POINTS

1. Distribution Box/Board is used to distribute electrical energy to final sub circuits or to other sub distribution boards in the installation.

2. Fuse is the most common and important type of safety device used for domestic and commercial installations.

3. A Circuit Breaker is a protective device used to make and break the electric circuit both in normal (manually) or abnormal (automatically) conditions.

4. The term "Electrical Load Capacity" refers to the total amount of power provided by the main source of electricity for use by your home's branch circuits and the lights, outlets, and appliances connected to them. Total electrical capacity of an electrical service is measured in amperage (amps).It may vary from few amperes to several amperes, depending upon the size of house.

5. To evaluate the load we need to understand the relationship between watts, volts, and amps. These three common electrical terms have a mathematical relationship that can be expressed as follows:

    - Volts x Amps = Watts
    - Amps = Watts/Volts

    These formulas can be used to calculate the capacity and loads of individual circuits, as well as for the entire electrical service.

6. A Single Phase System consists of just two conductors (wires): one is called the phase (sometimes line, live or hot), through which the current flows and the other is called neutral, which acts as a return path to complete the circuit.

7. In a Three-Phase system, we have a minimum of three conductors or wires carrying AC voltages. It is more economical to transmit power using a 3-phase power supply when

compared to a single phase power supply as a 3-phase supply can transmit three times the power with just three conductors when compared to a two – conductor single – phase power supply.

Multiple Choice Questions

Select the most appropriate option (✓)

1. ---------- are used to make or break the electric circuit.

   a. Switches b. Plugs c. LED d. Socket

2. Fuse is a most common device.

   a. Indicating b. Safety c. Recording d. None

3. Ceiling Fans have power range:

   a. 40-50 watts b. 40-60 Watts c. 60-120 Watts d. None

4. In a three phase system we have minimum conductors:

   a. 2 b. 3 c. 4 d. 5

5. In three phase AC Supply Current generated at distributed at

   a. 120 degrees b. 240 degrees c. 360 degrees d. None

6. A single phase system usually consists of just _____ conductors (wires)

   a. 2 b. 3 c. 4 d.5

7. In a three phase system we have a minimum of three conductors or wires carrying _____ voltages.

   a. DC b. AC c. Both AC & DC d. None of above

8. Star connections are often used in application which require _____ starting current.

   a. No b. Less c. High d. None of above

9. Delta connections are used for _____ distance

   a. Short b. Long c. Both a & b d. None of above

ANSWER KEY

1 (a)	2(b)	3(c)	4(b)	5 (a)
6 (a)	7(b)	8(b)	9 (a)	

Short Questions

Give short answer to the following questions.

1. Define single phase wiring.
2. Define three phase wiring.
3. What is MCCB?
4. What is meant by load calculation?
5. What do you mean load distribution?
6. Define star connection.
7. Define delta connection.

Long Questions

Answer the following questions in detail .

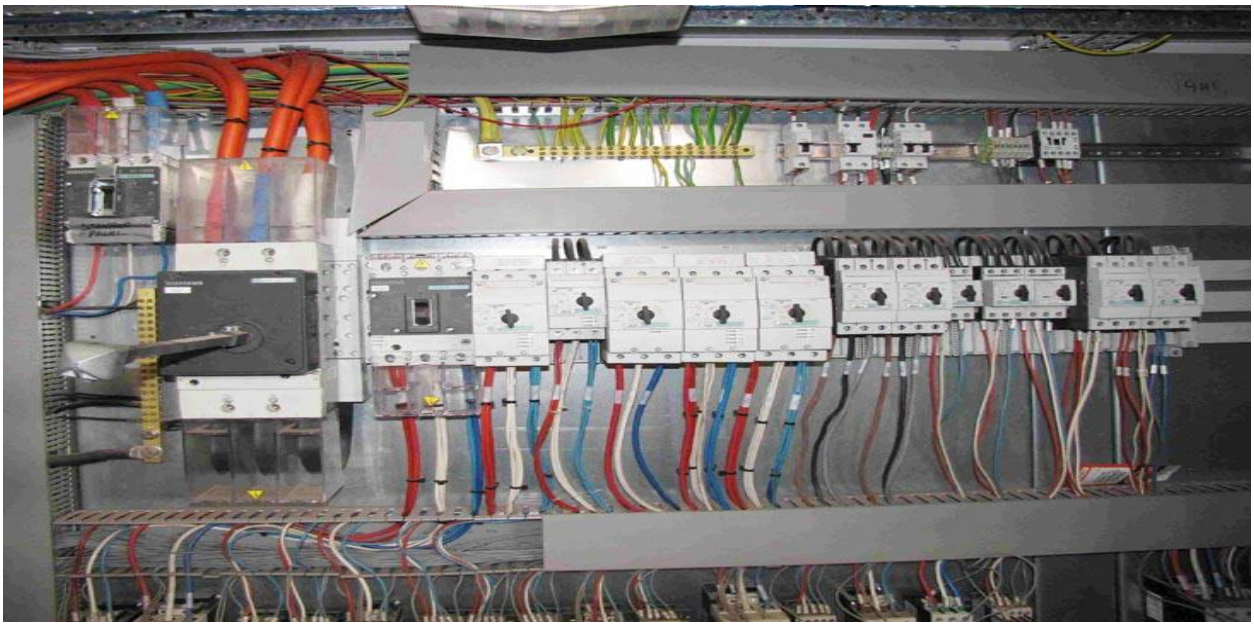
1. Describe the procedure and formula for load calculation.
2. Explain three phase supply.
3. Compare star and delta connections in detail.
4. Describe the connection of single and three phase devices to three phase supply.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment.

Chapter 04

Control and Protective Devices



Students Learning Outcomes

After Completion of this Chapter you will be able to:

- define various types of control and protective devices.
- use Protective Devices.
- explain the control and function of protective devices.

4.1 Control & Protective Devices

A device used to protect equipment, machinery, components and devices in electrical and electronic circuit against short circuit, over current and earth faults is called as protective devices. It is also used to protect operator against accidental contact with the faulty equipment, falling which the operator may get a severe shock.

Necessity of Protective Devices

Protective devices are necessary to protect electrical appliance or equipment against:

i. Short Circuit
ii. Abnormal variations in the supply voltage
iii. Overloading of equipment
iv. To protect operator against accidental contact with the faulty equipment, falling which the operator may get a severe shock.

Types of Protective Device

Different types of the protective device that are commonly used in electrical and electronic circuit

1. Fuse Wire or Fuse
2. MCB (Miniature Circuit Breaker)
3. ELCB (Earth Leakage Circuit Breaker)
4. ELCB & MCB
5. Earthing or Grounding

4.2 Use of Protective Devices

1. Fuse

Fuse generally means a fuse wire, placed in a fuse holder. It is a safety device, which protects electrical and electronic circuit against over loads, short circuit and earth faults. The fuse link or fuse wire is made of low resistivity material and low melting point.

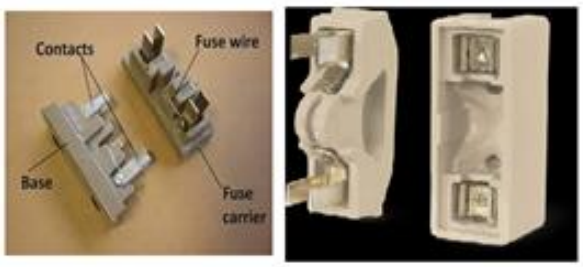


Fig. 4.1 Fuse & Operation of Fuse

Operation of a Fuse

Fuse is a short length of wire designated to melt and separate in case of excessive current. The fuse is connected in the phase of the supply. It is always connected in series with the circuit / components that need to be protected. When the current drawn by the circuit exceeds the rated current of the fuse wire, the fuse wire melts and breaks. This disconnects the supply from the circuit and thus protects the circuit and the components in the circuit.

