Technical and Vocational Stream
Learning Resource Material

Industrial Installation and Maintenance
(Grade 10)
Electrical Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline, self-reliance, creativity and thoughtfulness. It is essential to develop linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills in students. It is also necessary to bring the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This learning resource material for Electrical engineering has been developed in line with the Secondary Level Electrical engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops, seminars and interaction programs attended by teachers, students, parents and concerned stakeholders.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Mr. Yubaraj Paudel and members of the subject committee Dr. Nandabikram Adhikari, Er. Chitra Bahadur Khadka, Mr. Damberdhwaj Angdembe, Er. Sanju Shrestha is highly acknowledged. This learning resource material is compiled and prepared by Er. Rupesh Maharjan, Er. Jaya Prakash maharjan, Er. Rakesh Singh, Er. Bigyan Pokharel. The subject matter of this material is edited by Mr. Badrinath Timsina and Mr. Khilanath Dhamala. Similarly, the language is edited by Mr. Saroj Kumar Mandal. CDC extends sincere thanks to all those who have contributed to developing this material in this form.

This learning resource material contains a wide coverage of subject matters and sample exercises which will help the learners to achieve the competencies and learning outcomes set in the curriculum. Each chapter in the material clearly and concisely deals with the subject matters required for the accomplishment of the learning outcomes. The Curriculum Development Centre always welcomes creative and constructive feedback for the further improvement of the material.

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Guidelines to Teachers

A. Facilitation Methods

The goal of this course is to combine the theoretical and practical aspects of the contents needed for the subject. The nature of contents included in this course demands the use of practical or learner focused facilitation processes. Therefore, the practical side of the facilitation process has been focused much. The instructor is expected to design and conduct a variety of practical methods, strategies or techniques which encourage students engage in the process of reflection, sharing, collaboration, exploration and innovation new ideas or learning. For this, the following teaching methods, strategies or techniques are suggested to adopt as per the course content nature and context.

Brainstorming

Brainstorming is a technique of teaching which is creative thinking process. In this technique, students freely speak or share their ideas on a given topic. The instructor does not judge students' ideas as being right or wrong, but rather encourages them to think and speak creatively and innovatively. In brainstorming time, the instructor expects students to generate their tentative and rough ideas on a given topic which are not judgmental. It is, therefore, brainstorming is free-wheeling, non-judgmental and unstructured in nature. Students or participants are encouraged to freely express their ideas throughout the brainstorming time. Whiteboard and other visual aids can be used to help organize the ideas as they are developed. Following the brainstorming session, concepts are examined and ranked in order of importance, opening the door for more development and execution. Brainstorming is an effective technique for problem-solving, invention, and decision-making because it taps into the group's combined knowledge and creative ideas.

Demonstration

Demonstration is a practical method of teaching in which the instructor shows or demonstrates the actions, materials, or processes. While demonstrating something the students in the class see, observe, discuss and share ideas on a given topic. Most importantly, abstract and complicated concepts can be presented into visible form through demonstration. Visualization bridges the gap between abstract ideas and concrete manifestations by utilizing the innate human ability to think visually. This enables students to make better decisions, develop their creative potential, and obtain deeper insights across a variety of subject areas.

Peer Discussion

Peer conversation is a cooperative process where students converse with their peers to exchange viewpoints, share ideas, and jointly investigate subjects that are relevant or of mutual interest. Peer discussion is an effective teaching strategy used in the classroom to encourage critical thinking, active learning, and knowledge development. Peer discussions encourage students to express their ideas clearly, listen to opposing points of view, and participate in debate or dialogue, all of which contribute to a deeper comprehension and memory of the course material. Peer discussions also help participants develop critical communication and teamwork skills by teaching them how to effectively articulate their views, persuasively defend their positions, and constructively respond to criticism.

Peer conversation is essential for professional growth and community building outside of the classroom because it allows practitioners to share best practices, work together, and solve problems as a group. In addition to expanding their knowledge horizon and deepening their understanding, peer discussions help students build lasting relationships and a feeling of community within their peer networks.

Group Work

Group work is a technique of teaching where more than two students or participants work together to complete a task, solve a problem or discuss on a given topic collaboratively. Group work is also a cooperative working process where students join and share their perspectives, abilities, and knowledge to take on challenging job or project. Group work in academic contexts promotes active learning, peer teaching, and the development of collaboration and communication skills. Group work helps individuals to do more together than they might individually do or achieve.

Gallery Walk

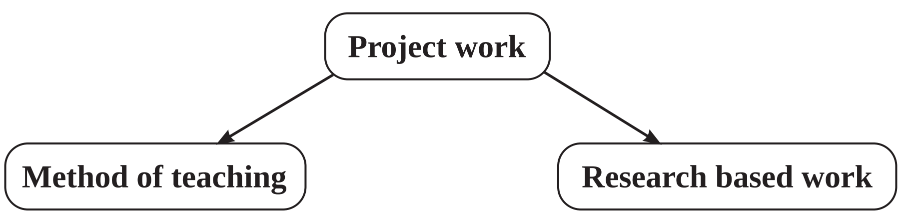
Gallery walk is a critical thinking strategy. It creates interactive learning environment in the classroom. It offers participants or students a structured way to observe exhibition or presentation and also provides opportunity to share ideas. It promotes peer-to-peer or group-to-group engagement by encouraging participants to observe, evaluate and comment on each other’s work or ideas. Students who engage in this process improve their communication and critical thinking abilities in addition to their comprehension of the subject matter, which leads to a deeper and more sophisticated investigation of the subjects at hand.

Interaction

The dynamic sharing of ideas, knowledge, and experiences between people or things is referred to as interaction, and it frequently takes place in social, academic, or professional settings. It includes a broad range of activities such as dialogue, collaboration or team work, negotiation, problem solving, etc. Mutual understanding, knowledge sharing, and interpersonal relationships are all facilitated by effective interaction. Interaction is essential for building relationships, encouraging learning, and stimulating creativity in both in-person and virtual contexts. Students can broaden their viewpoints, hone their abilities, and jointly achieve solutions to difficult problems by actively interacting with others.

Project Work

Project work is a special kind of work that consists of a problematic situation which requires systematic investigation to explore innovative ideas and solutions. Project work can be used in two senses. First, it is a method of teaching in regular class. The next is: it is a research work that requires planned investigation to explore something new. This concept can be presented in the following figure.



Project work entails individuals or teams working together to achieve particular educational objectives. It consists of a number of organized tasks, activities, and deliverables. The end product is important for project work. Generally, project work will be carried out in three stages. They are:

- Planning
- Investigation
- Reporting

B. Instructional Waterials

Instructional materials are the tools and resources that teachers use to help students. These resources/materials engage students, strengthen learning, and improve conceptual comprehension while supporting the educational goals of a course or program. Different learning styles and preferences can be accommodated by the variety of instructional resources available. Here are a few examples of typical educational resource types:

- Daily used materials
- Related Pictures
- Reference books
- **Slides and presentation:** PowerPoint slides, keynote presentations, or other visual aids that help convey information in a visually appealing and organized manner.
- **Audiovisual materials:** Videos, animations, podcasts, and other multimedia resources that bring concepts to life and cater to auditory and visual learners.
- **Online Resources:** Websites, online articles, e-books, and other web-based materials that can be accessed for further reading and research.

Maps, charts, and graphs: Visual representations that help learners understand relationships, patterns, and trends in different subjects.

Real-life examples and Case Studies: Stories, examples, or case studies that illustrate the practical application of theoretical concepts and principles.

C. Assessment

Formative Test

Classroom discussions: Engage students in discussions to assess their understanding of concepts.
Quizzes and polls: Use short quizzes or polls to check comprehension during or after a lesson.
Homework exercises: Assign tasks that provide ongoing feedback on individual progress.
Peer review: Have students review and provide feedback on each other's work.

Summative Test

Exams: Conduct comprehensive exams at the end of a unit or semester.
Final Projects: Assign projects that demonstrate overall understanding of the subject.

Peer Assessment

Group projects: Evaluate individual contributions within a group project.
Peer feedback forms: Provide structured forms for students to assess their peers.
Classroom Presentations: Have students assess each other's presentations.

Objective Test

Multiple-choice tests: Use multiple-choice questions to assess knowledge.
True/False questions: Assess factual understanding with true/false questions.
Matching exercises: Evaluate associations between concepts or terms.

Portfolio Assessment

Compilation of work: Collect and assess a variety of student work samples.
Reflection statements: Ask students to write reflective statements about their work.
Showcase events: Organize events where students present their portfolios to peers or instructors.

Observational Assessment

Classroom observations: Observe students' behavior and engagement during class.
Performance observations: Assess practical skills through direct observation.
Field Trips: Evaluate students' ability to apply knowledge in real-world settings.

List of Abbreviation

AC - Alternating Current

GO - Gang Operated

HV - High Voltage

LBS - Load Break Switches

LOTO - Lock Out-Tag Out

LV - Low Voltage

MCB - Miniature Circuit Breaker

MCCB - Molded Case Circuit Breaker

NEA - Nepal Electricity Authority

OLR - Over Load Relay

PPE - Personal Protective Equipment

PTW - Permit-To-Work

SLD - Single Line Diagram

Fire and Safety Standards

Unit 1

1.1 Codes of Practice for Electrical Wiring Regulations

The codes of practice for electrical wiring regulations are established to ensure safety, reliability, and efficiency in electrical installations. These regulations address various protective measures to prevent hazards associated with electrical systems.

1.1.1 Protection Against Electric Shock

Electric shock occurs when an electric current passes through the body. The severity of electric shock can range from mild discomfort to severe injury or even death, depending on factors such as the amount of current, the duration of exposure, and the path the current takes through the body.

Some key ways to protect against electric shock are:

a. Insulate the live parts of electrical appliances and tools by using rubber, plastic or non-conducting materials.

b. Connect the metal parts of the electrical equipment to the ground using proper size of earth conductor which ultimately helps in preventing any electrical shock.

c. Do wiring properly by following the standards for wiring which can prevent the electric shock.

d. Regular maintenance and repair of the electrical equipment can definitely prevent any electric shock in future.

e. Use PPE like insulating gloves, safety goggles, insulating shoes, insulating mat, face shield, etc. during operation and maintenance of high voltage electrical equipmentwhich definitely protect against the electrical shock

f. Follow safe work practice such as de-energizing equipment before maintenance or repair work.

1.1.2 Protection Against Thermal Effects

Protection against thermal effects, in the context of electrical safety, involves safeguarding against overheating, fire hazards, and other temperature-related risks that can arise from electrical equipment and systems.

Here are several measures to mitigate thermal effects:

a. Ensuring that electrical equipment, such as transformers, motors, and switchgear, is adequately ventilated and cooled, helps prevent overheating

b. Ensuring that electrical equipment is appropriately sized and rated for the electrical load it will handle is crucial

c. Keeping electrical equipment and surroundings clean and free from dust and debris helps in efficient heat dissipation

d. Following industry standards and manufacturer recommendations for installation, operation, and maintenance of electrical equipment ensures that they are used within their designed temperature limits.

e. In high-risk areas, employing fire detection systems like smoke detectors and fire suppression systems such as sprinklers can mitigate the risk of fire resulting from electrical overheating.

1.1.3 Protection Against Overcurrent

Protection against overcurrent is crucial in electrical systems to prevent damage to equipment, fire hazards, and electrical failures caused by excessive current flow. Overcurrent can occur due to various reasons like short circuits, overloads, or faults in the system. Several protective measures are employed to mitigate the risks associated with overcurrent:

a. Circuit breakers are devices designed to automatically interrupt the flow of electricity when a fault or overcurrent condition is detected

b. Overload relays are used to protect motors from overheating due to excessive current drawn during prolonged operation

c. While primarily used for personal protection against electric shock, GFCIs also detect overcurrent situations resulting from ground faults and quickly interrupt the circuit to prevent hazards.

d. Ensuring that conductors, circuit breakers, fuses, and other protective devices are appropriately sized and rated for the electrical load that they handle helps to prevent from overcurrent situations.

e. Periodic checks and maintenance of electrical systems help to detect potential issues that could lead to overcurrent conditions

f. Adhering to industry standards and regulations for installation, operation, and maintenance of electrical systems ensures that appropriate protective measures are in place to prevent overcurrent situations

1.1.4 Protection Against Fault Currents

Protection against fault currents is essential to prevent damage to electrical equipment, fire hazards, and ensure the safety of individuals working with or around electrical systems. Fault currents, which occur due to short circuits or ground faults, can lead to sudden and excessive current flow through the system. Here are several measures used for protection against fault currents:

a. Circuit breakers, fuses, and relays are primary devices used to protect against fault currents. They quickly interrupt the flow of current when a fault occurs, isolating the affected section of the circuit to prevent damage

b. Ground Fault Circuit Interrupters (GFCIs) and Ground Fault Protection Relays (GFPRs) are specifically designed to detect ground faults, which occurs when a live wire comes in contact with a grounded surface

c. Arc Fault Circuit Interrupters (AFCIs) are specialized devices that detect dangerous arcing in electrical circuits. They disconnect the power supply upon detecting these arcs, which can lead to fires.

d. Proper design and installation of electrical systems, including separation of circuits, insulation, and clear labeling of circuits, help to reduce the likelihood of fault currents and aid in their quick identification and isolation

e. Adhering to industry standards and regulations for the installation, operation, and maintenance of electrical systems ensures that appropriate protective measures are in place to handle fault currents effectively

1.2. Electric Safety Signs and Colors

1.2.1 Electrical Safety Signs

Electrical safety signs are used to alert individuals to potential electrical hazards and provide information on how to stay safe around electrical equipment and installations. These signs use symbols, text, and colors to convey important information about electrical dangers. Here are somecommon electrical safety signs and their meanings:

a. **Prohibition Signs**

A sign prohibiting behavior likely to increase or cause danger are included in prohibition signs. For e.g. “No access for unauthorized personnel”. These signs should be used for “Do Not” commands. For example – to indicate that smoking is not allowed in a particular area. In the workplace they should be used to reinforce instructions prohibiting dangerous activities.

Fig.1.1: Prohibition Sign

Signs prohibiting an activity appear as a circular red band with a single diagonal cross line descending from left to right at a 45-degree angle. The background should be solid white with the imagery indicating the nature of the command in black.

b. Mandatory Signs

Mandatory signs in an electrical safety system are used to convey actions that are required or mandatory for ensuring safety when working with electrical equipment or installations. These signs typically feature a *blue circular background with a white symbol or text* to indicate what must be done. It's crucial to follow these mandatory signs in an electrical safety system to ensure the safety of individuals working with or around electrical equipment. Failure to comply with these requirements can result in serious accidents, injuries, or damage to equipment. Some examples are: wear personal protective equipment (PPE), Face shield required, ear protection required, etc.

Fig.1.2: Mandatory Sign

c. **Warning Signs**

A sign giving warning of a hazard or danger are included in warning signs. For e.g. “Danger: High Voltage”. These signs should be used to make people aware of a nearby danger. For example, a flammable liquid store. Signs warning of a particular hazard appear as a black band in the shape of an equilateral triangle. The background within the band should be yellow with the imagery indicating the type of hazard in black, positioned centrally on the sign.