Rating of Fuse Wire

The maximum current that a fuse can carry, without being burnt, is called the rating of the fuse wire. It is expressed in Amperes. Current rating of the fuse, selected for the circuit, should be equal to the maximum current rating of the machinery, appliance or components connected in the circuit.

Fuse Carrier and Fuse Channel

Fuse carrier and channel are made of porcelain or Bakelite material. They are used for all domestic, commercial and industrial application up to 100 A capacity.

Cartridge Fuse

This fuse unit is in the form of a cartridge. Its normally manufactured in the range of 2 A to 100 A. Whenever the fuse blows off, fuse with carrier is replaced by a new one. As it is sealed, it cannot be rewired.

Fig. 4.2 Fuse carrier and fuse channel

Cartridge fuses are used to protect motors and branch circuit where higher amps or volt ratings are required. They are available in wide variety of sizes, amp and volt ratings up to 600 Vac and 600 amps.

Cartridge fuses are used extensively in commercial, industrial and agricultural applications as well as residential fuse panels, air conditioning, pumps, appliances and other equipment.

Cartridge Fuses are available in two types-

General Purpose fuses have no time delay and protect fuse panel, appliances and branch circuits.

Heavy Duty fuses have a time delay feature.

HRC Fuse

HRC Fuse – High Rupture Capacity fuse unit. It is normally designed for high current. When fuse is blown off, the entire unit is to be replaced by a new one. It cannot be rewired as it is a sealed one.

Fig. 4.3 HRC Fuse

Characteristics of a Good Fuse Wire

A good fuse wire should possess the following characteristics

a. Low resistivity
b. Low melting point
c. Low conductivity of the metal vapors formed, when the fuse is blown off.

Advantages of HRC Fuse

i. They require maintenance
ii. They are reliable
iii. They operate at high speed.
iv. They have consistent performance

They clear both low and high fault current with equal efficiency.

2. Miniature Circuit Breaker

It is safety device which work magneto thermic release principle. It is connected in the phase, between the supply and load. It is manufactured in standard rating of 6A to 40 A. We can see it on the meter board of each and every house.

Fig. 4.4 Miniature Circuit Breaker

When the current drawn by load exceeds the rated value, it acts and trips the circuit, the protecting the apparatus, operator and appliance.

Advantages of MCB

1. Open the circuit in less than 5 milli seconds.
2. Automatic switch off under overload and short circuit condition
3. No fuse to replace or rewire. It needs no repairs.
4. Supply is restored by resetting it again.

3. Earth Leakage Circuit Breaker

This is a domestic safety device, which trips the circuit when there is a small leakage to earth or body of the appliance. Thus it protects the operator from shocks and accidents. This is connected in the circuit of the appliance to be protected.

There are two types of ELCB

1. Voltage Earth Leakage Circuit Breaker
2. Current Earth Leakage Circuit Breaker

Fig. 4.5 Earth Leakage Circuit Breaker

4. MCB & ELCB

It is the combination of both MCB and ELCB placed in one unit. It acts on both the occasion of earth leakage and overload and protect the circuit, appliance and the operator.

Activity 4.1
Identify the different fuses (kit-kat, HRC, Cartridge Fuse).
Components/Instruments
Different types of Fuses
Step 1: Arrange the class in small groups. Step 2: Determine the type of different fuses available.

Activity 4.2
Connect the fuses in the circuit.
Components/Instruments
Different types of Fuses, Electric Toolkit, Connecting wires
Step 1: Arrange the class in small groups. Step 2: Select the electronic circuit. Step 3: Integrate fuse in the circuit at proper place.

5. Earthing Or Grounding

Connecting the metal body of an electrical appliance, machinery or an electrical installation to earth, through a low resistance wire, is called Earthing or Grounding.

Necessity of Earthing

Earthing is necessary for all domestic, commercial and industrial installation to safeguard the operator, tall buildings and machinery against lightning.

Metal body of all the electrical appliances, equipment and machinery, the earth points of all three-pin sockets and the body of the energy meter are connected to earth through a thick G.I. wire.

Whenever a live wire comes in contact with the body of the appliance, it is directly connected to earth wire and hence the body voltage comes to zero. Therefor the operator does not get any shock, when he comes in contact with body of the appliance.

The high voltage included during lightning is discharged to earth through grounding wire and thereby building and machinery are protected.

Activity 4.3:
Identify the overload relay and circuit breaker.
Components/Instruments :
Overload Relay, Circuit Breaker.
Step 1: Arrange the class in small group. Step 2: Determine the type of different circuit breakers and overload relays .

Activity 4.4:
Connect over load relay and circuit breaker in the circuit and check their functionality.
Components/Instruments :
Overload Relay, Circuit Breaker, Connecting Wire, Electrical Toolkit.
Step 1: Arrange the class in small groups. Step 2: Select the electrical circuit. Step 3: Connect overload relay and circuit breaker in the circuit. Step 4: Verify the proper functioning of protective devices.

Key Points

- A device used to protect equipment, machinery, components and devices in electrical and electronic circuit against short circuit, over current and earth faults is called as protective devices.
- Protective devices are necessary to protect electrical appliance or equipment against
  i. Short Circuit
  ii. Abnormal variations in the supply voltage
  iii. Overloading of equipment
  iv. To protect operator against accidental contact with the faulty equipment, falling which the operator may get a severe shock.
- Different types of the protective devices commonly used in electrical and electronic circuit are:
  ii. Fuse Wire or Fuse
  iii. MCB (Miniature Circuit Breaker)
  iv. ELCB (Earth Leakage Circuit Breaker)
  v. ELCB & MCB
  vi. Earthing or Grounding
- Fuse generally means a fuse wire, placed in a fuse holder. It is a safety device, which protects electrical and electronic circuit against over loads, short circuit and earth faults. The fuse link or fuse wire is made of low resistivity material and low melting point.
- **HRC Fuse** –High Rupture Capacity fuse unit. It is normally designed for high current. When fuse is blown off, the entire unit is to be replaced by a new one. It cannot be rewired as it is a sealed one.
- **Miniature Circuit Breaker** -It is safety device which works as magneto thermic release principle. It is connected in the phase, between the supply and load. It is manufactured in standard rating of 6A to 40 A. We can see it on the meter board of each and every house. When the current drawn by load exceeds the rated value, it acts and trips the circuit, the protecting the apparatus, operator and appliance.
- **Earth Leakage Circuit Breaker-**This is a domestic safety device, which trips the circuit when there is a small leakage to earth or body of the appliance. Thus it protects the operator

from shocks and accidents. This is connected in the circuit of the appliance to be protected. There are two types of ELCB

i. Voltage Earth Leakage Circuit Breaker

ii. Current Earth Leakage Circuit Breaker

- Connecting the metal body of an electrical appliance, machinery or an electrical installation to earth, through a low resistance wire, is called Earthing or Grounding.

Multiple Choice Questions

Select the most appropriate option (✓)

1. A fuse is provided in an electric circuit for
   a. Safeguarding the installation against fault currents
   b. Reducing the current flowing in the circuit
   c. Reducing the power consumption
   d. All of the above
2. The rating of fuse wire is always expressed in;
   a. Volts b. Amperes c. Volts-Ampere d. Ampere hours
3. A fuse is normally a
   a. Power limiting device b. Voltage limiting device
   c. Current limiting device d. Power factor correcting device
4. Protection of fuses is generally not used beyond
   a. 200 A b. 50 A c. 25 A d. 10 A
5. A material best suited for manufacturing of fuse wire is
   a. Silver b. Copper c. Aluminium d. Zinc
6. In comparison to rewire-able fuse, HBC fuses have the advantage(s) of
   a. High speed operation b. High rupturing capacity
   c. No ageing effect d. All of the above
7. MCB stands for
   a. Miniature Circuit Breaker b. Minimum Current Break
   c. Most Common Breaker d. None of these

8. MCCB stands for
   a. Moulded Case Circuit Breaker b. Minimum Current Carrying Breaker
   c. Most Common Circuit Breaker d. Make Contact Control Brush
9. Body of cartridge fuse is made with this material
   c. Glass b.Ceramic c.Mica d. Both (a) & (b)
10. MCB as compared to MCCB
   a. Is less accurate b.Has less current rating
   c. Is used for single phase supply d. All of above
11. Tripping mechanism of MCB may be
   a. Thermal type b. Magnetic type
   c. Mechanical type d. Both (a) & (b)
12. Earthing of electrical equipment is necessary for the protection against
   a. Overloading b. Voltage fluctuation
   c. Danger of electric shock d. High conductor temperature
13. The earth wire should be
   a. Good conductor of electricity b. Mechanically strong
   c. Mechanically strong but bad conductor of electricity d. Both (a) & (b)
14. The resistance of earth should be
   a. Infinite b. High c. Low d. Minimum
15. Which of the following soil will be preferred for Earthing
   a. Wet clayey soil b. Dry and rocky soil
   c. Sandy soil d. Both (a) & (b)
16. Earth electrode can be in the form of
   a. Strip or wire b. Rod or pipe c. Plate d. Any of these
17. Which of the following cannot be used as earth continuity conductor?
   a. Gas pipe b. Water pipe
   c. Structural steel members d. Both (a) & (b)
18. Which of the following mixture is preferred for filling around the earth electrode for effective Earthing?
   a. Coal-lime mixture b. Lime-sand mixture
   c. Sawdust-Sand mixture d. Any of the above

19. Inside the earth pit, the Earthing electrode (plate) should be placed

a. Horizontally b. Vertically

c. Inclined at 45° d. In any position

20. Resistance of an earth continuity conductor should be less than;

a. 5 Ohm b. 1 Ohm c. 10 Ohm d. 70 Ohm

ANSWER KEY

1.	c	2.	b	3.	b	4.	a	5.	b
6.	c	7.	c	8.	c	9.	c	10.	d
11.	d	12.	a	13.	c	14.	d	15.	a
16.	a	17.	a	18.	a	19.	d	20.	b

Short Questions

Give Short answer of the following questions.

1. Define fuse.
2. Enlist types of fuses.
3. Define current rating of fuse.
4. Define MCB.
5. Write two differences between MCB and MCCB.
6. Write two differences between HBC and MCB.
7. Define earth leakage circuit breaker and enlist its types.
8. Define breaking capacity of circuit breaker.
9. Write applications of MCB.
10. Write any two advantages and disadvantages of HBC fuse.
11. Write any two advantages and disadvantages of MCB.
12. Define earthing.
13. Enlist types of earthing system.
14. What is difference between equipment earthing and neutral earthing?

15. Write the names of four components of wiring which can be used as earth continuity conductor.
16. Write minimum and maximum size of earth continuity conductor of copper.
17. Write two advantages of rod earthing over plate earthing.
18. Write the names of four types of earth electrode.

Long Questions

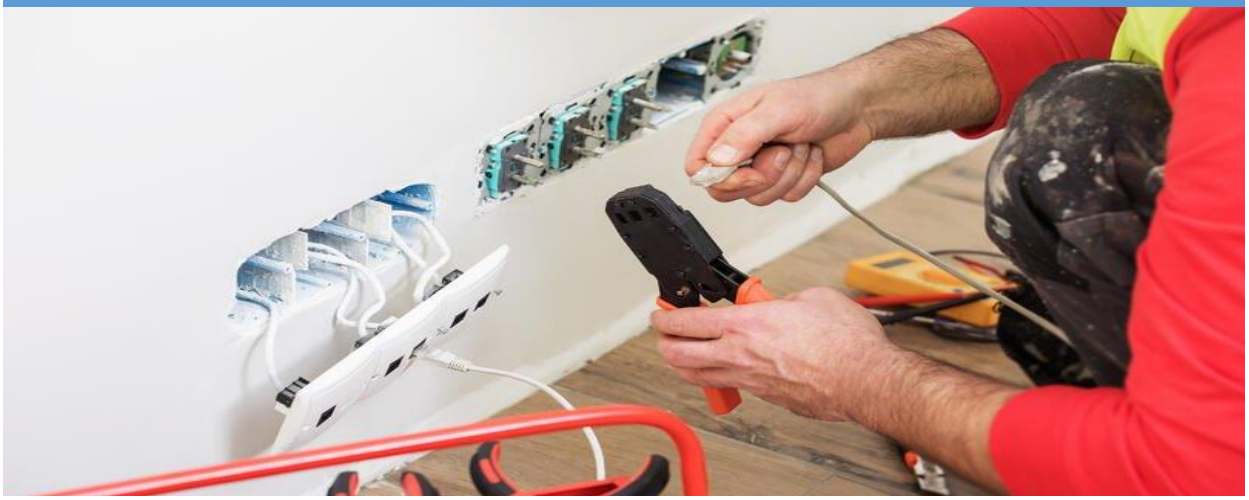
Answer the following questions in detail.

1. Describe the construction of HBC and MCB.
2. Compare MCB and MCCB.
3. Compare HBC and rewire able fuse.
4. Make sketch and explain working of current operated earth leakage circuit breaker.
5. Write in detail the method of rod Earthing.
6. How Earthing provides protection against electric shock, explain with the help of neat sketch.
7. Write note on strip Earthing and protective multiple Earthing.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment.

Chapter 05
Repair/Maintenance of Electrical Installations



Learning Outcomes

After studying this Chapter you will be able to:

- recognize measuring and testing instruments.
- explain the function of different measuring and testing instruments.
- explain application techniques of different measuring instruments for testing with safety measures.
- explain the importance of preventive maintenance.
- describe the tools/equipment and material used for preventive maintenance as specified by the manufacturers.
- explain the schedule of preventive maintenance.
- understand procedure for record updation regarding preventive maintenance.
- know about the nature of faults in electrical installations
- explain the checking procedure in electrical installations for fault identification.
- explain causes of faults in wiring
- describe the procedure/techniques for fault identification.
- describe the techniques for troubleshooting
- explain tagging procedure (maintenance card) of machinery.
- describe the preventive measure according to identified faults.

5.1 Measuring & Testing Instruments

Our life is incomplete without electricity. We need electricity for everyday use including entertainment, working on a computer, using washing machines or escaping from the summer heat with the aid of air conditioners. Everything needs electricity to operate. However, we need to ensure whether everything is working appropriately and accurately. This necessitates the importance of **Electrical Measuring Instruments**.