Fig.1.3: Warning Sign

d. **Safe Condition Signs**

Safe condition signs in an electrical system are used to indicate the location of safety equipment, emergency exits, or safe conditions. These signs typically feature a *green rectangular or square background with white symbols or text*. They convey information about the availability of safety features or the way to exit safely. It's important for individuals to be familiar with these safe condition signs in an electrical system to quickly and effectively respond to emergencies or locate safety equipment when needed. Regular training and drills can help reinforce awareness of these signs and appropriate actions in emergency situations. Some examples are: *emergency exit sign, first aid sign, emergency stop button, fire extinguisher sign,* etc.

Fig.1.4: Safe Condition Sign

e. Supplementary Signs

Supplementary signs in an electrical system are used to provide additional information or clarification about specific conditions or actions related to electrical safety. These signs are often used in conjunction with other safety signs to convey more detailed instructions or warnings. Supplementary signs typically feature a white background with black symbols or text. Supplementary signs are essential for enhancing communication and ensuring that individuals have the necessary information to work safely with electrical systems. When using supplementary signs, it's important to ensure that they are clear, easily understood, and placed in proximity to the relevant safety signs or equipment. Some example of these type of signs are: *Voltage rating*, *equipment identification*, *Specific PPE requirement*, etc.

1.2.2 Safety Symbols

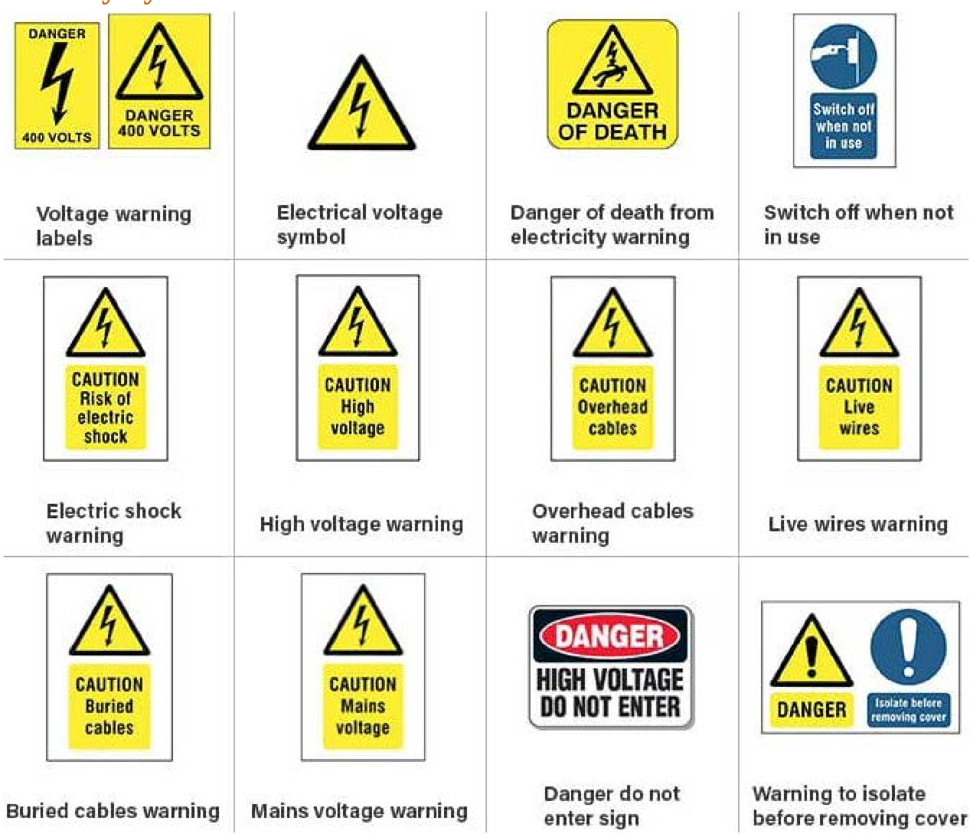


Fig.1.5: Safety Symbols

Safety symbols are universally recognized graphical representations used to communicate specific hazards, warnings, and precautions related to various objects, substances, or environments. These symbols are designed to quickly convey essential safety information without language barriers, ensuring that individuals, especially in workplaces or public spaces, are aware of potential dangers and necessary precautions

1.2.3 Safety Colors

Safety colors play a vital role in conveying information, particularly in alerting individuals to potential hazards, guiding them on safety procedures, and promoting a safe environment. These colors are used across various industries, workplaces, and public spaces to enhance safety awareness. Here are some common safety colors along with their meanings:

a. **Red:** Red is often used to indicate immediate hazards, danger, or prohibition. It's employed to grab attention and alert individuals to stop, indicating danger, fire-related hazards, or emergency stop situations.

b. **Orange:** Orange signifies warnings and potential hazards. It's used to indicate caution, especially in situations where there's a need to proceed carefully or exercise caution.

c. **Yellow or Amber:** Yellow or amber is typically used to denote caution, alertness, or warning. It's used in areas where there are potential risks that require attention but might not pose immediate danger

d. **Green:** Green often represents safety, indicating safe conditions, emergency exits, or first aid locations. It signifies areas where there's no immediate danger and can also indicate safe equipment operation.

e. **Blue:** Blue is frequently used for informational or mandatory signs. It can indicate mandatory actions or information, such as indicating a particular action to be taken or providing information about a certain area or equipment.

f. **White:** White is generally used for additional information or to display general information or safety instructions. It can be used as a background color for other safety symbols or signs to enhance visibility.

g. **Black:** Black is often used for lettering or borders to provide contrast and visibility, especially on safety signs or labels. It's typically used in conjunction with other safety colors to improve readability.

h. **Purple:** Purple is less common but can signify radiation hazards or dangerous materials. It's used in some cases to denote specific hazards related to radiation or other designated hazards.

i. **Brown:** Brown is sometimes used to denote potential hazards related to combustible materials or to indicate specific hazards in certain contexts, although it's less frequently used compared to other safety colors

1.3 Personal Protective Equipment

Personal Protective Equipment (PPE) refers to specialized gear or clothing worn by individuals to protect themselves from various workplace hazards, injuries, or health risks. PPE serves as a crucial line of defense against different types of dangers, such as physical, chemical, biological, electrical, and environmental hazards.

PPE-1: Helmets

Purpose: Head protection against falling objects, impact, and electrical hazards.
Examples: Hard hats designed to meet specific safety standards for construction, industrial, and utility workers.

Fig.1.6: Helmet

PPE-2: Safety Footwear

Purpose: Protects feet from crushing hazards, punctures, slips, and electrical dangers.
Examples: Steel-toed boots or shoes for impact resistance, safety shoes for enhanced traction and stability.

Fig.1.7: Safety Footwear

PPE-3: Respiratory Protective Equipment

Purpose: Shields against inhalation of hazardous substances, particles, dust, fumes, gases, or vapors.

Fig. 1. 8 Safety Mask

Examples: N95 masks, P100 masks, respirators with cartridges for specific chemicals or particulates.

PPE-4: Arm and Hand Protection

Purpose: Guards against cuts, burns, chemical exposure, abrasions, or biological hazards.
Examples: Chemical-resistant gloves, cut-resistant gloves, heat-resistant gloves, disposable gloves for medical settings.

Fig.1.9: Safety Gloves

PPE-5: Eye and Face Protection

Purpose: Shields the eyes and face from impact, chemical splashes, dust, or harmful light exposure.
Examples: Safety glasses, goggles, face shields with adjustable headbands for added protection.

Fig.1.10: Safety glasses

PPE-6: Protective Clothing and Coverall

Purpose: Provides full-body protection against chemical splashes, hazardous particles, biohazards, or environmental contaminants.
Examples: Coveralls, aprons, lab coats made of materials resistant to chemicals or biological hazards.

Fig.1.11: Safety Clothes

PPE-7: Ear Protection

Purpose: Mitigates the risk of hearing damage caused by loud noises or machinery.

Examples: Earplugs made of foam or silicone, earmuffs with adjustable headbands for noise reduction.

Fig.1.12: Safety Headbands

PPE-8: Safety Belts and Harnesses

Purpose: Prevents falls from heights, providing support and safety when working at elevated positions.

Examples: Safety harnesses, safety belts, lanyards designed to arrest falls and protect workers at elevated sites.

Fig.1.13: Safety belt

Each category of PPE serves a specific purpose in protecting workers from different workplace hazards. It's crucial to select the appropriate type of PPE based on the nature of the job, potential risks, and specific safety requirements to ensure maximum effectiveness in safeguarding workers' health and safety. Regular inspection, proper maintenance, and training on PPE usage are essential aspects of workplace safety protocols.

1.4 Firefighting and Fire Suppression Equipment

1.4.1 Concept and Importance of Firefighting and Fire Suppression Equipment

Firefighting and fire suppression equipment are essential tools used to combat and control fires, ensuring the safety of individuals and properties. These tools are designed to extinguish, contain, or control fires, minimizing their impact and preventing further damage.

Importance of Firefighting and Fire Suppression Equipment

Life Safety: These tools are crucial for protecting human lives by suppressing fires and enabling safe evacuation.

Property Protection: They help in minimizing damage to buildings, infrastructure, and valuable assets.

Preventing Escalation: Effective firefighting equipment can prevent small fires from escalating into larger, more destructive ones.

Emergency Response: Fire suppression tools are essential for emergency responders to manage and control fire incidents effectively.

Risk Mitigation: They reduce the risk of fire-related injuries, fatalities, and financial losses.

1.4.2 Classification of Fires

Fires can be classified into different categories based on the type of fuel that is burning. The most commonly used classification system for fires is based on the following classes:

Class A Fires: These are fires involving ordinary combustibles such as wood, paper, cloth, or plastics. Class A fires are typically extinguished by cooling the fuel source with water or other extinguishing agents.

Class B Fires: These are fires involving flammable liquids such as gasoline, oil, or grease. Class B fires are typically extinguished by smothering the fuel source with foam, powder, or carbon dioxide.

Class C Fires: These are fires involving electrical equipment such as appliances, wiring, or circuit breakers. Class C fires require specialized extinguishing agents that are nonconductive and can extinguish the fire without damaging the equipment. Example : CO_2, dry chemical agents.

Class D Fires: These are fires involving flammable metals such as magnesium, titanium, or potassium. Class D fires require specialized extinguishing agents that are specifically designed to extinguish fires involving these types of metals. Example : special dry powder extinguishing agent.

Class K Fires: These are fires involving cooking oils, grease, or animal fats. Class K fires are typically extinguished by using specialized extinguishing agents that react with the oils and fats to create a soapy foam that smothers the fire. Example : wet chemical extinguisher agent.

1.4.3 Firefighting and Fire Suppression Equipment

Firefighting and fire suppression equipment encompass a wide range of tools and systems designed to combat and control fires of different magnitudes and types.

Different types of firefighting and fire suppression equipment are available to combat fires based on their classification and specific requirements. Some common equipment includes:

a. **Fire Extinguishers:** Portable devices that contain extinguishing agents suitable for specific fire classes. They come in various types:

i. **Water Extinguishers (Class A):** Suitable for fires involving ordinary combustibles like wood, paper, and cloth.

ii. **Dry Chemical Extinguishers (Class ABC or BC):** Effective for multiple fire classes, including flammable liquids, electrical fires, and ordinary combustibles.

iii. **CO_2 Extinguishers (Class BC or Class K):** Used for electrical fires and flammable liquid fires without leaving residue.

iv. **Foam Extinguishers (Class AB):** Ideal for flammable liquids and ordinary combustibles

Fig.1.14: Different types of fire extinguishers

b. **Fire Hoses and Nozzles:** Connected to a water supply or a pump, these hoses deliver water or firefighting agents to extinguish larger fires. They come in various sizes and types, such as straight-stream, fog, or combination nozzles.

Fig.1.15: Fire Nozzle

c. **Fire Sprinkler Systems:** Installed in buildings to automatically release water or other extinguishing agents when a fire is detected. Sprinkler heads activate individually based on heat, limiting the fire's spread and minimizing damage.

d. **Fire Blankets:** Made of fire-resistant materials, fire blankets are used to smother small fires, wrap around individuals to protect them from flames, or as covers for rescuing people in emergency situations.

e. **Fire Hydrants:** Fixed water outlets strategically located in urban areas and connected to the water supply. Firefighters connect hoses to hydrants to access a ready supply of water for firefighting.

f. **Fire Suppression Systems:** Specialized systems designed for specific fire hazards or environments:

g. **Foam-Based Systems:** Utilized for flammable liquid fires, creating a blanket-like layer to prevent fuel ignition.

h. **Gas-Based Systems:** Designed to suppress fires in enclosed spaces by displacing oxygen or inhibiting the chemical reaction required for combustion.

k. **Dry Chemical Systems:** Effective for Class D fires involving combustible metals like magnesium or lithium.

l. **Firefighting Vehicles and Equipment:** Fire departments use various vehicles equipped with pumps, hoses, and other tools for firefighting operations. These include fire engines, aerial ladder trucks, and specialized vehicles for hazardous material incidents.

m. **Personal Protective Equipment (PPE):** Essential gear for firefighters, including helmets, turnout gear (fire-resistant clothing), gloves, boots, and self-contained breathing apparatus (SCBA) to protect against heat, flames, and smoke inhalation

1.5 Lock Out-Tag Out (LOTO) and Permit to Work (PTW)

1.5.1 Concept and Necessity of LOTO

Lock Out-Tag Out (LOTO) is a safety procedure used in industries and workplaces to ensure that dangerous machines or equipment are properly shut off and cannot be restarted before maintenance or servicing work is performed. The procedure involves isolating energy sources and placing locks or tags on the energy isolation devices to prevent accidental or unauthorized startup of the machinery". The key concepts of LOTO include:

Fig.1.16: LOTO

Energy Isolation: This involves identifying and controlling all energy sources (electrical, mechanical, hydraulic, pneumatic, etc.) that power the machinery or equipment.

Locking Devices: Physical locks are used to secure energy isolation points, ensuring that the machinery remains in a deactivated state during maintenance or repair work.

Tagging: Tags are attached to the locks to provide information about who is working on the equipment, when the lock was applied, and why the equipment is locked out.

The necessity of LOTO lies in preventing hazardous energy releases, which can cause severe injuries or fatalities to workers servicing or maintaining machinery. It ensures the safety of employees by minimizing the risk of accidental startup, electrical shocks, or unexpected energy discharge.

1.5.2 Concept and Necessity of PTW System

The **Permit-To-Work (PTW)** system is a formal procedure used in hazardous industries such as oil refineries, chemical plants, and construction sites. It ensures that specific tasks are carried out safely by controlling potential hazards through a systematic authorization process. Key concepts of the PTW system include:

Risk Assessment: Before any work begins, a thorough risk assessment is conducted to identify potential hazards associated with the task.

Authorization: A formal permit is issued only after assessing the risks involved and implementing necessary control measures.

Work Control: The permit outlines the specific work to be performed, safety precautions, and any special requirements or limitations.

Communication: Clear communication among involved parties ensures everyone understands the risks, precautions, and steps required to safely complete the job.

The necessity of a PTW system lies in managing high-risk activities to prevent accidents, injuries, and environmental damage. It provides a structured approach to identify, assess, and control hazards, thereby ensuring that work is conducted in a safe and controlled manner.

Both LOTO and PTW systems are essential safety procedures designed to protect workers, prevent accidents, and ensure a safe working environment in high-risk industries.

Exercise

Choose the correct answer from the given alternatives.