A measuring instrument is a device that is used to compare the two quantities for determining the value or magnitude of an unknown quantity or variable. An instrument serves as an extension of human facility. In electrical engineering, we come across current, voltage, resistance , power, energy, flux, frequency, power factor etc. which are not visible to eye. The instruments, which are used to measure these quantities, are known as electrical measuring instruments. These instruments are used for following purposes.

Fig. 5.1 Test Equipments

- **i.** The main functions of the measurement system are indicating, recording, detecting, controlling and testing the electrical quantities.
- **ii.** They have good potential to provide accurate results, we can perform our role with great reliance.
- **iii.** When we want to verify the readings, we may require to calibrate electrical measuring instrument to match the readings of a particular standard.
- **iv.** It helps to control and monitoring the operation in an electrical system.
- **v.** In generating power stations, instruments are used for data recording, measuring the value, fault detecting and many more purpose.
- **vi.** It helps to detect and protect from hazard conditions.
- **vii.** Measuring instrument uses for the analysis of experimental data in an electrical system.
- **viii.** It is essential for displaying accurate numerical values. Digital multimeter is one of them.

ix. Mostly, it utilizes in testing in the lab, industrial environment, science, and engineering study, building an electrical and electronics project etc.

5.2 Function of Different Measuring and Testing Instruments

Electrical measuring instrument are classified based on the nature of the operation, function, purpose, uses and many other terms. Generally, it is classified into two categories.

1. Absolute Instrument

This instrument gives the value of the electrical quantity to measure in terms of the constant and its deflection. This instrument is known as 'Absolute Instrument'. It is also called a Primary Instrument or Indirect Instrument. These instruments are not required to compare with the standard values.

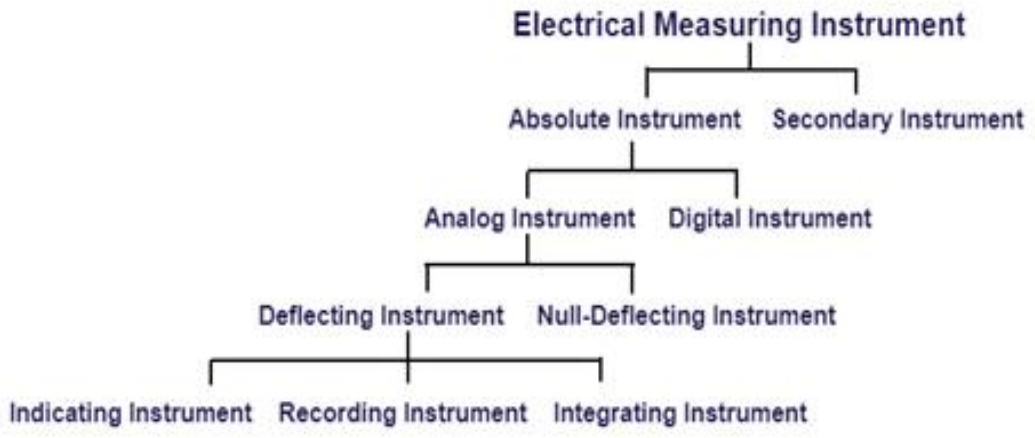
Example

Tangent Galvanometer is the best example of an absolute instrument. It is used for detecting and displaying an electric current unit.

2. Secondary Instrument

The instrument gives the value of the quantity to be measured directly into the deflection. This instrument is known as 'Secondary Instrument'. It is also called as **Direct Instruments**. These instrument values are required to compare with absolute instruments or standard value of the instruments.

You can easily understand the classification of an instrument through the block chart.



Following are the most popular and widely used instruments from above types.

i. Ammeter

Ammeter is a measuring instrument used to measure direct or alternating electric current in an electric circuit. They vary in operating principles and accuracies. When the units of currents are very minimal namely milliamperes and microamperes, they are measured in milliammeter and microammeter. It can be analog or digital type.

Fig. 5.2 Ammeter

ii. Voltmeter

Voltage meter is an instrument used to measure the direct or alternating Voltage. The commercial voltmeter employs an electromechanical mechanism in which current is translated into a voltage when running through the wire. However, in the case of other voltmeters such as electrostatic voltmeter, the voltage is measured directly. It can be analog or digital type.

Fig. 5.3 Voltmeter

iii. Ohmmeter

An ohmmeter is an instrument that is used to measure the resistance and they can measure the value of resistance accurately. According to their measurement and construction, these instruments are classified into the series type and shunt type ohmmeter. It can be used to check the continuity of the electrical circuits and components. Series type ohmmeters are used to measure the high resistance values while the shunt type is used to measure low resistance value.

Fig. 5.4 ohmmeter

iv. Wattmeter

Watt-meters are used to measure power, these instruments are similar in design and construction of an ammeter. It can be used to measure the average electric power in watts. Wattmeter has two coils they are current and pressure coil.

Fig. 5.5 wattmeter

v. Multimeters

Fig. 5.6 Multi meter

Multimeters can be used to make various electrical measurements, they can be used to measure AC and DC voltage, AC and DC current, and resistance. It is known as multimeter because it can do the functions of various meters such as voltmeter, ammeter, and ohm-meter. Multimeters can also be used to check the continuity. Multimeters are of two types i.e. are analog and digital multimeter. Analog multi-meter has an analog scale and they are less accurate, while the digital multimeter and the reading are in digital and they are more accurate.

vi. Flux meter

A Flux meter is one kind of electronic device including a digital display. This instrument is used to measure the magnetic flux in stable magnets, quality control & magnetic products sorting. These meters are flexible to use in production and laboratory enterprise.

Fig. 5.7 Flux meter

vii. Oscilloscope

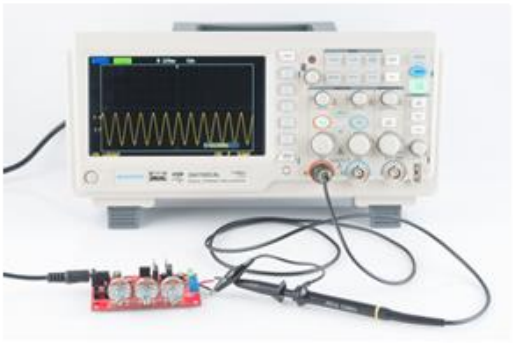


Fig. 5.8 oscilloscope

An oscilloscope is a laboratory instrument commonly used to display and analyze the waveform of electronic signals. In effect, the device draws a graph of the instantaneous signal voltage as a function of time. A typical oscilloscope can display alternating current (AC) or pulsating direct current (DC) waveforms having a frequency as low as approximately 1 hertz (Hz) or as high as several megahertz (MHz). High-end oscilloscopes can display signals having frequencies up to several hundred gigahertz (GHz).

viii. Energy Meter

Fig. 5.9 Energy Meter

Energy Meter or Watt-Hour Meter is an electrical instrument that measures the amount of electrical energy used by the consumers. If one uses one kilowatt in one-hour duration, one unit of energy gets consumed. So energy meters measure the rapid voltage and currents, calculate their product and give instantaneous power.

ix. Frequency meter

Fig. 5.10 Frequency Meter

A frequency meter is an instrument that displays the frequency of a periodic electrical signal. Various types of mechanical frequency meters were used in the past, but since the 1970s these have almost universally been replaced by digital frequency counters.

x. Power Factor Meter

A power factor meter is an electric instrument which is used to measure the power factor of various electrical machines like DC Generator, AC Motor & transformer etc. It is also used for measuring the power factor of various transmission and distribution lines of various electric power supplies. These power supplies may be from Grid Stations, Substations or from Power Houses. Power factor must be 0.8 to unity. If power factor decreases from 0.8 then the voltage and the current will imbalanced and the power is disturbed. So, in grid stations, Substations the power factor must be between 0.8 to unity. The Power Factor is the cosine of angle φ between the voltage and the current of the transmission lines and electrical machines.