1. Which of the following should you NOT use to extinguish an electrical fire?

   a. Water b. CO_2 extinguisher

   c. Fire blanket d. Dry chemical extinguisher

2. Which of the following is NOT a common electrical hazard?

   a. Electrical shock b. Power outage

   c. Arc flash d. Electrical fire

3. Which safety color is commonly used to mark physical hazards or dangerous machinery?

   a. Red b. Orange c. Yellow d. Blue

4. In the classification of fires, which class involves electrical equipment as the source of fire?

   a. Class A b. Class B c. Class C d. Class D

5. When is Lock Out-Tag Out typically applied to machinery and equipment?

   a. During routine maintenance b. Only during emergency situations

   c. After a machine breakdown d. When equipment is running at full capacity

6. Overcurrent protection is essential for preventing............

   a. Electric shocks b. Thermal effects

   c. Fires due to excessive current d. Fault currents

7. Classification of fires is based on.................

   a. The color of the flames b. The type of fuel involved

   c. The size of the fire d. The temperature of the fire

8. PTW is used to.....................

   a. Control access to buildings b. Authorize and control hazardous work

   c. Conduct fire drills d. Prevent unauthorized access

9. Warning signs are used to..................

   a. Indicate safe conditions b. Require specific actions

c. Alert to potential dangers   d. Prohibit actions

10. What color is frequently used for informational signs or notices?

    a. Red   b. Green   c. Blue   d. Orange

Write short answer to the following questions.

1. What are the uses of different safety colors used in electrical system?
2. How fire is classified on the basis of class and their extinguisher?
3. What are the necessities of LOTO and PTW?
4. What are the ways to protection against electric shock?
5. How can be thermal effects can be mitigated?
6. Which measures are employed to mitigate the risks associated with overcurrent?
7. What are the measures used for protection against fault currents?

Write long answer to the following questions.

1. What are the firefighting and fire suppression equipment? How these equipment's help to extinguish the fire?
2. Write the full form of PPE. Mention any eight PPEs with their purpose and example.
3. What are the uses of different safety colors used for electrical works?
4. Define electrical safety signs. How the electrical safety signs can be classified?

Project Works

1. To identify different types of fire extinguishers available at school (water, CO2, foam, dry chemical) and learn their uses.
2. To learn about different types of PPE used in electrical work and other potentially hazardous situations.
3. To create a comprehensive fire safety plan for their school or a section of their community.
4. To display electrical safety signs and colors.
5. To conduct a fire hazard assessment of a specific area (e.g., a workshop, a home, a school lab).
6. To demonstrate the use of different firefighting equipment (e.g., fire extinguishers, fire blankets).

Unit 2 Distribution System in Industrial Installations

2.1 Introduction to Distribution System

Electric power, produced at the power stations, is located at distances far away from the consumers. It is then transmitted over large distances to load centers with the help of conductors known as transmission lines. Finally, it is distributed to a large number of small and big consumers through a distribution network.

2.1.1 Types of Distribution System

a) Primary Distribution System

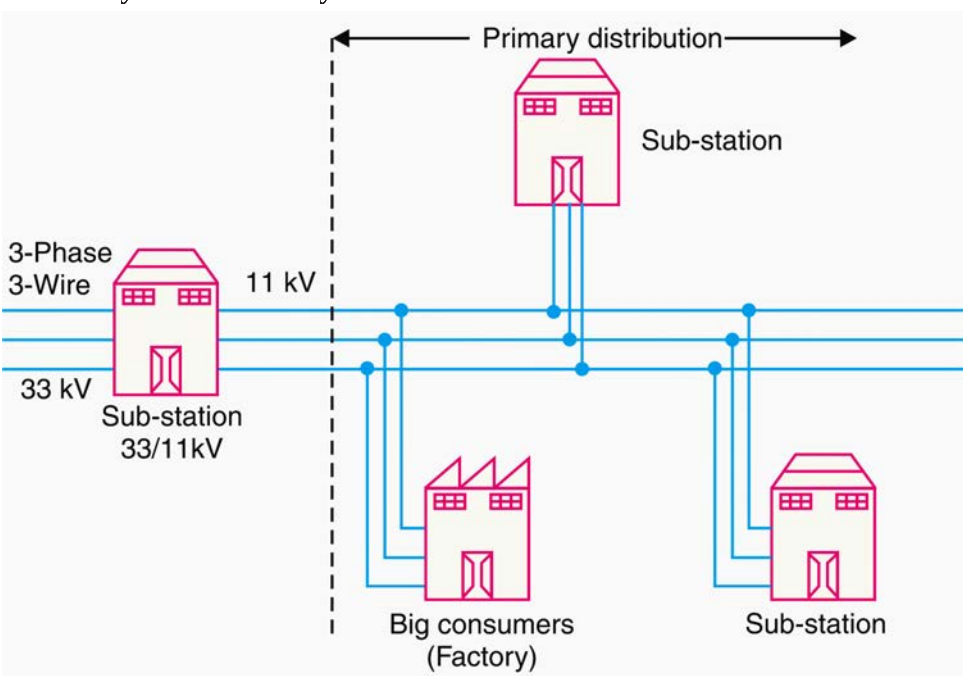


Fig.2.1: Primary Distribution System

The primary distribution system refers to the initial stage of electrical power distribution from a substation to consumers. It is responsible for delivering electricity from the high-voltage transmission system to lower voltage levels that can be used by homes, businesses, and other entities.

Here are some key points about the primary distribution system:

Substation: The primary distribution system begins at a substation, which is a facility where the high-voltage electricity from the transmission system is stepped down to a lower voltage level for distribution. Substations typically house transformers, switchgear, and other equipment necessary for power distribution.

Voltage Levels: The primary distribution system operates at medium voltage levels, typically ranging from a few thousand volts up to around 33,000 volts, depending on the specific power system and country. The exact voltage level may vary, but the goal is to bring the electricity to a level that can be safely used by consumers.

Feeders: From the substation, the primary distribution system uses power lines called feeders to carry the electricity to different areas. Feeders are typically overhead lines supported by utility poles or underground cables, depending on the infrastructure and location.

Distribution Transformers: Along the feeders, distribution transformers are installed to further step down the voltage to a level suitable for consumption. These transformers are usually located on utility poles or in pad-mounted enclosures and convert the medium voltage to low voltage, typically 11kV/240 volts for residential areas.

Sub-distribution: The primary distribution system also includes secondary distribution systems that deliver electricity to individual consumers. These secondary systems branch out from the feeders and consist of service lines and wiring that connect to homes, buildings, and other facilities.

Protection and Control: The primary distribution system incorporates various protective devices, such as fuses, circuit breakers, and reclosers, to detect and isolate faults or abnormal conditions. These devices help ensure the safety and reliability of the distribution system by minimizing the impact of faults and interruptions.

Metering: Within the primary distribution system, utility companies install electric meter at consumer premises to measure and monitor electricity consumption. This enables accurate billing and helps manage the load on the distribution system

b) Secondary Distribution System

The secondary distribution system consists of a network of overhead lines, underground cables, transformers, switchgear, and other equipment. It is responsible for delivering electricity to residential, commercial, and industrial customers. The voltages in the secondary distribution system vary depending on the location and the specific requirements of the electrical grid, but typical voltages include 240 V (volts) for residential customers and 415 V for commercial and industrial customers. The secondary distribution system includes distribution substations, where the voltage is further reduced to appropriate levels for consumption by end users. Transformers are used to step down the voltage, and switchgear is employed to control the flow of electricity and protect the system from faults or overloads. Within the secondary distribution system, power lines or cables are interconnected in a grid-like fashion to ensure redundancy and reliability. This interconnected network allows electricity to be rerouted in case of equipment failure or maintenance activities, minimizing disruptions to consumers

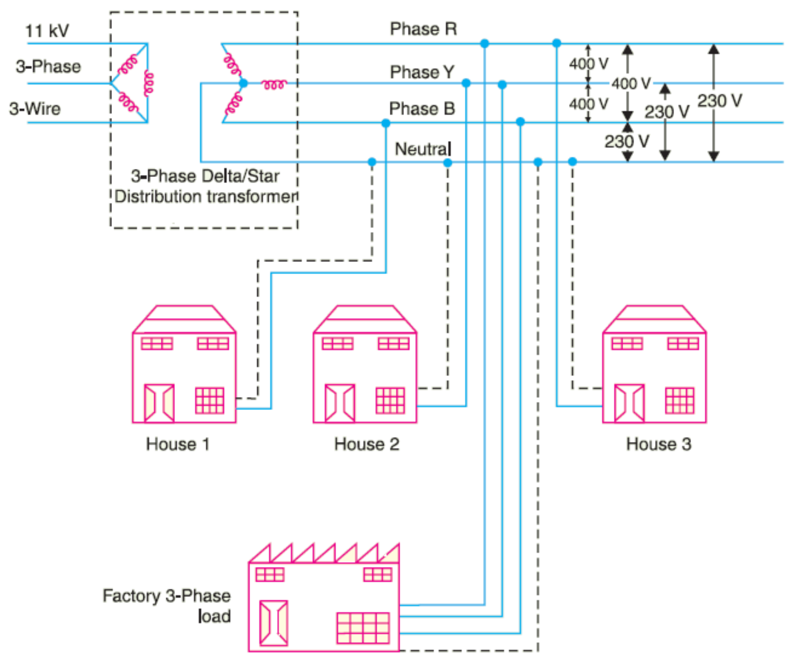


Fig.2.2: Secondary Distribution System

2.1.2 Single Phase and Three Phase Power Supply System

When electrical power is distributed to its point of utilization, it is normally either in the form of single-phase or three-phase alternating current (AC) voltage. Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors. Single-phase systems can be of two major types-single-phase two wire systems or single-phase three-wire systems.

Three-phase electric power is a common method of alternating current electric power generation, transmission, and distribution. It is a type of polyphase system and is the most common method used by electrical grids worldwide to transfer power. It is also used to power large motors and other heavy loads.

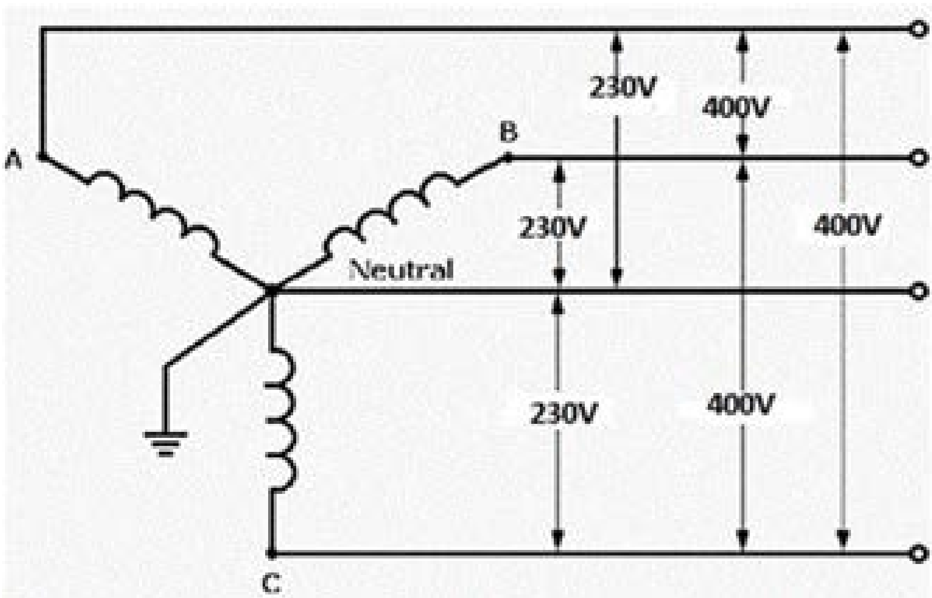


Fig.2.3: Three phase four wire system

2.1.3 Three Phase Four Wire System

The 3-phase, 4 wire system is widely used for the distribution of electric power in commercial and industrial buildings. The single-phase load is connected between any line and neutral wire while a 3-phase load is connected across the three lines. The current in the neutral wire will be the phasor sum of three-line currents.

2.1.4 Star and Delta Connections

Star and delta connections are two common methods used for connecting three-phase electrical systems. These connections are used to distribute power to various types of loads, such as motors, transformers, and other three-phase equipment.

a. Star Connection (Y Connection)

In a star connection, the beginning of each coil is left open ad ends are connected in a common point called the neutral or star point (denoted as "N"). The line conductors are connected to the other ends of the windings, forming a star shape. The star connection is also known as the Y connection due to its shape.

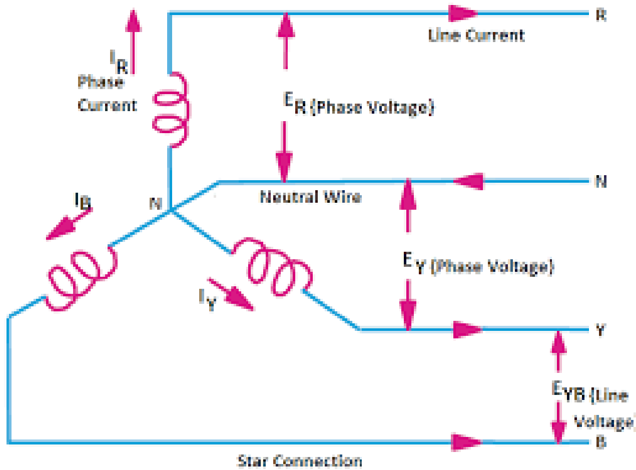


Fig.2.4: Star Connection (Y Connection)

Mathematical Relation:

Line voltage (V_L) = $\sqrt{3}$ Phase voltage (L_{ph})

Line current (I_L) = Phase current (I_{ph})

Advantages of Star Connection

i. It provides a neutral point, which is essential for supplying single-phase loads in addition to three-phase loads.

ii. The phase voltages are lower than the line voltages, making it suitable for loads with lower voltage ratings, when connected phase-to-neutral.

iii. It is relatively simple to connect and disconnect devices in a star connection.

b. Delta Connection (Δ Connection)

Here, one end of the first coil is connected to the beginning end of an another coil and so on, so closed mesh is formed. In a delta connection, the three windings of the three- phase system are connected together in a triangular or delta shape. The line conductors are connected to the junctions between the windings. The delta connection is also known as the mesh connection.

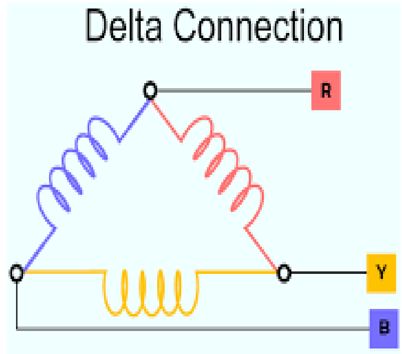


Fig.2.5: Delta Connection (Δ Connection)

Mathematical Relation:

Line voltage (V_L) = Phase voltage (L_{ph})

Line current (I_L) = $\sqrt{3}$Phase current (I_{ph})

Advantages of Delta Connection

i. It provides line voltages equal to the phase voltages, making it suitable for loads with higher voltage ratings.

ii. It requires fewer turns in each winding, reducing the amount of copper required for the windings.

iii. In allows for higher line currents for a given phase current rating of the windings compiled to star connection.