Fig. 5.11 Power Factor Meter

xi. Megger

The Megger is the instrument used for measuring the resistance of the insulation. It works on the principle of comparison, i.e. the resistance of the insulation is compared with the known value of resistance. If the resistance of the insulation is high, the pointer of the moving coil deflects towards the infinity, and if it is low, then the pointer indicates zero resistance. The accuracy of the Megger is high as compared to other instruments.

Fig. 5.12 Megger

Activity 5.1
Identify & Select the required measuring/ testing instruments.
Components/Instruments
Various Measuring / Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Get the scope of measurement from the instructor. Step 3: Verify the instrument as per the scope and observe the available ranges. Select the instrument as per the requirement. Step 4: Record the necessary observations.

Activity 5.2
Perform measurement of current of a given circuit with the help of meter with safety measures.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Make the connection of the meter in the circuit as per the instructions provided by the instructor. Step 3: Record the current values as per the instructions of the instructor.

Activity 5.3
Perform measurement of voltage of a given circuit with the help of meter with safety measures.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Make the connection of the meter in the circuit as per the instructions provided by the instructor. Step 3: Record the current values as per the instructions of the instructor.

Activity 5.4
Perform measurement of resistance of a given circuit with the help of meter with safety measures.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Make the connection of the meter in the circuit as per the instructions provided by the instructor. Step 3: Record the current values as per the instructions of the instructor.

Activity 5.5
Perform measurement of power of a given circuit with the help of meter with safety measures.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Make the connection of the meter in the circuit as per the instructions provided by the instructor. Step 3: Record the current values as per the instructions of the instructor.

5.3 Importance of Preventive Maintenance

There are two types of maintenance strategies which are commonly used by companies for the equipment.

i. Reactive Maintenance

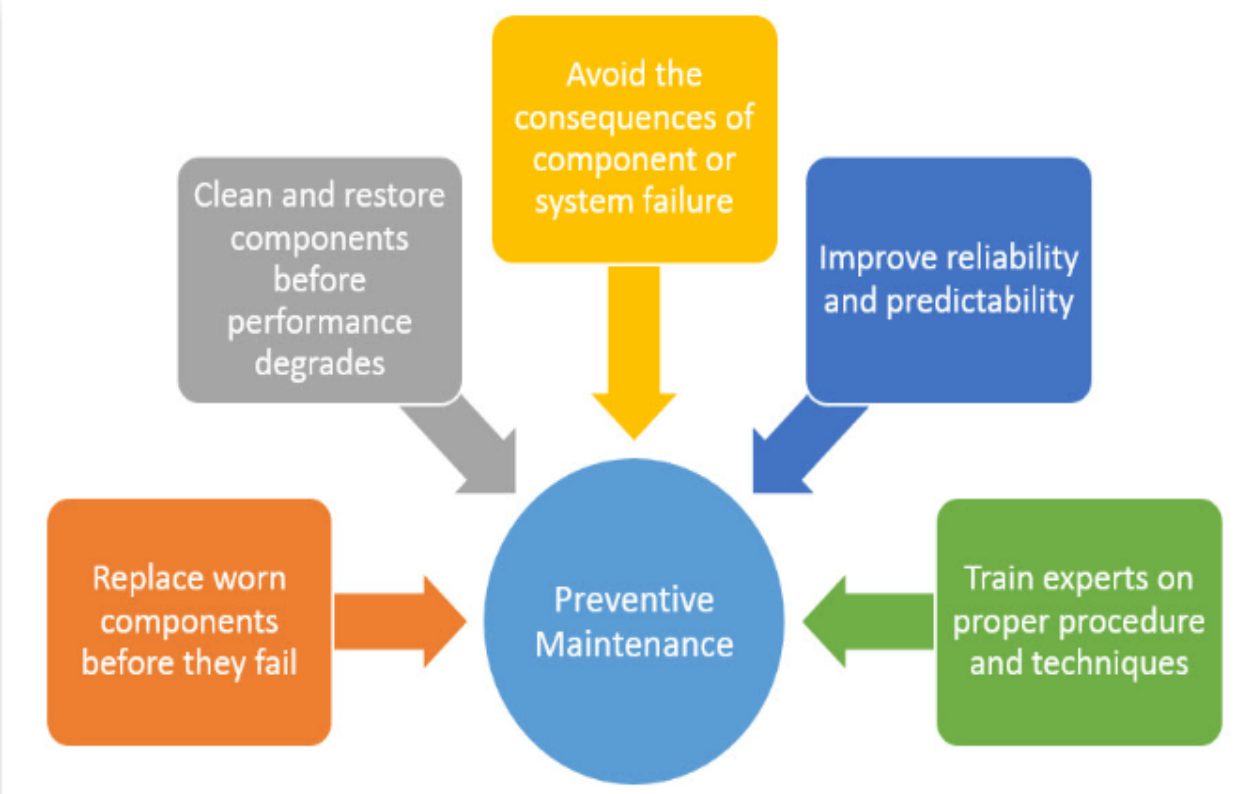
Reactive maintenance (also known as breakdown maintenance) refers to repairs that are done when equipment has already broken down, in order to restore the equipment to its normal operating condition.

ii. Preventive Maintenance

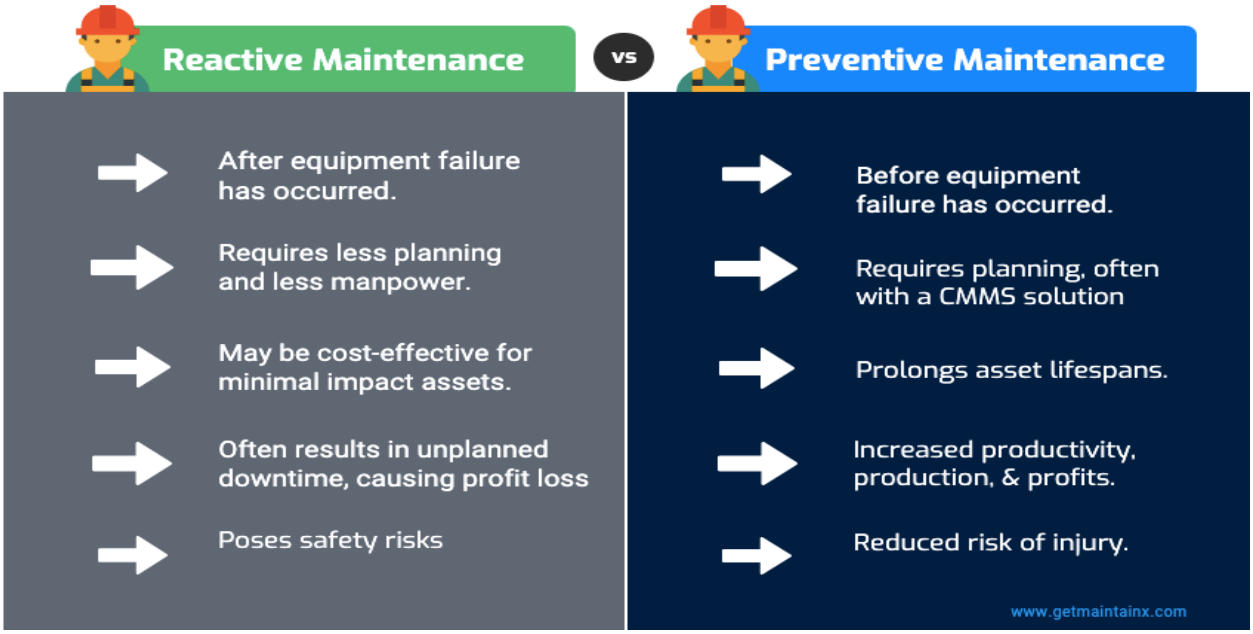
Preventive maintenance involves taking the necessary precautions and actions to prevent accidents or equipment failures from occurring before they happen. For example performing regular business and equipment inspections, cleaning and lubricating essential equipment, and tidying your business's grounds are all examples of preventive maintenance. Preventive maintenance means fixing small problems before they become big ones. The primary goals of preventive maintenance programs are to a) maximize an asset's useful life and b) avoid unplanned downtimes. **Downtime** is the amount of time a system, machine, or piece of equipment remains inoperable.

Three elements of preventive maintenance are highlighted below.

1. Systematic
2. Performed routinely
3. Aimed at reducing or minimizing failures.



Preventive Maintenance vs Reactive Maintenance



5.4 Tools/Equipment and Material Used For Preventive Maintenance as Specified By the Manufacturers

Every asset differs greatly in terms of operation, specifications, lifetime and maintenance needs. For this reason one must gather information about each equipment particularity before putting together their maintenance checklist. Following tools are used for preventive maintenance.

- The main source of information is the asset's Original Equipment Manufacturer (OEM) recommendations. This is a manual provided by the manufacturer that contains schedules for necessary maintenance, the usage of critical spare parts, and basic maintenance work instructions.
- Preventive maintenance software enables you to schedule maintenance, send alerts to the right people when a job is due, and increase resource access and allocation that make planned tasks quicker and more effective. As a result, you're able to streamline processes that help preventive maintenance flourish.
- Material and spares needed are as per the equipment.
- Repair tools are also as per the nature of the equipment.

5.5 Schedule for Preventive Maintenance

Preventive maintenance schedule (also called preventative maintenance schedule) is a set of planned maintenance tasks that happens regularly on critical assets to avoid equipment failure. An effective preventive maintenance plan helps companies to avoid downtime, to save money, and to keep the workplace safe.

The steps to create a preventive maintenance program are outlined below.

i. **Prioritize Assets by Maintenance Needs**

It is recommend that you make a list of your company's most critical equipment, and start the PM schedule with them especially if this is the first time that you are putting together a proactive maintenance planning.

ii. **Collect Historical Data About Each Asset**

After you have a rough idea of equipment you want to include on your preventative maintenance plan, it's time to gather data about all the work orders and unplanned downtime that each asset went through in the past few years.

iii. **Make Projections About Assets Maintenance Needs**

Every asset differs greatly in terms of operation lifetime and maintenance needs. For this reason, you must gather information about each equipment's particularity before putting together their maintenance checklist.

The main source of information is the asset's Original Equipment Manufacturer (OEM) recommendations. This is a manual provided by the manufacturer that contains schedules for necessary maintenance, the usage of critical spare parts, and basic maintenance work instructions.

iv. **Put Together The Initial Preventive Maintenance Plan**

After analyzing historical data, verifying the recommendations from the OEM, and talking to your field technicians, it is time to organize the information. You should write down all preventive maintenance tasks for each asset along with how often you need to perform each of those tasks on a particular piece of equipment. You should end up with something similar to this for each one of your assets.

v. **Verify Progress and Adjust As Needed**

As your maintenance team gets used to this optimized workflow, you will also be monitoring progress and making adjustments. You can expect to do regular adjustments

based on the results you get. This will help you keep an optimal return on the investment you're making.

vi. **Expand Your Preventive Maintenance Program**

With the initial preventative maintenance program, give your team the chance to get acquainted with the new approach to maintenance. It also provides chance to understand how to use preventive maintenance software to optimize the PM program and expand it accordingly.

5.6 Procedure for Record Updating Regarding Preventive Maintenance

Maintenance records of work equipment are a key part of health and safety management, requiring efficient storage and management. Paperwork is often kept for extended periods of time for health and safety or compliance purposes.

Common documentation includes O&M Manuals, electrical certifications, vehicle/fleet maintenance, building records, equipment maintenance for production/ work equipment and upkeep of medical equipment e.g. sterilization records. If not managed properly, this can cause issues with health and safety, lack of office space, non-compliance and production levels. Asset management and maintenance can be improved through efficient, digital document & records management, keeping a record of information for each asset together with indexed data for information such as:-

- Asset number
- Maintenance dates and times
- Equipment maintenance detail
- New parts added
- Manufacturer's recommendations for maintenance
- Amount of use
- Equipment environment conditions
- User experience and knowledge
- Risk assessment information

Activity 5.6
Follow maintenance schedule of electrical installations.
Components/Instruments
Electrical Instrument under consideration for maintenance. Electrical Test Instrument Kit.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Get the operation and maintenance manual of the electrical machine and study the features carefully under the guidance of instructor. Step 3: Follow the maintenance schedule as laid down in the manual under the supervision of instructor.

Activity 5.7
Select the desired equipment tools and materials for preventive maintenance.
Components/Instruments
Electrical Instrument under consideration for maintenance. Electrical Test Instrument Kit.
Step 1: Select the materials required for the maintenance as laid down in the operation manual of the machine according to the nature of the electrical installation. Step 2: Record the observations as per instructions

Activity 5.8
Perform preventive maintenance of electrical installations.
Components/Instruments
Electrical Instrument under consideration for maintenance. Electrical Test Instrument Kit.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Perform the preventive maintenance for the selected electrical installation. Step 3: Record the observations as per the instructions of the instructor.

5.7 Nature of Faults in Electrical Installations / Wiring

It is important to have idea regarding the nature of the faults which can happen with electrical installations for smooth operations and to reduce the maintenance down time. If we are able to identify and understand the type of faults can occur it's really easy to minimize the hazards of these faults and reduce to risk of it.

Three common electrical faults mainly can occur are;

- Short Circuit Electrical Faults
- Open Circuit Faults
- Overload Circuit Faults

5.8 Fault Identification Procedure in Electrical Installations / Wiring

Fault identification for the above listed faults for electrical installations can be carried out as follows

i. Short Circuit Electrical Faults

A short-circuit is an abnormal low-resistance connection between two nodes of an electrical circuit that are meant to be at different voltages. This results in an excessive electric current .The Short Circuit is a more serious reason for a breaker tripping. A short circuit is caused when the supply wire touches another supply wire or touches a neutral wire. It can also be caused if there is a break in a wire in the circuit. Damage form short circuits can be reduced or prevented by employing fuses, circuit breakers, or other overload protection, which disconnect the power in reaction to excessive current.

How to Identify Short Circuit Faults?