2.2 Electrical Drawing Symbols and Legends

2.2.1 Drawings, Specifications and Standards

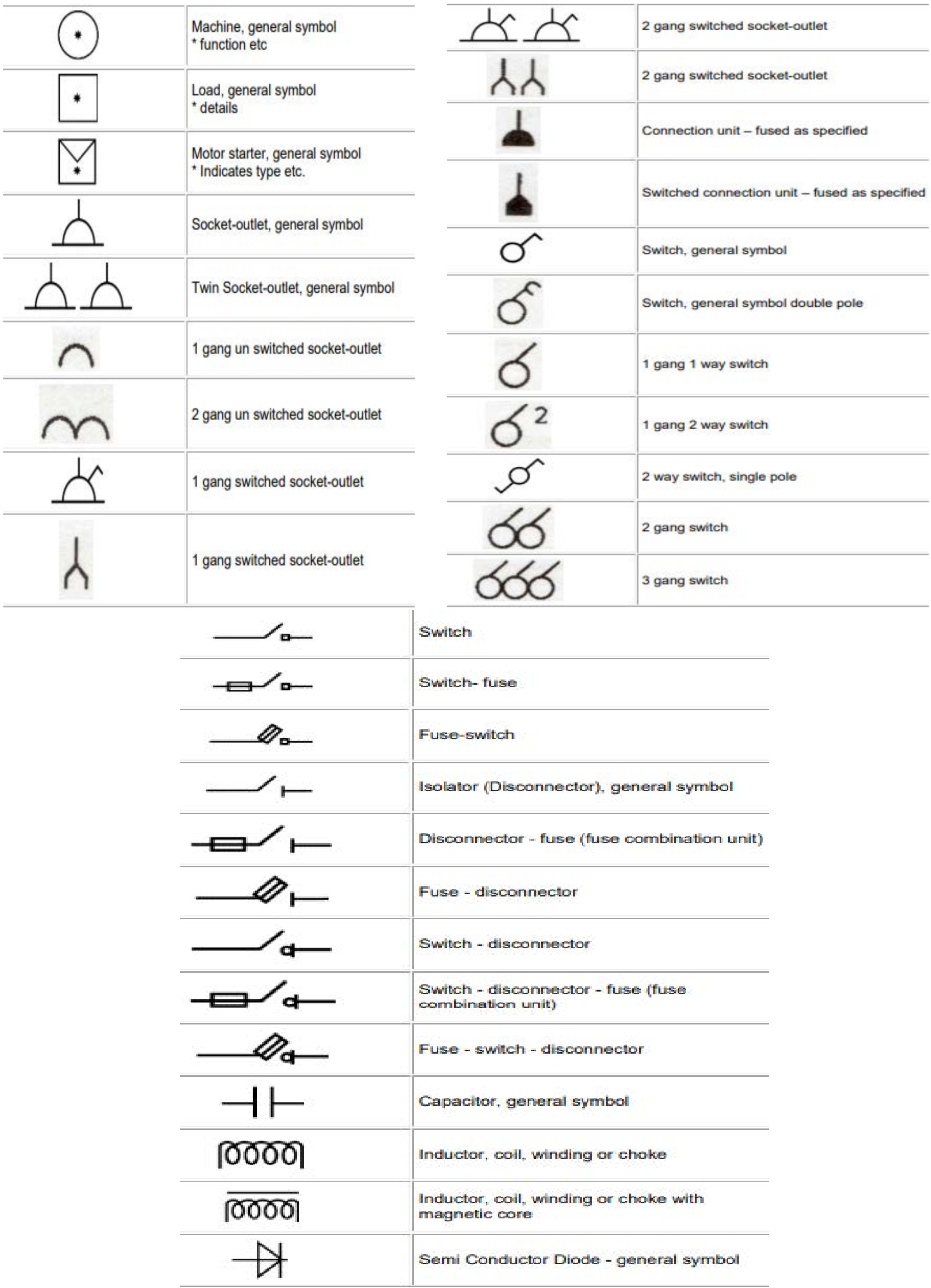


Fig.2.6: Different electrical symbols

2.2.2. Nepal Electricity Authority (NEA) Distribution Rules & Regulations and 11 kV and 400/230 V Overhead Line

NEA Distribution Rules and Regulations

i. **Safety Standards:** NEA distribution rules and regulations typically prioritize safety. They may include guidelines for equipment installation, maintenance, and operation to ensure the safety of both the public and utility personnel.

ii. **Technical Specifications:** These regulations define the technical requirements for various aspects of the distribution system, including voltage levels, insulation levels, system protection, metering, and more.

iii. **Connection Procedures:** NEA guidelines often outline the procedures for connecting new consumers to the distribution network, including application processes, technical requirements for connection, and associated fees.

iv. **Power Quality and Reliability:** Regulations may address power quality issues such as voltage levels, frequency variations, harmonic distortions, and measures to maintain a reliable supply of electricity.

v. **Metering and Billing:** NEA regulations often provide guidelines on metering, billing procedures, and consumer rights regarding accurate measurement and billing of electricity usage.

vi. **Grid Code Compliance:** Grid code requirements, which define the technical and operational standards for interconnection with the grid, are typically specified to ensure compatibility and stable operation of the distribution network.

vii. **Renewable Energy Integration:** With the increasing adoption of renewable energy sources, NEA regulations may include provisions for grid integration of distributed generation systems, such as solar panels and wind turbines.

11 kV and 400/230 V Overhead Line

i. **Voltage Levels:** 11 kV (kilovolts) refers to an electrical voltage level commonly used in medium voltage distribution systems. It is higher than the low voltage (LV) level but lower than high voltage (HV) or extra high voltage (EHV) levels. The 400/230 V refers to the voltage levels used in the low voltage distribution system, where the voltage is typically supplied as 400 volts between phases and 230 volts between phase and neutral.

ii. **Overhead Lines:** Overhead lines are a type of power transmission and distribution infrastructure where electrical conductors are mounted on poles or towers above the ground. These conductors, typically made of aluminum or copper, carry the electric power from the generating stations to distribution transformers and ultimately to consumers. Overhead lines are a common method of power transmission due to their cost- effectiveness and ease of installation and maintenance.

2.3 Single line diagram of Distribution Lines

2.3.1 Single Line Diagram of 11KV to end Users

Single Line Diagram (SLD) is a simplified notation for representing a power system by means of simple symbolsfor each component. In a single line diagram, the system components are usually drawn in the form of their symbols.

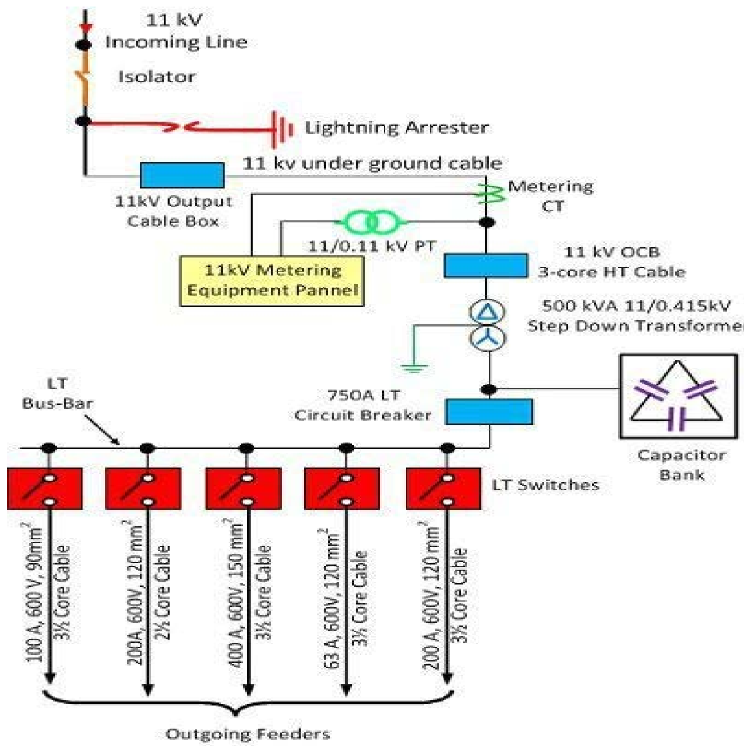


Fig.2.7: Single line diagram of 11kV to end users

The working of the electrical equipment used in the substation is explained below:-

a) **Isolator –** The isolator connects or disconnects the incoming circuit when the supply is already interrupted. The isolator is placed on the supply side of the circuit breaker so that the circuit breaker can be isolated from the live parts of the maintenance.

b) **Lightning Arrester –** The lightning arrester is a protective device which protects the system from lightning effects. It has two terminals one is high voltage and the other is the ground voltage. The high voltage terminal is connected to the transmission line and the ground terminal passes the high voltage surges to earth

c) **CT Metering –** The metering current transformer (CT) measures and records the current when their secondary terminal is connected to the metering equipment panel.

d) **Step-down Transformer –** The step-down transformer converts the high voltage current into the low voltage current.

e) **Capacitor Bank –** The capacitor bank consists series or parallel connection of the capacitor. The main function of the capacitor bank is to improve the power factor of the line

f) **Circuit Breaker –** The circuit breaker interrupts the abnormal or faults current flowing through the line. It is a kind of electrical switch with arc interrupting device which open or closes the contacts when the fault occurs in the system. The outgoing feeder supplies the input power to the consumer end.

2.3.2 NEA 11 kV and 400V/230V Overhead Line Construction

Nepal Electricity Authority (NEA) has specific standards and guidelines for the construction of 11kV and 400V/230V overhead lines. These standards ensure safety, reliability, and efficiency in the distribution of electricity.

Key Considerations for Overhead Line Construction

1. 11kV Overhead Lines

a) **Conductor Selection:** Conductors are typically made of aluminum alloy (AAC or AAAC) due to their light weight and good conductivity. The conductor size is determined based on the load demand and line length.

b) **Insulator Selection:** Porcelain or polymer insulators are used to isolate the conductors from the supporting structures. The insulator type and string length are selected based on voltage level, pollution levels, and environmental conditions.

c) **Pole Selection:** Wooden or concrete poles are commonly used as supporting structures. The pole height and strength are determined based on line voltage, span length, and wind and ice loads.

d) **Hardware:** Quality hardware, such as clamps, brackets, and bolts, is used to securely fasten the conductors to the insulators and poles.

e) **Sag and Tension:** Proper sag and tension are maintained in the conductors to ensure safe and reliable operation.

f) **Clearance:** Adequate clearance is maintained between the conductors and ground, as well as between adjacent conductors, to prevent electrical faults and hazards.

2. 400V/230V Overhead Lines

a) **Conductor Selection:** Aluminum conductors, often bare or insulated, are used for 400V/230V distribution lines.

b) **Insulator Selection:** Shakle-type insulators are commonly used to support the conductors.

c) **Pole Selection:** Wooden or concrete poles are used, with the height and strength determined by the line voltage and span length.

d) **Hardware:** Similar to 11kV lines, quality hardware is used to secure the conductors to the insulators and poles.

2.4. Installation of Aluminum Conductor Steel Reinforced (ACSR) and Aerial Bundled Conductors (ABC) in feeders and Distributors

The installation of Aluminum Conductor Steel Reinforced (ACSR) and Aerial Bundled Conductors (ABC) for in feeders and distributors involves several steps. Here's a general outline of the process:

a. **Planning and Design:** Determine the requirements of the electrical system, including voltage levels, load capacity, and environmental conditions. Calculate the conductor size and type based on the electrical parameters and the expected load. Design the route and positioning of the conductors, considering factors such as clearance requirements, pole locations, and support structures.

b. **Material Procurement:** Purchase the required lengths of ACSR and ABC conductors based on the design specifications. Ensure that the conductors meet the necessary standards and quality requirements.

c. **Preparing the Worksite:** Clear the area of any obstacles or vegetation that may interfere with the installation process. Install poles or support structures at designated locations according to the planned route.

d. **Installation of ACSR Conductors:** Attach the steel messenger wire to the support structures using suitable clamps or fittings. Pull the ACSR conductor along the length of the messenger wire using tensioning equipment. Secure the ACSR conductor to the support structures using clamps or suspension fittings at regular intervals. Install additional components as necessary, such as vibration dampers or spacers, to maintain proper conductor spacing and minimize line vibrations.

e. **Installation of ABC Conductors:** Attach the bundled conductors to support structures using appropriate fittings, such as suspension clamps or brackets. Carefully unroll the ABC conductor bundle along the length of the support structures, ensuring that it remains properly aligned and tensioned. Secure the ABC conductors to the support structures using suitable clamps or brackets at regular intervals. Install accessories like insulators, tensioners, and spacers to maintain proper spacing and tension in the conductors.

f. **Termination and Connection:** Install termination hardware, such as compression fittings or bolted connectors, at the ends of the conductors to make electrical connections. Connect the conductors to the associated equipment, such as transformers, switches, or distribution panels, following proper electrical and safety guidelines.

g. **Testing and Commissioning:** Perform necessary electrical tests, such as insulation resistance tests or continuity checks, to ensure the integrity of the installed conductors. Verify the electrical performance and stability of the installed system under normal operating conditions. Make any required adjustments or repairs based on the testing results

2.5 Definition and Need of Distribution Switchgear

Distribution switchgear refers to a collection of electrical equipment and devices that are used to control, protect, and isolate electrical power distribution systems. It is an integral part of the electrical infrastructure, serving as a link between the power generation and the end-user distribution networks. The primary function of distribution switchgear is to control the flow of electrical power, monitor system parameters, and safeguard the electrical distribution system from faults and abnormalities. It typically includes various components, such as circuit breakers, switches, fuses, relays, meters, and protective devices, all housed in a common enclosure. The need for distribution switchgear arises from several factors:

1. **Power Distribution Control:** Distribution switchgear allows for the control and regulation of electrical power distribution. It enables operators to switch power supply between different sources, redistribute power to different areas, and control the flow of electricity to meet the demand.
2. **Fault Protection:** Switchgear incorporates protective devices such as circuit breakers and fuses that detect and respond to faults in the distribution system. They can interrupt the flow of electrical current in the event of a short circuit, overload, or other abnormal conditions, preventing damage to the equipment and minimizing the risk of electrical hazards.
3. **System Monitoring and Metering:** Distribution switchgear often includes meters, relays, and monitoring devices that provide real-time information about the electrical parameters of the distribution system. This data helps operators monitor power consumption, identify abnormalities or inefficiencies, and facilitate maintenance and troubleshooting activities.
4. **Isolation and Maintenance:** Switchgear allows for the isolation of specific sections of the distribution system, enabling maintenance or repairs to be carried out safely without affecting the rest of the network. It provides a means to de-energize and isolate specific circuits or equipment, ensuring the safety of personnel working on the system.
5. **Enhanced Reliability and Continuity:** By incorporating protective devices and reliable switching mechanisms, distribution switchgear enhances the reliability and continuity of the electrical supply. It helps to minimize downtime, reduce the impact of faults, and restore power quickly in case of disruptions, improving the overall performance of the distribution system.

2.5.1 Medium Voltage Switchgear

2.5.1.1 Knife Switches

Knife Switches are manually operated electric Switching device that is used to control the flow of electricity in a circuit. It consists of a hinge which allows a metal lever, or knife to be lifted from or inserted into slot to or break or make electrical contact**.** Depending on the number of contact, knife switches are subdivided into single pole, double pole, triple pole types.

Fig.2.8: Knife Switch

2.5.1.2 Load Break Switches (with fuse and without fuse)

Load Break Switch with Fuse: It provides both switching and overcurrent protection. When a fault occurs, the fuse melts, interrupting the circuit and preventing damage to the equipment. It combines switching and protection in a single device. It offers reliable overcurrent protection.

Fig.2.9: Load Break Switch with Fuse

Load Break Switch without Fuse: It primarily used for switching operations, not overcurrent protection. It relies on external protective devices, such as circuit breakers, to provide overcurrent protection. It is simpler design and potentially lower cost. It can be used for high-frequency switching.

Fig.2.10: Load Break Switch without Fuse

2.5.1.3 Earthing Switches

An earthing switch, or grounding switch, is a protective mechanical device that grounds parts of an electrical circuit. It is crucial for ensuring safety during maintenance by providing a path to ground for fault currents. These switches do not carry current under normal conditions but are activated during faults, ensuring that equipment and personnel are protected from electrical hazards.

Fig.2.11: Earthing Switches

2.5.1.4 Circuit Breakers (ACB, VCB, OCB CB)

Circuit Breaker

Circuit Breaker is an automatically operated electrical switch design to protect an electrical Circuit from damage caused by overload or Short circuit.

Operating Principle: Current Breaker (CB) consists of fixed and movable contacts, called electrode. Under normal condition, Contact remain closed, and will open automatically when system become faulty. When fault occurs, trip coil gets energized and moving contacts are pulled apart, thus opening circuit When contacts, of CB are separated, an arc struck between them. The production of arc delays current interruption process and also generates heat which may damage the CB as well as the system. Main problems in a CB is to extinguish the arc with in shortest time, so that we used different medium for Arc extinction such as Oil, Air, Vacuum.

C.B are classified on the Basis of medium used for arc extinction.

1. Oil Circuit Breaker
2. Air Circuit Breaker
3. Vacuum Circuit Breaker

1. Oil Circuit Breaker (OCB)

C.B in which the current carrying contacts operate in oil is called oil Circuit Breaker. Oil is used as a medium of arc extinction quenching. It is generally used upto 66KV.

Types

1. Bulk oil CB
2. Minimum oil C.B

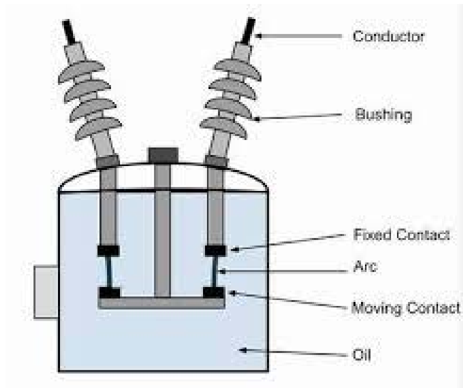


Fig.2.12: Oil Circuit Breaker (OCB)

2. **Air Circuit Breaker (ACB)**

   CB in which the current carrying contacts operates in air is called Air Circuit Breaker. It uses Atmospheric air as an arc quenching medium. It is used for low voltage application upto 11KV.

Types

1. Air Blast CB
2. Air Break CB

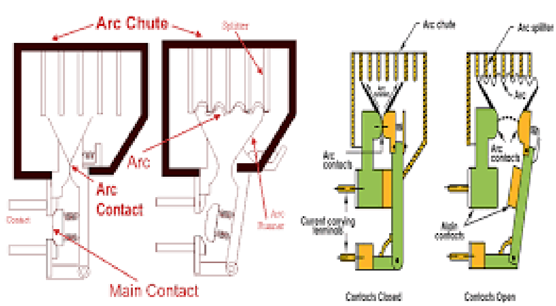


Fig.2.13: Air Circuit Breaker (ACB)

3. **Vacuum Circuit Breaker (VCB)**

   CBs in which Vacuum is used to extinct the arc is called Vacuum Circuit Breaker. Vacuum of the order of 10^{-5} to10^{-7} torr is used as arc extinguishing medium. These are generally used from 11kV to 66kV.

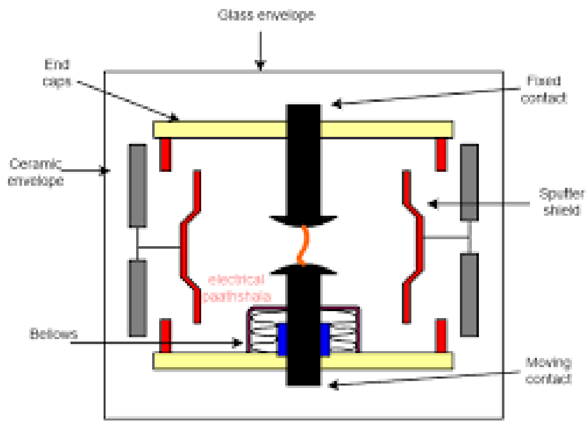


Fig.2.14: Vacuum Circuit Breaker (VCB)

2.5.2 Low Voltage Switchgear

2.5.2.1 Isolators

Isolators are device capable of making or breaking a circuit breaker under no-load condition. It is also called no load breaking switch or disconnected switch. It is used for disconnecting feeders, circuit breakers, transformer and bus bar for regular maintenance and repair works. The isolator must be capable of carrying maximum fault current for the time, the fault is being cleared by an interrupting device in series with it. In high voltage installation the capacitance betweens lines and earth is significant through the line is disconnected by opening circuit breaker and then isolator. Still there is some voltage to which the capacitance is charged. To discharge this voltage after disconnection isolators are usually incorporated with earth terminal. Isolators are used extensively for connecting at tiers, feeders, for repair and maintenance of lines, transformers, circuit breakers or any component of the system.

Fig.2.15: Isolator

2.5.2.2 Load Break Switches (LBS)

A load breaking switch is designed to interrupt current flow while the circuit is under load. It can safely break the circuit without causing an arc, making it suitable for switching applications where the load must remain connected during operation. This type of switch is essential for maintaining system reliability and safety, particularly in distribution networks where frequent switching is required.

Fig.2.16: Load Break Switches

2.5.2.3 Contactors

It is a device operated by an electromagnet for repeatedly establishing and interrupting an electric circuit. Contactors are like normal switches but the only difference is that the contactors have an electromagnet that holds the contacts when energized whereas switches do not have it. Contactor consists of main contacts and auxiliary contacts. Auxiliary contacts may be Normally Open(NO) or Normally Closed(NC) contacts. A normally open contact closes when the contactor closes or when the contactor coil is energized. A normally closed contact opens when the contactor closes or when the contactor coil is de- energized. There are two circuits associated with an electromagnet; the main circuit and the control circuit.

Fig.2.17: Contactor

Applications

- Switching of resistance or inductive loads
- Switching of induction motors
- Switching of capacitor banks
- Switching of commercial, industrial and street lighting

2.5.2.4 Fuse Switch

A fuse is a simple, low-cost electrical safety device that protects electrical circuits from overcurrent. It Consists of a metal wire or strip that melts when excessive current flows through it. When the current exceeds the fuse rating, the metal melts, breaking the circuit and stopping the current flow. Commonly used in household appliances, automotive applications, and small electronic devices.

Fig.2.18: Rewirable Fuse

Advantages

a. Simple and cost-effective

b. Reliable in operation

Disadvantages

a. Needs replacement after each operation

b. Provides limited protection (only against overcurrent)

Types: Cartridge fuse, glass fuse, ceramic fuse, blade fuse

2.5.2.5 LV Circuit Breakers: MCB, MCCB, RCCBs

LV (Low Voltage) circuit breakers are electrical devices used to protect electrical circuits from overloads and short circuits in low voltage systems. They are an essential component of electrical distribution systems and are commonly found in residential, commercial, and industrial applications.

1. **Miniature Circuit Breaker (MCB)**

A MCB is an automatic switch designed to protect an electrical circuit from overcurrent and short circuits. It consists of a switch mechanism that can be manually switch on. Thermal element trips the circuit in case of overcurrent and solenoid coil magnetizes, trips in case of short circuit. It trips (automatically turns off) the circuit when current exceeds its rated limit, preventing damage, can be reset after tripping. It is widely used in residential, commercial, and light industrial applications.

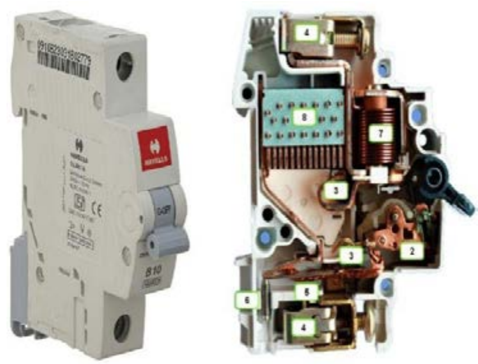


Fig.2.19: Miniature Circuit Breaker (MCB)

Advantages

a. Reusable after tripping

b. Provides more precise protection

c. Easy to operate and reset

Disadvantages

a. More expensive than fuses

b. Limited to lower current ratings (up to about 100A)

Types: Single-pole, double-pole, triple-pole, four-pole..

2. **Molded Case Circuit Breaker (MCCB)**

A MCCB is a type of circuit breaker that can handle higher current ratings and provides protection against overload, short circuit, and ground faults. It is enclosed in a molded case; includes adjustable trip settings and a switch mechanism. It trips to break the circuit when detecting an overload or short circuit. It can be reset after tripping. It is suitable for industrial and commercial applications where higher current requires.

Fig.2.20: Molded Case Circuit Breaker (MCCB)

Advantages

a. Handles higher current ratings (up to 2500A)

b. Adjustable trip settings for precise protection

c. Reusable and resettable

Disadvantages

a. More expensive than MCBs

b. Larger in size

Types: Thermal magnetic, electronic trip, and instantaneous trip MCCBs.

3. Residual Current Circuit Breaker (RCCB)

A RCCB is a safety device designed to protect against electric shock and electrical fires caused by earth faults. It contains a residual current detector and a tripping mechanism. It detects imbalance between live and neutral currents (indicating leakage current) and trips the circuit to prevent electric shock. It is commonly used in residential, commercial, and industrial installations for personal safety.

Advantages

a. Provides protection against electric shock

b. Prevents electrical fires from earth faults

c. Can detect very small leakage currents (typically 30mA)

Disadvantages

a. Does not provide protection against overloads or short circuits

b. Needs to be used in conjunction with other protective devices like MCBs or fuses

Types: Two-pole, four-pole.

Fig.2.21: Residual Current Circuit Breaker (RCCB)

2.5.3 Protective and Control Devices (Bus bars, Isolating links, Earthing links, CBs, Instrument transformers (current and voltage), Protective relays and Lightning Arresters)

a. **Busbar:** An electrical bus bar is defined as a conductor or a group of conductors used for collecting electrical energy from the incoming feeders and distributes them to the outgoing feeders. It is also a point where different equipments can be connected. Bus bar may be of copper, aluminium or steel.

Fig.2.22 Busbar

b. **Isolating Links:** In low voltage three phase 4 wire system, all three phase are connected and protected by TP MCB/MCCB whereas neutral is not protected but connected by a piece of simple flat conductor which is called link. If more number of neutral conductor need to be connected at a place then we call it neutral link or neutral busbar.

In generator, there is mcb for phase and link for neutral- it may be in form of isolator.

c. **Earthing Links:** In a distribution board there is a connector, where all the neutral conductor are connected with the earth electrode.

Fig.2.23: Earthing Link

d. **CBs (Circuit Breaker) :** MCB, MCCB and air circuit of low current rating has built in thermal and magnetic protection devices of fixed or adjustable type. In higher rating and OCB, VCB, SF6 has closing and shunt trip coil only so it does not sense fault current like earth fault and short circuit fault. To sense faults CTs and PTs are provided. CT sense the abnormal current and operates the relay which informs the shunt trip coil to trip. Closing and shunt trip coil is used for normal ON/OFF operations too.

e. **Instrument transformers (current and voltage):** Instrument transformers, including current transformers (CTs) and voltage transformers (VTs), are devices used in electrical power systems to provide accurate measurements and protection. They are typically used in high-voltage and high-current circuits.

i. **Current Transformers (CTs):** Current transformers are designed to measure or monitor electrical current flowing through a conductor. They step down the high current levels to a proportional lower current that can be safely measured by instruments. Mostly CTs consist of a primary winding, which is connected in series with the circuit carrying the current to be measured, and a secondary winding that is connected to the measuring instrument or protective relay.

Fig.2.24: Current Transformers (CTs)

ii. **Voltage Transformers (VTs):** Voltage transformers, also known as potential transformers (PTs), are used to step down high voltage levels to lower and safer voltage levels for measurement and protection purposes. VTs have a primary winding connected in parallel to the circuit where voltage is to be measured, and a secondary winding connected to the measuring instrument or protective device.

Fig.2.25: Voltage Transformers (VTs)

f. **Protective Relays and Lightning Arresters**

i. **Protective Relays**: Protective relays are devices designed to detect abnormal electrical conditions in a power system and initiate appropriate actions to isolate the faulted section or equipment. Their primary function is to monitor various electrical parameters, such as voltage, current, frequency, and phase angle, and make decisions based on predefined settings. When a fault or abnormal condition is detected, the protective relay sends a trip signal to circuit breakers or other switching devices to disconnect the faulty section from the rest of the system. This helps prevent further damage and ensures continuity of supply to unaffected parts of the system.

Fig.2.26: Protective Relays

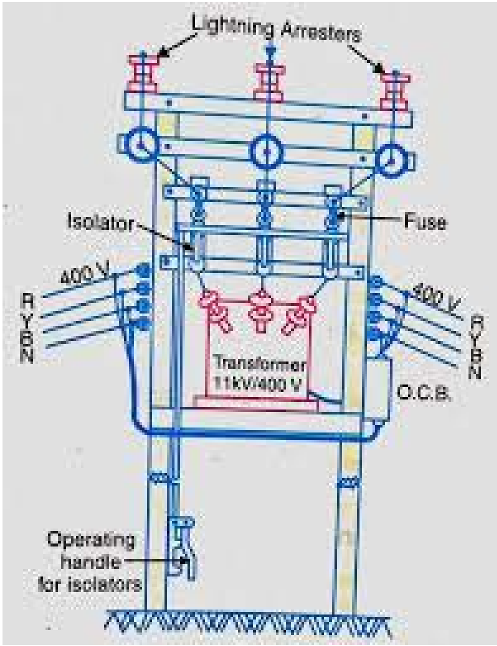
ii. **Lightning Arrestor**: Lightning arresters, also known as surge arresters or lightning surge protectors, are devices used to divert lightning surges away from sensitive equipment and structures, such as power lines, substations, buildings, and communication systems. Lightning is a natural phenomenon that can cause extremely high voltage surges that may damage or destroy electrical equipment. A lightning arrester provides a low-impedance path for the lightning surge to flow towards the ground, thereby protecting the connected equipment from excessive voltages.

Fig.2.27: Lightning Arrestor

2.6 Pole Mounted Substation

2.6.1 Introduction to Pole Mounted Substation

A pole-mounted substation, also known as a pole-mounted transformer or a pole-top substation, is a type of electrical substation that is mounted on a utility pole. It is used to transform and distribute electrical power. The transformer and associated equipment are secured to the pole, often at a height that allows for easy maintenance and access. The primary component of a pole-mounted substation is the transformer. It steps down the incoming medium voltage electricity from the distribution network to a lower voltage suitable for local consumption. Pole-mounted substations are relatively compact and space-saving compared to larger ground-mounted substations. They are often used in urban or densely populated areas where space is limited or in rural areas where it is not feasible to install larger substations.