- Confirm that power is off at the outlet into which your device is plugged.
- Inspect your power cords for damage or a melted appearance.
- Check your outlets and plugs for the smell of burning or brown or black discoloration.
- Check the insulation on the wires to make sure it is not cracked and touching a black and red wire together.
- If you do not find the problem, repeat the process for all the outlets in the circuit.

ii. Open Circuit Electrical Faults

A circuit is said to be OPEN when a break exists in a complete conducting pathway. Although an open circuit occurs when a switch is used to de energize a circuit, an open may also cause accident. To restore a circuit to proper operation, the open must be located, its cause determined, and repairs made. Sometimes an open can be located visually by a close inspection of the circuit components. Defective components, such as burned out resistors, can usually be discovered by this method. Others, such as a break in wire covered by insulation or the melted element of an enclosed fuse, are not visible to the eye. Under such conditions, the understanding of the effect an open has on circuit conditions enables a technician to make use of test equipment to locate the open component.

iii. Overloaded Electrical Fault

An overloaded circuit is the primary reason for a breaker tripping. It occurs when a circuit has more connected electrical load than it is supposed to have. When more current runs through the circuit than the circuit was intended to take, the circuit breaker is designed. Circuit breakers come in different ratings that determine how much current they will allow to flow through the circuit.

If a 15 Amp circuit breaker is protecting a 15 Amp circuit, and 20 Amps of current start to flow through it because a hair dryer, TV and small personal heater were all connected to the same circuit and were on at the same time then the circuit breaker trips to prevent overheating of the circuit.

How to Fix Overloaded Circuit Trips

- The most probable reason the breaker tripped is that you simply have too much plugged into one outlet or multiple outlets connected to one circuit.
- For example Move lamps, heaters, irons, hair dryers and other heavy power consuming devices to a different circuit not being heavily used so Turn off some of the devices on the circuit to reduce the load.
- Loose connections are another possible but less common cause.
- With power off, check outlets for a loose wire and the electrical service panel supply connected to the circuit breaker to see if it has become loose

- If these suggestions do not solve the problem you may have a more serious problem such as a Short Circuit or Ground Fault.

Hope you have some idea about the types of electrical faults can occur in electrical engineering industry.

Earth Fault

A Ground Fault condition exists when the Earth wire touches the ground wire (bare copper) or the side of a metal outlet box (because the metal box is connected to the ground wire. The ground fault is a type of short circuit. This ensures that all exposed conductive surfaces are at the same electrical potential as the surface of the Earth, to avoid the risk of electrical shock if a person touches a device in which an insulation fault has occurred. It ensures that in the case of an insulation fault a very high current flows, which will trigger an over current protection device (fuse, circuit breaker) that disconnects the power supply.

How to Identify Earth Fault?

Same as Short Circuit you have to also check that supply is not touching the side of the metal outlet box or the ground wire.

Necessity of Earthing

- To provide safety to personnel and equipment.
- To maintain a voltage in healthy phases in the event of a fault in one phase.
- To protect equipment and buildings from lightning.
- To serve as a return conductor in communication and traction works

5.9 Techniques for Troubleshooting

A simple, but effective, method of investigating an electrical problem can be adopted by using this seven-step process when faced with a problem.

i. Gather the information
ii. Understand the malfunction
iii. Identify which parameters need to be evaluated
iv. Identify the source of the problem
v. Correct/repair the component

vi. Verify the repair

vii. Perform root cause analysis

5.10 Tagging Procedure (Maintenance Card) of Machinery

Inspection Tags and Maintenance Tags and Stone house Signs are used to ensure all machinery and other important equipment is working properly to keep your workers safe. Maintenance tags are used to identify equipment or machinery that has been taken out of service for repair and should not be used. Our selection of Maintenance Tags include Out of Order Tags, Out of Service Tags, and Do Not Operate Tags. Storehouse Signs' Equipment Tags convey important messages to workers about specific pieces of equipment. Our Equipment Tags can be used to mark equipment that is locked out for servicing, equipment that is out of order/out of service or equipment that needs repair, maintenance or inspection.

For maintenance record keeping, machine maintenance cards are used. General template is shown in figure below.

COMPANY NAME

Maintenance Schedule

Date: _____

Prepared By: _____

Submitted To: _____

Approved By: _____

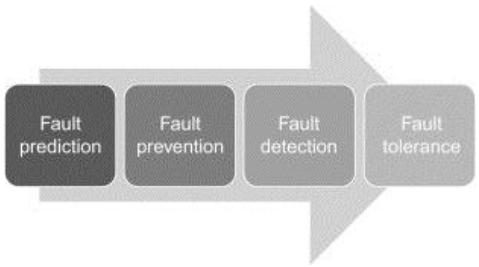
No.	Task Description	Task Duration	Due Date	Target Date	Resource Names	Person Responsible	Predecessor

Activity 5.9
Prepare maintenance chart of electrical installations.
Components/Instruments
Electrical installation, Operational Manual
Step 1: Select the electrical installation Step 2: Follow the instructions provide in operational/maintenance manual Step 3: Prepare maintenance chart according to the given instructions

5.11 Preventive Measure According to Identified Faults

According to the identified faults, an analysis be made and a procedure be devised to minimize the fault in future. Accordingly preventive measures be adopted as per the nature of the operation and type of the machinery involved.

The four-step process for fault mitigation is given in Fig. below.



i. **Fault Prediction**

Fault prediction involves adopting various models to predict the potential faults.

i. **Fault Prevention**

Fault prevention is a proactive strategy to identify all potential areas where a fault can occur and to close those gaps.

ii. **Fault Detection**

Fault detection can be achieved through various validation techniques. This includes devising comprehensive test cases, continuous integration and testing, cross-verification using traceability matrix, automated testing, and so on.

iii. **Fault Tolerance**

Fault tolerance can be achieved at various levels.

Activity 5.10
Perform visual checking of the circuit for fault detection.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Perform visual checks for fault detection Step 3: Record the observations

Activity 5.11
Perform the desired tests for fault identification.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Perform desired tests for fault detection Step 3: Record the observations

Activity 5.12
Troubleshoot the faulty short circuit/ open circuit in electrical installation.
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Perform troubleshooting to rectify fault. Step 3: Record the observations

Activity 5.13
Replace/repair the faulty components**.**
Components/Instruments
Various Measuring/Test Equipment.
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Change/Repair the faulty component Step 3: Record the observations

Activity 5.14
Document the troubleshooting report.
Components/Instruments
Maintenance Record, Writing Material
Step 1: Collect the maintenance history Step 2: Generate troubleshooting report

Activity 5.15
Test the installed electrical equipment for safe and optimum performance according to standards & regulations.
Components/Instruments
Various Measuring/Test Equipment, Electrical Equipment
Step 1: Issue the materials from the store as per the list provided by instructor. Step 2: Test Run Electrical Equipment Step 3: Ensure the proper functioning of the equipment Step 3: Record the parameters/observations

Key points

- A measuring instrument is a device that is used to compare the two quantities for determining the value or magnitude of an unknown quantity or variable. An instrument serves as an extension of human facility.
- In electrical engineering, we come across current, voltage, resistance , power, energy, flux, frequency, power factor etc. which are not visible to eye. The instruments, which are used to measure these quantities, are known as electrical measuring instruments.
- The main functions of the measurement system are indicating, recording, detecting, controlling and testing the electrical quantities.
- Electrical measuring instrument are classified based on the nature of the operation, function, purpose, uses and many other terms. Generally, it is classified into two categories:
  - ✓ Absolute Instrument
  - ✓ Secondary Instrument
- Following are the most popular and widely used instruments:
  - ✓ Ammeter
  - ✓ Voltmeter
  - ✓ Ohmmeter
  - ✓ Wattmeter
  - ✓ Multimeter
  - ✓ Flux meter
  - ✓ Oscilloscope
  - ✓ Energy Meter
  - ✓ Frequency Meter
  - ✓ Power Meter
  - ✓ Megger
- There are two types of maintenance strategies which are commonly used by companies for the equipment.
  - ✓ Reactive Maintenance
  - ✓ Preventive Maintenance
- Downtime is the amount of time a system, machine, or piece of equipment remains inoperable.
- Preventive maintenance schedule is a set of planned maintenance tasks that happens regularly on critical assets to avoid equipment failure. An effective preventive maintenance plan helps companies to avoid downtime, to save money, and to keep the workplace safe.