2.6.2 Main Components of Pole Mounted Substation (Lightning Arrestor, Gang Operated (GO) Switch, Drop Out Fuse, Rod gap Arrestor, Transformer, MCCB, Busbars and Cables)

The main components of a pole-mounted substation typically include the following:

1. **Transformer:** The transformer is a key component of the pole-mounted substation. It steps down the voltage from the medium voltage level to a lower voltage suitable for local distribution. The transformer can be oil-filled or dry-type, depending on the specific design and requirements.

2. **Lighting Arrestor:** A lightning arrestor is installed to protect the substation and its equipment from damage caused by lightning strikes. It provides a path of least resistance for lightning surges, diverting them safely to the ground.

3. **Gang Operated (GO) Switch:** The GO switch is used for manual switching operations. It allows for the isolation and connection of the substation from the distribution network. It enables maintenance personnel to safely work on the equipment without affecting the power supply to customers.

4. **Dropout Fuse:** The dropout fuse is a protective device that is designed to disconnect the substation from the distribution network in case of overloads or faults. It interrupts the current flow when the current exceeds a predetermined level, thereby protecting the equipment and the distribution system.

5. **Molded Case Circuit Breaker (MCCB):** An MCCB is a type of circuit breaker that provides protection against short circuits, overloads, and electrical faults. It is used to protect the substation equipment and the connected distribution lines from excessive current flow.

6. **Busbars and Cables:** Busbars are used to distribute electrical power within the substation. They provide a low-resistance path for the current to flow between the transformer, switchgear, and other components. Cables are used to connect the substation to the distribution lines or other substations in the network.

2.7 Jointing Techniques and Terminations of Overhead and Underground Cables

Jointing techniques and terminations for overhead and underground cables are essential for ensuring reliable and efficient electrical connections. Here are the commonly used methods for jointing and terminating both types of cables

2.7.1 Jointing Techniques of Overhead and Underground Cables

Cable Joint requires a secure and reliable connection between two or more lines. This is done to extend cable lengths, repair damaged cables, or join cables of different sizes or thicknesses. The objective is to maintain the electrical mechanical integrity of the cable and to eliminate the risk of electrical faults, overheating, and other potential hazards cable connections can be made using various methods.

1. **Cold shrink joints:** Cold shrink joints are designed for easy and quick installation. The joint is pre-stretched and is on a removable tendon. Once over the cable joint, the core is removed, allowing the shrinkage sleeve to slide and secure it. This method eliminates the need for special tools for heating guns, reducing the risk of overheating the blades.

Fig.2.29: Cold shrink joint

2. **Heat Shrink Joint:** Heat shrink joints apply heat shrinkage to a specially designed tube surrounding a cable joint. The heat causes the tube to contract, creating a tight seal. The temperature used must be controlled to avoid damage to the insulation or bond of the cable.

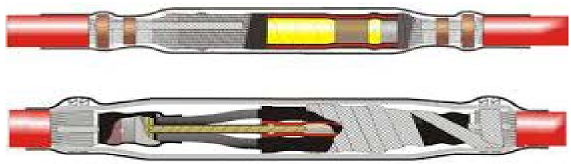


Fig.2.30: Heat Shrink Joint

3. **Resin-filled joints:** Resin-filled eggs are especially effective in harsh environments where moisture and contamination are a concern. The cable joint is housed in a resin-filled housing, which provides excellent protection against moisture, chemicals and physical damage. The resin also acts as a joint insulator and improves the overall mechanical strength of the joint.

Fig.2.31: Resin-filled joint

4. **Taped Joints:** Taped cells use insulating tape or mastic tape to secure the cable ties. This method is suitable for low voltage and high voltage cables. It is important to ensure adequate pressure and coverage when taping to maintain the required levels of insulation and protection.

2.7.2 Terminations of Overhead and Underground Cables

Cable termination consists of connecting a cable end to a device, device, or termination point. Proper shutdown provides reliable and safe electrical connections while preventing issues such as signal loss, voltage, and overheating. Different finishing methods are used for different materials:

1. **Crimp Termination:** Crimp termination involves attaching a metal connector or terminal to the end of the cable. The cable is inserted into the connector and a crimping tool is used to press the connector into the cable. Proper crimping ensures strong electrical connections and mechanical integrity. Depending on the application and the type of connection, different types of crimps (hexagonal, indented, etc.) are used.

Fig.2.32: Crimp Termination

2. **Compression Termination:** Compression terminations are typically used in high-power applications where a strong and reliable connection is required. A compression lug or connector is placed on the disconnected end of the cable, and hydraulic tools are used to compress the connector into the cable, preventing gas leakage and less tension in the cable.

Fig.2.33: Compression Termination

3. **Solder Termination:** Solder finishing involves melting the solder on the cable metal and on the terminal or connector. This method provides a stronger and less complicated connection. However, it takes skill and precision to avoid overheating the lines and damaging the insulation.

Fig.2.34: Solder Termination

Exercise

Choose the correct answer from the given alternatives.

1. Which type of the power transmission is more efficient for long-distance transmission?

   a. Single-phase b. Three-phase
   c. Both have similar efficiency d. None of the above

2. In a single-phase distribution system, how many conductors are typically used to transmitpower to load?

   a. One b. Two c. Three d. Four

3. The full form of VCB is............

   a. Volume Circuit Breaker b. Vacuum Circuit Breaker
   c. Volatile Circuit Breaker d. Versatile Circuit Breaker

4. Isolator operates on ……… conditions.

   a. Sometimes ON load and sometimes NO load
   b. ON load c. NO load d. Full load

5. The primary purpose of a pole-mounted substation is............

   a. To generate electricity
   b. To transmit electricity over long distance
   c. To distribute and control electrical power in local area
   d. To protect against lightning strikes

6. Which type of load is most suitable for a three-phase distribution system?

   a. Residential lighting b. Industrial motors
   c. Single-phase heaters d. Small appliances

7. In a three-phase distribution system, the standard voltage in Nepal is...........

   a. 120 Volt b. 330 Volt c. 400 Volt d. 220 Volt

8. ACSR stands for................

   a. Aluminum Conductor Solid Rod b. Aluminum Conductor Steel Reinforced
   c. Alternating Current System Relay d. Automatic Circuit Switch Regulator

9. Terminations are used for..........

a. Connecting cables to equipment   b. Measuring voltage

c. Protecting against lightning   d. Disconnecting the substation manually

10. In a star connection, the line voltage is............

a. Equal to the phase voltage   b. √3 times the phase voltage

c. 1/√3 times the phase voltage   d. None of the above

Write short answer to the following questions.

1. Differentiate between single phase and three phase system.
2. Write the advantages of three phase over single-phase distribution system.
3. What are the main components of pole mounted substation? Describe them in short.
4. Define distribution switchgear. Why is the important of it?
5. Write short notes on:
   a. Single phase power supply system
   b. Three phase power supply system
   c. Three phase four wire system
   d. Star and delta connection
6. What are the differences between star and delta connection?

Write long answer to the following questions.

1. What is the Single Line Diagram (SLD)? Draw a single line diagram of 11kV to end user and explain each of the components.
2. What do you mean by distribution system? List out its types and explain any one of them in detail.
3. What are the protective and control devices used in distribution system?
4. Define medium voltage switchgear. How the medium voltage switchgear devices are divided?
5. Define low voltage switchgear. How the low voltage switchgear devices are listed?
6. What methods are employed for jointing and terminating overhead and underground cables?

Project Work

1. To design and build a small-scale model of a distribution system, showcasing primary and secondary distribution.
2. To create a single-line diagram of the electrical distribution system for a specific area (e.g., their school, a neighborhood).
3. To research and present on the characteristics, applications, and advantages/ disadvantages of different types of conductors (ACSR, ABC, etc.).
4. To research and report on the distribution standards and regulations used by their local electricity authority (NEA in this case).
5. To design a layout for a pole-mounted substation, considering the placement of different components.
6. To research and create a guide to jointing and termination techniques for overhead and underground cables.
7. Install 3-phase 4 wire supply system for single phase and 3 phase distribution board.
8. Field visit to nearby industrial installations.

Unit 3 Industrial Wiring

3.1 Basics of Industrial Wiring as Per NBC

The Nepal National Building Code (NBC) provides comprehensive guidelines for electrical installations in industrial buildings. Here's a breakdown of the key points relevant to industrial wiring.

3.1.1 Supply Characteristics and Parameters

3.1.1.1 Industrial Substations

The general requirements for substation installations given in Part 2 of the Code shall apply in addition to those given below:

If the load demand is high, which may necessitate supply above 650 V or if conditions of supply of local Electric supply Company requires so, a separate substation should be set up. For an outdoor substation, general guidelines as given in Part 2 of the Code shall apply. For bringing the supply into the factory building, a separate indoor accommodation, as close as possible to the main load centre, should be provided to house the switchgear equipment. The supply conductors should preferably be brought into the building underground to reduce the possibility of interruption of power supply. The accommodation for substation equipment as well as for main distribution panel shall be properly chosen to prevent access by any unauthorized person. It shall be provided with proper ventilation and lighting. In cases where the load currents are high (400 A and above) and the transformers are located just outside the building, a busbar trunking system may be desirable. These trunkings should, however, be straight and short as far as possible.

3.1.1.1.1 Location of Transformers and Switchgear

Location of transformer shall preferably at load centre subject restrictions related hazards such as fire. Special attention shall be given to mandatory provisions related to oil filled transformers. Use of K class insulating liquids having fire point >300°C may be considered.

Requirement of indoor or outdoor transformer sub-station may depend on site, type of industry, environmental conditions and other factors of external influences. Location of control switchgears its accessibility from the point of view of operation shall be precisely designed.

Protection on primary and secondary side of transformer shall conform requirements mandated under CEA (Measures related to Safety and Electric Supply) Regulations, 2010 (latest amended version).

Restricted areas shall be precisely marked and suitably locked so that unauthorised person shall not have an access within.

3.1.1.1.2 For small substations up to 1 600 kVA capacity, it is also possible to locate the substation at the load centre, without a separate room. This yields considerable economies in cost. In such cases, the transformer shall be of dry type.

3.1.1.2 Distribution of Power

3.1.1.2.1 From the point of supply, power is distributed to loads in steps depending on quantum of load and expanse. Main control panel, sub-distribution and local distributions panels shall have appropriate control switchgears to isolate and break supply as desired. Settings shall be done with appropriate discrimination to maintain sequence of tripping. Local isolation in case of fault shall be important aspect of design.

3.1.1.2.2 Electrical panels/switch-boards may be floor or wall mounted and designed conforming IS/IEC 61439. Access routes shall always be maintained free without hindrances. Clear space around/arc-flash distances as mentioned under Part 1 Section 22 shall be maintained. Provision of separate room and adequate ventilation/ positive pressure may be necessary to protect panels from external influences like dust, corrosive smokes, etc.

Switch-boards shall be so designed and installed so that provisions considering possibilities of internal arc fault are adequate and tested (IEC/TR 61641). Where necessary, internal arc-fault mitigation system (IAMS) may be adopted.

3.1.1.2.3 Cables, bus-duct routes shall be well planned and maintained considering risk factors. Cables at difference voltage levels should be laid with separation at least 250 mm and clearly identified. Cables at voltages above 1000 V should be laid at the lowest level in trenches, and at the highest level on walls. Use of cable ladder, trey helps structured cabling work. Earth continuity shall be properly maintained in such work. All entry points shall be properly sealed with fire resistant material. Method of construction shall be as per IS 1255.

3.1.1.2.4 All switchgear equipment used in industrial installations shall have appropriate ingress protection. Selection shall also be done considering appropriate range and setting facility of overload, short-circuit currents and other add-on protections. All switchgear equipment used in industrial installations shall be metal enclosed. Switchgear shall not be mounted on woodwork.

3.1.1.2.5 In certain installations where supply is from remote transformer substations, it may be necessary to protect main circuits with circuit-breakers operated by earth leakage trips, in order to ensure effective earth fault protection.

3.1.1.2.6 Where large electric motors, furnaces or other heavy electrical equipment is installed, the main circuits shall be protected by circuit-breakers or contactors of air-break or oil-immersed type fitted with suitable instantaneous and time delay over current devices together with earth leakage and back-up protection where necessary.

3.1.1.2.7 It may be necessary to provide for connection of capacitors for power-factor correction; and when capacitors are to be installed advice of capacitor and switchgear manufacturers shall be sought.

3.1.1.2.8 Sufficient additional space shall be provided for modifications, alterations, anticipated future extensions.

3.1.1.3 Wiring System

The selection of a wiring system to be adopted in a factory shall depend upon the factors enumerated in Part 1/Sec 9 of the Code. The wiring system available for general use are listed in Annex C. Selection from a group of alternative systems shall be made in accordance with Annex C, keeping in view the points mentioned under **3.1.1.3.1.**

3.1.1.3.1 Design and selection of wiring system and material shall be done considering:

a) Situation, such as location, structure, etc.;

b) External influences, such as climatic conditions, environment, etc.;

c) Hazard classification;

d) Scope for modifications, future expansions. For example, overhead busbar trunking with tap-offs facilitates modification in machine shops;

e) Compatibility to face emergency situation; and

f) Type and class of operators, users, occupants.

3.1.1.3.2 Electrical installation for lifts, hoists shall be done in consultation with the manufacturer and circuit supplying lift equipment shall distinct and separate.

3.1.2 System Protection

3.1.2.1 Protection of Circuits

3.1.2.1.1 Appropriate protection shall be provided at switch-boards and distribution boards for all circuits and sub-circuits against overcurrent and earth faults according to IS 732, and Part 1 of this code. The protective apparatus shall be capable of interrupting any short-circuit current that may occur, without danger. The ratings and settings of fuses, circuit breakers and the protective devices shall be coordinated to afford selectivity in operation where necessary.

Where circuit-breakers are used for protection of a main circuit and of the sub-circuits derived therefrom, discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuits to operate at lower current settings and shorter time-lag than the main circuit-breaker.

Where HRC type fuses are used for backup protection of circuit-breakers, or where HRC fuses are used for protection of main circuits and circuit-breakers for the protection of sub-circuits derived therefrom, in the event of short circuits exceeding the breaking capacity of the circuit-breakers, the HRC fuses shall operate earlier than the circuit-breakers; but for smaller overloads within the breaking capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse.

If re-wireable type fuses are used to protect sub-circuits derived form a main circuit protected by HRC type fuses, the main circuit fuse shall normally blow in the event of a short-circuit or earth fault occurring on a sub-circuit, although discrimination may be achieved in respect of overload currents. The use of re-wireable fuses is restricted to the circuits with short-circuit level of 4 kA; for higher level either cartridge or HRC fuses/Circuit breakers shall be used.

Provision shall also be made for control of general lighting and other emergency services through separate main circuits and distribution boards from the power circuits.

If necessary, independent source of supply for emergency service in particular installations may be provided as supply to DG.

3.1.2.1.2 Overvoltage Protection

Provisions of 4.5 of IS 732 shall apply.

Surge protective devices may be provided at the incomers of the sub distribution

boards. Building should be protected by suitable lightning and surge protectors/ arresters.

Additional overvoltage protection for equipment used in critical for the process should be considered (example,of such equipment could be PLC, control and monitoring system).

3.1.2.2 Fire-safety Requirements

Besides fire-fighting equipment, the fire detection and extinguishing systems, as recommended in Part 4 of SP 7 shall be followed.

Reference is also drawn to IS 1646 and clause 4.3 of IS 732 regarding rules and regulations relating to electrical installations from the point of fire safety. Annex D covers specific requirements for fire safety for representative industries.

3.2. Panel Board and Distribution Board

Panel boards and distribution boards are electrical enclosures that house electrical components and facilitate the distribution of electrical power within a building or facility. Here's a brief overview of these two types of boards:

3.2.1 Panel Board

Main panel board, also known as load centers or breaker panels, are typically used in residential, commercial, and industrial settings. They are the central point where electrical circuits originate and are distributed to various areas or loads within a building. Panel boards are designed to protect electrical circuits and provide a means to control and distribute electrical power.

Key features of panel boards include:

Fig.3.1: Panel Board

Main Breaker: The main breaker is a large circuit breaker that controls the flow of electricity from the main power source to the panel board. It provides overcurrent protection for the entire panel.

Circuit Breakers: Panel boards contain multiple circuit breakers, each dedicated to protecting a specific circuit or group of circuits. Circuit breakers trip and interrupt the electrical flow when an overload, short circuit, or ground fault occurs, preventing damage to the wiring and electrical devices.

Busbars: Busbars are metal strips or bars within the panel board that conduct electrical power from the main breaker to the circuit breakers. They act as a central distribution point for electricity within the panel.

Neutral and Ground Bars: Panel boards have separate bars for neutral and grounding connections. The neutral bar connects the neutral wires of circuits, while the ground bar is used for grounding wires and connections.

3.2.2 Distribution Boards

Distribution boards, also known as sub-panels or sub-distribution boards, are secondary panels that receive electrical power from the main panel board and distribute it to specific areas or loads within a building or facility. They are often used when the main panel board cannot accommodate all the required circuits or when there is a need to distribute power to different zones or floors.

Fig.3.2: Distribution Board

Key features of distribution boards include:

Feeder: Distribution boards receive power from the main panel board through a main feeder cable.

Circuit Breakers or MCBs: Distribution boards contain circuit breakers or miniature circuit breakers (MCBs) to protect individual circuits or groups of circuits. These circuit breakers are typically smaller than those found in the main panel board and provide localized protection.

Load Connections: The distribution board has terminals or connections for the distribution of electrical power to specific loads or circuits. These connections may include terminals for phase conductors, neutral conductors, and grounding conductors.

Overcurrent Protection: Like panel boards, distribution boards provide overcurrent protection for the circuits they serve. This protection is achieved through circuit breakers or MCBs that trip and interrupt the electrical flow in case of overloads or faults.

3.3. Cable Management System

A Cable Management System (CMS) is essential for organizing and securing cables in various settings, such as offices, data centers, and industrial environments. It helps prevent cable clutter, ensures safety, and enhances the aesthetics and functionality of a space. Here are some key components and aspects of a Cable Management System:

a. **Cable Trays:** These are structures used to support and route cables in large installations like buildings and industrial setups. They come in different types, including ladder, perforated, and wire mesh trays.

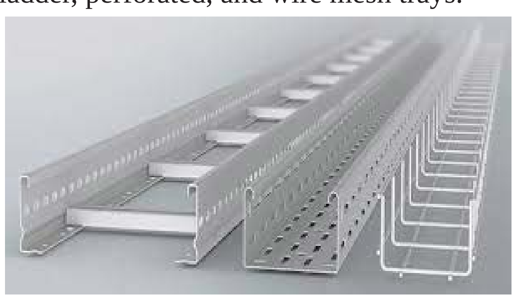


Fig.3.3: Cable Trays

b. **Cable Conduits:** Protective tubing through which cables are run to safeguard them from environmental factors such as moisture, heat, or physical damage. Conduits can be made from materials like plastic, metal, or fiberglass.

Fig.3.4: Cable Conduits

c. **Cable Raceways:** Enclosed channels that house and conceal cables, commonly used in offices and home setups to hide cables along walls or ceilings.

Fig.3.5: Cable Raceway

d. **Cable Ties and Clips:** Simple, easy accessory used to bundle cables together, keeping them organized and out of the way.

Fig.3.6: Cable Ties and Clips

e. **Cable Labels and Tags:** These are used to identify individual cables for easier management and trouble shooting in complex systems, such as server rooms or control panels.

Fig.3.7: Cable Labels and Tags

f. **Cable Organizers:** Accessories like cable sleeves, wraps, and boxes designed to group cables neatly and prevent tangling, commonly used in personal or small office setups.

Fig.3.8: Cable Organizers

g. **Cable Routing and Pathways:** Planning efficient routes for cables to minimize interference, signal loss, or the need for future maintenance. This is particularly important in environments with high cable density, like data centers.

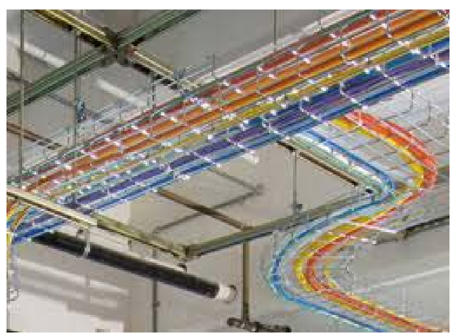


Fig.3.9: Cable Routing and Pathways

A good CMS can reduce the risk of damage, lower maintenance costs, and create a more efficient, scalable setup for future upgrades or repairs.

Importance of Cable Management System

a. **Safety:** Proper cable management reduces the risk of electrical hazards, such as short circuits, overheating, or fire, by preventing cables from getting tangled, damaged, or exposed to wear and tear.

b. **Efficiency:** An organized cable system makes it easier to troubleshoot, replace, or upgrade cables, saving time and effort during maintenance and repairs.

c. **Aesthetic Appeal:** Cable management helps keep spaces neat and professional-looking by concealing cables, reducing clutter, and preventing tangled cords that can create a chaotic or unprofessional appearance.

d. **Space Optimization:** A CMS optimizes the use of available space by organizing cables efficiently, which is especially important in environments with limited room, such as server rooms or home offices.

e. **Longevity of Cables:** Proper cable management helps extend the lifespan of cables by preventing unnecessary wear, stress, or physical damage, ultimately reducing the need for frequent replacements.

3.4 Types of Cable Joints (Straight through Joints, T-Joint, Terminal Joint, Conductor Joint, Brittania Joint, Married Joints, Sleeve Joint and Compression Joint)

Cable joints are used to connect, repair, or extend electrical cables. Different types of cable joints are designed for various purposes and environments, ensuring safe and reliable electrical connections. Below are the common types of cable joints:

1. **Straight Through Joint**

   A straight-through joint is used to connect two cables of the same type and size in a continuous line. It ensures a seamless connection with minimal loss or resistance. Typically used for joining low, medium, and high voltage cables in electrical distribution systems.

Fig.3.10: Straight Through Joint

2. **T-Joint**

   A T-joint connects a main cable to a secondary branch, forming a "T" shape. It is designed to allow current to flow from the main cable to the secondary cable. Commonly used in situations where a branch needs to be taken from a main cable to power a secondary circuit.

Fig.3.11: T-Joint

3. **Terminal Joint**

   A terminal joint connects a cable to a terminal or a device like a switch or a transformer. It is designed to securely terminate the cable and facilitate electrical contact with a terminal. Used in various electrical systems where cables need to be connected to electrical terminals or equipment.

Fig.3.12:. Terminal Joint

4. Conductor Joint

A conductor joint is used to join two or more conductors (wires) within a cable. It ensures that the electrical continuity is maintained across the joined conductors. Often used in power distribution systems to extend cables or repair broken conductors.

5. Britannia Joint

The Britannia joint is a type of conductor joint that involves connecting copper or aluminum conductors with a mechanical compression method. It uses a specialized connector and ensures a reliable and low-resistance connection. Commonly used in overhead lines and power distribution systems, where copper or aluminum conductors are used.

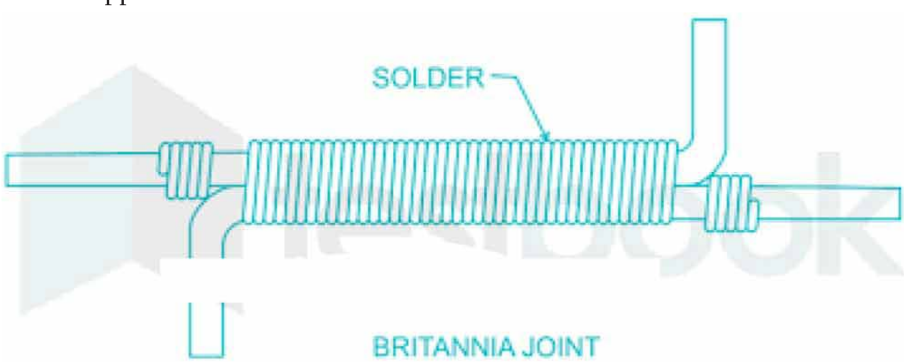


Fig.3.13: Britannia Joint

6. Married Joints

A married joint is a type of joint where two cables are spliced together, often with a joining sleeve or similar component. The cables are typically fused or twisted together and then encased to provide insulation. Used for joining cables in medium and high voltage power systems.

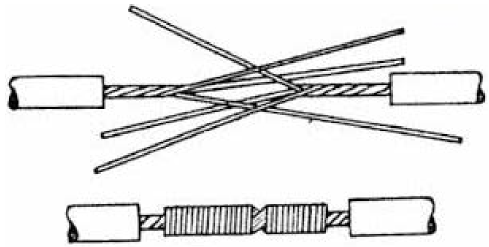


Fig.3.14: Married Joints

7. **Sleeve Joint**

A sleeve joint uses a metal or plastic sleeve to connect the ends of two cables. The cables are inserted into the sleeve, and the sleeve is then compressed or heated to form a strong connection. Commonly used in low voltage applications for joining two wires or cables.

Fig.3.15: Sleeve Joint

8. **Compression Joint**

A compression joint involves the use of a compression fitting, which tightly secures the cable ends together. This method provides a high level of security and ensures that there is no risk of disconnection due to vibration or movement. Typically used in environments where vibration or movement is present, such as in automotive or industrial machinery wiring.

Fig.3.16: Compression Joint

3.5. Installation of Motors

Installing electric motors properly is crucial for their efficient operation and longevity. Here are some best practices to follow when installing electric motors:

1. **Planning and Preparation**

   Review the manufacturer's installation instructions and guidelines specific to the motor model you are working with. Ensure that the motor is suitable for the intended application and meets the required specifications. Determine the proper location for the motor installation, considering factors such as accessibility, ventilation, and safety. Ensure that the electrical supply and wiring are properly sized and compatible with the motor's voltage and current requirements.

2. **Mounting**

   Choose a suitable mounting method based on the motor's design and the application requirements (e.g., foot mounting, flange mounting). Use appropriate mounting hardware and ensure that the motor is securely attached to its mounting surface. Verify that the mounting surface is clean, level, and capable of supporting the weight of the motor. Follow the manufacturer's recommended torque values for the mounting bolts or fasteners.

3. **Alignment**

   Proper alignment between the motor and driven equipment is crucial for optimal performance and to avoid excessive wear or vibration. Ensure that the motor shaft and driven equipment shaft are aligned within the specified tolerances. Utilize precision alignment tools such as dial indicators or laser alignment systems to achieve accurate alignment. Follow the manufacturer's guidelines for alignment procedures, including any recommendations for shimming or adjustment.

4. **Electrical Connections**

   Follow all relevant electrical codes and safety regulations when making electrical connections to the motor. Verify that the motor is properly grounded to prevent electrical hazards. Ensure that the electrical supply matches the motor's voltage and frequency requirements. Use appropriate wire sizes and connectors to handle the motor's current load. Tighten electrical connections securely to prevent loose or overheating connections.

5. **Cooling and Ventilation**

   Ensure that the motor has adequate cooling and ventilation to dissipate heat effectively. Allow sufficient clearance around the motor for proper airflow. Avoid blocking ventilation openings on the motor housing. If necessary, install additional cooling devices such as fans or heat sinks as recommended by the manufacturer.

6. **Testing and Commissioning**

   Before putting the motor into full operation, perform thorough testing and commissioning. Check that the motor rotates smoothly. Check the motor's rotation direction and ensure it matches the required direction. Measure the motor's electrical parameters, such as voltage, current, and insulation resistance, to ensure they are within acceptable limits.

7. **Documentation and Maintenance**

   Maintain accurate records of the motor installation, including mounting details, alignment measurements, electrical connections, and test results. Follow the manufacturer's recommended maintenance schedule for the motor, including periodic inspections, lubrication (if applicable), and any other required maintenance tasks.

3.6. Power Factor Improvement

Power factor

It is defined as the cosine of angle of lead or lag between the current and the voltage. i.e. pf.= cosϕ Here, ϕ is the phase angle between phase voltage and phase current of the load The value of pf. will be leading in a capacitive circuit and it will be lagging in a inductive circuit.

Causes of Low Power Factor

1. Transformers and AC motors operate at lagging power factor. The p.f. falls due to decrease in load. e.g. For induction motor, in full load, p.f.=0.8

   in 50% full load, p.f.=0.7

   in 25% full load, p.f.=0.5

   in no load, p.f.=0.1 2.

2. Due to increase in supply voltage during low-load periods(lunch time, night hours), the magnetizing current of inductive reactance increases and p.f. of whole plant

(system) decreases.

3. Due to improper repair and maintenance, the power factor of motor falls. Due to less winding, leakage of flux increases and pf decreases. Due to heavily worn out bearings, the rotor may catch at stator.
4. Arc lamp and discharge lamps operate at low power factor.
5. Industrial furnaces such as arc and induction furnaces operate at very lagging p.f.

Effects of Low Power Factor

1. The rating of transformers and generators is directly proportional to the output current. So large transformers or generators are required to deliver same load at low p.f.
2. For same power to be supplied, the cross-sectional area of bus-bar and the contact area of switch gear should be enlarged.
3. In low power factor, the transmission, distribution cables has to carry more current. So the size of the wire should be increased to maintain current density which increases materials cost.
4. There is more energy loss due to low power factor, which results in poor efficiency.
5. It results in large voltage drops in generators, transformers, transmission lines and distributers.

Disadvantages of a Low Power Factor

1. Ratings of alternator, transformer & switchgear increased.
2. Power loss in system increases.
3. Size of conductor increased.
4. Poor voltage regulation.
5. System efficiency decreases.
6. Penalty in power factor tariff

3.6.1 Importance of Power Factor Improvement

Importance of Power Factor Improvement

The improvement of power factor is very important for both consumers and generating stations as discussed below :

(i) **For consumers:** A consumer has to pay electricity charges for his maximum demand in kVA plus the units consumed. If the consumer improves the power factor, then there is a reduction in his maximum kVA demand and consequently there will be annual saving due to maximum demand charges. Although power factor improvement involves extra annual expenditure on account of p.f. correction equipment, yet improvement of p.f. to a proper value result in the net annual saving for the consumer.

(ii) **For generating stations:** A generating station is as much concerned with power factor improvement as the consumer. The generators in a power station are rated in kVA but the useful output depends upon kW output. As station output is kW = kVA × cos φ, therefore, number of units supplied by it depends upon the power factor. The greater the power factor of the generating station, the higher is the kWh it delivers to the system. This leads to the conclusion that improved power factor increases the earning capacity of the power station.

Advantages of Power Factor Improvement

1. Reduction in current through the device
2. Reduction in energy loss in the system
3. Reduction in size of conductor required for transmission and distribution
4. Reduction in kVA, loading of generator and transformers.
5. Reduction in material cost.
6. Increase in voltage level across load.