- Maintenance records of work equipment are a key part of health and safety management, requiring efficient storage and management. Paperwork is often kept for extended periods of time for health and safety or compliance purposes.
  - ✓ Common documentation includes O&M Manuals, electrical certifications, vehicle/fleet maintenance, building records, equipment maintenance for production/ work equipment and upkeep of medical equipment e.g. sterilization records.
- Three common electrical faults mainly can occur are;
  - ✓ Short Circuit Electrical Faults
  - ✓ Open Circuit Faults
  - ✓ Overload Circuit Faults
- Inspection Tags and Maintenance Tags and Stonehouse Signs are used to ensure all machinery and other important equipment is working properly to help keep your workers safe.

Exercise

Select the most appropriate option (✓)

1. A measuring instrument is a device that is used to compare the two quantities for determining the value or magnitude of an unknown quantity or variable.
   a. Value or Magnitude of Unknown Quantity or Variable
   b. Price of Unknown Quantity or Variable
   c. Expiry of Unknown Quantity or Variable
   d. All of the above
2. The Instruments used to measure Current , Voltage & Resistance are called:
   a. Mechanical Instruments b. Chemical Instruments
   c. Electrical Instruments d. None of Above
3. Electrical Instruments are classified into two categories as
   a. Absolute & Secondary b. Primary and Hybrid
   c. Linear & Non-Linear d. Analog & Digital

4. A wattmeter is an instrument used to measure:
   a. Current b. Resistance
   c. Power d. Continuity
5. A Megger is an instrument used to measure
   a. Insulation Resistance b. Leakage Current
   c. Flux d. Conductance
6. Maintenance strategies adopted by industrial organizations are
   a. Reactive and Preventive b. Routine and Emergency
   c. Monthly & Annually d. None of Above
7. Downtime is the amount of time a system, machine, or piece of equipment remains
   a. Functional b. Non-Functional
   c. Partially Operational c. All of Above
8. A ---------- is an abnormal low-resistance connection between two nodes of an electrical circuit that are meant to be at different Voltages
   a. Open Circuit b. Short Circuit
   c. High Impedance d. None of Above
9. ---------- are used to ensure all machinery and other important equipment is working properly to help keep your workers safe.
   a. Inspection Tags & Maintenance Tags b. Safety Symbols
   c. Bar Codes d. All of above
10. ---------- condition exists when the Earth wire touches the ground wire (bare copper) or the side of a metal outlet box (because the metal box is connected to the ground wire.
   a. Earth Fault b. Overhead Fault
   c. Open Circuit Fault d. None of above.

ANSWER KEY

1.	a	2.	c	3.	a	4.	c	5.	a
6.	a	7.	b	8.	b	9.	a	10.	a

Short Questions

Give short answer of the following questions.

1. Define measuring instrument.
2. Write any two purposes of using measuring instruments.
3. Enlist two categories of electrical measuring instruments.
4. Differentiate between ammeter and voltmeter.
5. Define wattmeter.
6. What is a flux meter?
7. Describe the application of power factor meter.
8. What do you understand preventive maintenance?
9. Define downtime.
10. Enlist the nature of faults that can occur in electrical installations.

Long Questions

Answer the following questions in detail.

1. Describe the function of flux meter, Oscilloscope, energy meter, frequency meter, power factor meter and megger.
2. Describe the different strategies adopted by industry for maintenance .Compare reactive and preventive maintenance in detail.
3. Describe the schedule of preventive maintenance.
4. Describe the procedure for record updating for preventive maintenance.
5. Describe the fault identification procedure in electrical installations.
6. Explain the tagging procedure of equipment and machinery.

Instructions for the Teachers

1. Adopt Health and Safety measures in the Lab.
2. Divide the students in group and properly monitor the activity and ensure the record of observations.
3. Use all the available ICT resources for better delivery of the content.
4. Ensure proper functioning of lab equipment

Glossary

Words/Terms	Meanings/Descriptions
Chapter 1:Rules and Regulations for Wiring	
IEE	Institute of Electrical Engineers, London
Voltage	It is the 'push' that causes charges to move in a wire or other electrical conductor
Resistance	It is the measure of the opposition to current flow in an electrical circuit
Chapter 2: Estimation for Electrician Works	
Wiring Diagram	Pictorial representation of an electric circuit, in which various elements, their connections and power source are shown in simplified shapes.
Map Measure	A tool used by the estimators of electrical estimating on the electrical drawings.
Tally	Device used for accounting or adding
Clamp	Device used for clamping large set of plans/drawings
Chapter 3:Industrial Wiring	
Magnet	A magnet is a material or object that produces a magnetic field
Flux	The total number of magnetic lines of force passing through a particular point
Magnetic Induction	The production of an electromotive force across an electrical conductor in a changing magnetic field
Chapter 4:Control and Protective Devices	
Protective Devices	A device used to protect equipment, machinery, components and devices in electrical and electronic circuit against short circuit, over current and earth faults
MCB	Miniature Circuit Breaker
ELCB	Earth Leakage Circuit Breaker
Chapter 5: Repair/Maintenance of Electrical Installations	
Measuring Instrument	A device that is used to compare the two quantities for determining the value or magnitude of an unknown quantity or variable.
Ammeter	A measuring instrument used to measure current
Wattmeter	A measuring instrument used to measure power
Flux Meter	A measuring instrument used to measure magnetic flux
Megger	A instrument used to measure insulation resistance

ABOUT THE AUTHOR

The Author of the Book, **Engr. Shahbaz Hussain** is a renowned TVET Expert having almost 26 years of experience in the sector. He has got his education from GCU and UET, Lahore. Apart from Pakistan, he has received his training from UK in the field of Curriculum Development. He has vast experience of teaching, TVET administration as Principal, District Manager, Director in the P-TEVTA and NAVTTC. He is the author of almost a dozens of Books for the TVET-DAE students. His famous publications/textbooks include:

i. Electric Circuits / Electrical Essential & Networks (ELTR-114)
ii. Electrical Essential & Networks (MTR-132)
iii. Electronic Devices & Circuits (ELTR-123)
iv. Microprocessor Architecture (ELTR-314)
v. Microprocessor Architecture (CIT-235)
vi. Principles of Electrical Engineering (ET-115)
vii. Propagation of Electromagnetic Waves (ELTR-212)
viii. Electrical Machines/Motors and Generators (ELTR-243)
ix. Electronics-1 (CIT-134)
x. Digital Logic Design (ET-282)
xi. Digital Circuits & Microprocessor Applications (IT-254)

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