3.6.2 Use of Power Factor Correction Devices (APFC and Static Capacitors)

Normally, the power factor of the whole load on a large generating station is in the region of 0·8 to 0·9. However, sometimes it is lower and, in such cases, it is generally desirable to take special steps to improve the power factor. This can be achieved by the following equipment:

1. Automatic Power Factor Correction (APFC) devices
2. Static Capacitors

3.6.2.1 Automatic Power Factor Correction (APFC)

APFC units automatically switch capacitor banks on and off to maintain a set power factor. APFC units use a microcontroller to read the power factor and determine which capacitor bank to switch on.

Composition of APFC Panel

APFC panel consists of several key components that work together to achieve automatic power factor correction

a. **Capacitor Banks:** These capacitor banks can be switched on or off to provide the necessary reactive power to the system. The capacitors are usually rated at KVAR and are designed to operate under high voltage conditions.

b. **Controllers:** Controllers are the brains of the APFC panel. They monitor the power factor, analyze the data, and control the switching of the capacitor banks. Modern controllers use microprocessors and advanced algorithms to provide precise control.

c. **Switching Devices (Thyristor Switches):** These devices (such as contactors or thyristors) are used to connect or disconnect the capacitor banks to the electrical system. They must be able to handle the high inrush currents associated with capacitor switching.

d. **Sensors:** Current and voltage sensors are used to measure the electrical parameters of the system. These measurements are essential for the controller to accurately decide when to switch the capacitor banks.

e. **Protective Devices:** APFC panels include various protective devices such as fuses, circuit breakers, and surge protectors to ensure the safety and reliability of the system. These devices protect the panel and connected equipment from faults and overvoltages.

Working of APFC Panel

a. **Monitoring:** The APFC panel continuously monitors the power factor of the electrical system using sensors and microprocessors. These devices measure the phase difference between voltage and current to determine the power factor in real time.

b. **Analysis:** Based on the data collected, the APFC panel analyzes the system's power factor. When it detects that the power factor has dropped below a predetermined threshold, it determines how much reactive power (measured in kVAR) needs to be added to the system to correct it.

c. **Activation:** The APFC panel then activates the necessary capacitor banks, introducing the required reactive power. These capacitors provide leading current, which counteracts the lagging current caused by inductive loads, thereby improving the power factor.

d. **Adjustment:** The system continuously adjusts the number of capacitors in operation based on real-time measurements. This dynamic adjustment ensures that the power factor remains close to 1, optimizing system efficiency and reducing energy costs.

Advantages

a. This system reduces energy losses to the systems.

b. Because of this device we will get lower electrical bill.

c. Reduces load on electrical parts, which could extend their lifespan.

d. It improves energy efficiency.

e. Power factor correction is performed automatically and in real time.

Disadvantages

a. These units are very expensive.

b. Installation is critical

c. Requires regular maintenance for proper operation.

d. For installation, this device requires significant space.

e. After some time, the capacitor bank and other electrical components needs to change.

3.6.2.2 Static Capacitors

The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load.

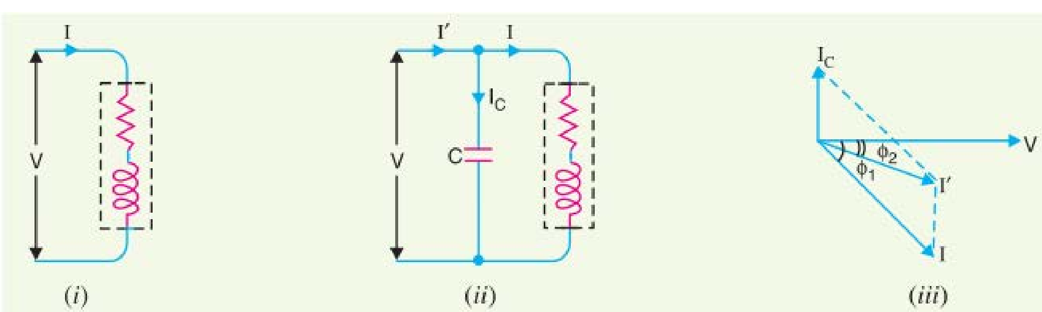


Fig.3.17: Static Capacitors

Illustration: To illustrate the power factor improvement by a capacitor, consider a single-phase load taking lagging current I at a power factor cos φ1 as shown in Fig. 3.17 The capacitor C is connected in parallel with the load. The capacitor draws current IC which leads the supply voltage by 90o. The resulting line current I′ is the phasor sum of I and IC and its angle of lag is φ2 as shown in the phasor diagram of Fig. 6.3. (iii). It is clear that φ2 is less than φ1 , so that cos φ2 is greater than cos φ1 . Hence, the power factor of the load is improved.

Advantages

(i) They have low losses.

(ii) They require little maintenance as there are no rotating parts.

(iii) They can be easily installed as they are light and require no foundation.

(iv) They can work under ordinary atmospheric conditions.

Disadvantages

(i) They have short service life ranging from 8 to 10 years.

(ii) They are easily damaged if the voltage exceeds the rated value.

(iii) Once the capacitors are damaged, their repair is uneconomical

Ewercise

Choose the correct answer from the given alternatives.

1. Which of the following device is commonly used to improve the power factor in anelectrical system?

   a. Inductor b. Capacitor c. Transformer d. Generator

2. Which of the following is a consequence of a low power factor in an electrical system?

   a. Increased energy efficiency b. Increased electrical losses

   c. Increased voltage stability d. Reduced electricity costs

3. Which joint is used for tapping electrical energy for service connections in overhead distribution lines?

   a. Straight-through Joint b. T-Joint

   c. Conductor Joint d. Married Joint

4. Which component is typically found on a panel board to protect circuits from overcurrent?

   a. Capacitor b. Transformer c. MCCB d. Motor

5. Which method is commonly used to organize cables in a data center?

   a. Cable trays b. Conduit c. Zip ties d. All of the above

6. When capacitors are connected to the electrical system for power factor correction, theyare usually connected in

   a. Series with load b. Parallel with load

   c. Series with source d. Parallel with source

7. NBC stands for................

   a. National Building Code b. National Bureau of Construction

   c. New Building Construction d. National Board of Contractors

8. What is the full form of APFC?

   a. Automatic Power Flow Control b. Automatic Power Factor Correction

   c. Advanced Power Frequency Control d. Applied Power Factor Calculation

9. Proper motor installation ensures...............

   a. High power factor
   b. Efficient and safe operation
   c. Low voltage drop
   d. High current flow

10. Which of the following equipment is found on the distribution board?

   a. Generators
   b. Transformers
   c. Circuit breakers and fuses
   d. Motors

Write short answer to the following questions.

1. Write short notes on panel and distribution boards.
2. How the motor installations process is carried out?
3. What are the types of cable joints. Describe them.
4. Why the power factor improvement is necessary?
5. What are the causes and effects of a low power factor?

Write long answer to the following questions.

1. What is the full form of NBC? What are the basics of industrial wiring as per NBC.
2. What is cable management system? Why it is necessary in industrial wiring?
3. How static capacitor and APFC devices helps in improving the power factor

Project Works

1. Field visit to a nearby industrial building.
2. To demonstrate the different types of cable joints
3. To design and build a small-scale model of an industrial panel board.
4. To design a cable management system for a specific industrial setting (e.g., a workshop, a factory floor)
5. To create an installation plan for an industrial motor.
6. Observation of different types of circuit breakers and report writing

Earthing Arrangements of Distribution System

Unit 4

4.1 Earthing of Electric Equipment

Earthing or Grounding is the term used for electrical connection to general mass of the earth. It can be defined as the connection of the non-current carrying parts of the electrical equipment's or the neutral point of the supply system to the general mass of the earth. In earthing, the metallic parts of an electrical installation such as metallic casing, stay wire, end terminals of cable armour etc. that do not carry current are connected to an earth electrode or conductor buried in moist earth using a thick metalconductor of low resistance for safety

4.1.1 Equipment and Neutral Earthing

Equipment Earthing

Such type of earthing is provided to the electrical equipment. The non-current carrying part of the equipment like their metallic frame is connected to the earth by the help of the conducting wire. If any fault occurs in the apparatus, the short-circuit current passes the earth by the help of wire. Thus, protecting the system from damage

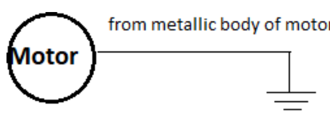


Fig.4.1: Equipment Earthing

Neutral Earthing

In neutral earthing, the neutral of the system is directly connected to earth by the help of the GI wire. The neutral earthing is also called the system earthing. Such type of earthing is mostly provided to the system which has star winding. For example, the neutral earthing is provided in the generator, transformer, motor etc.

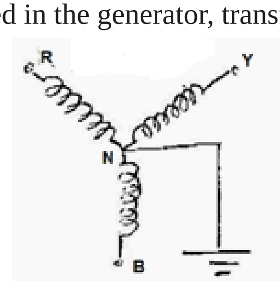


Fig.4.2: Neutral Earthing

4.1.2 Substation Earthing

Substation earthing is a critical safety measure in electrical power systems. It involves connecting various conductive parts of the substation to the ground, ensuring that any fault currents are safely diverted to the earth, minimizing the risk of electric shock and equipment damage.

4.1.2.1. Step and Touch Voltage Regulations

1. **Step Voltage:** This refers to the potential difference that a person experiences when taking a step on the ground near a faulted area or substation. It is the voltage difference between the feet of a person standing on the ground, which can lead to current flowing through the legs and potentially causing harm.

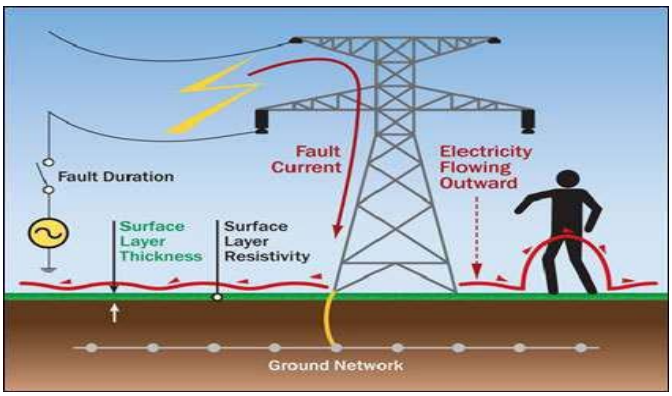


Fig.4.3: Step Voltage

2. **Touch Voltage:** This is the voltage that a person would experience when touching a grounded object (like a fence or equipment) while standing on the ground. It is the potential difference between the object and the ground at the point where the person is standing.

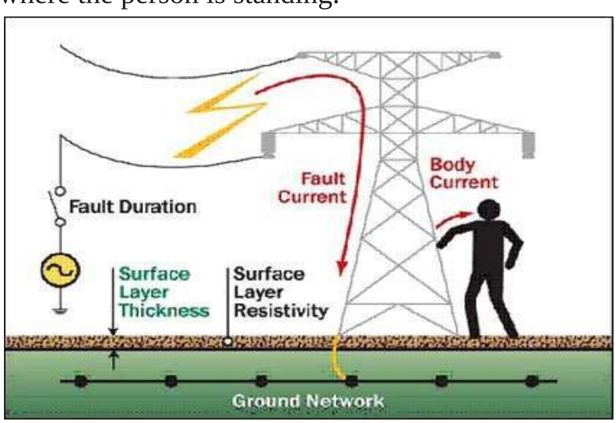


Fig.4.4: Touch Voltage

Regulations and Standards

Regulations typically set limits on maximum allowable step and touch voltages to ensure safety. These limits can vary by country and may be influenced by various standards such as IEEE 80 (Guide for Safety in AC Substation Grounding). Grounding systems in substations must be designed to minimize step and touch voltages.

Key considerations Include

a. **Electrode Configuration:** Proper placement and design of grounding electrodes can help distribute fault currents and reduce voltages.

b. **Soil Resistivity:** The resistivity of the soil affects how current disperses, impacting step and touch voltages. Lower resistivity soils generally provide better grounding performance.

c. **Fault Current Analysis:** Understanding the expected fault currents helps in designing the grounding system to handle such events without exceeding voltage limits.

Safety Practices

a. Regular testing and maintenance of grounding systems to ensure they are functioning effectively.

b. Monitoring of soil conditions and adjustments to grounding systems as necessary to maintain compliance with safety standards. By adhering to these regulations and principles, substations can mitigate risks associated with step and touch voltages, ensuring the safety of personnel working nearby.

4.1.2.2. Substation Earthing Mats

The earthing system in high voltage sub-stations consists of a number of interconnected bare conductors buried horizontally at a depth of about 0.5m. Such a system, known as earthing grid or mat, provides common earth for all devices and metallic structures in the substation. The mat or grid is connected to several earth electrodes which are vertically grounded and each about 3m long. The materials for earthing conductor should have high conductivity and low underground corrosion. Copper, steel & aluminium are used for earthing systems. Modern substation earthing has buried horizontal mesh of steel or copper rods and vertical electrodes welded/clamped to the mesh and vertical risers, galvanized steel strips, copper bars, etc are connected to the grounding points and mesh. The substation earthing should have low earth resistance, low touch potential and low step potential. Earthing and Grounding are the same terms used for earthing. Grounding is the commonly word used for earthing in the North American standards like IEEE, NEC, ANSI and UL etc while, Earthing is used in European, Common wealth countries andBritain standards like IS and IEC etc.

Substation earthing system is provided for the following purposes;

1. Safety of operational and maintenance staff,
2. Discharge of electrical charges to ground,
3. Grounding of overhead shielding wires,
4. Electro-magnetic interference, etc

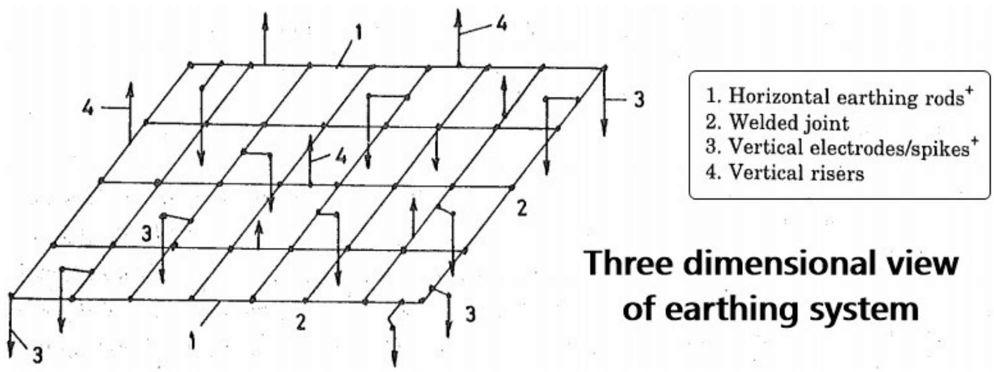


Fig.4.5: Substation Earthing Mats

4.2 System Earthing

4.2.1 Definition and Purpose of System Earthing

Definition of System Earthing

System earthing, also known as grounding, is the intentional connection of an electrical system's conductive parts (such as the neutral point of a transformer, generator, or other equipment) to the earth using a low-resistance conductor. It ensures that parts of the system maintain a defined electrical potential with respect to the ground.

Purpose of System Earthing

a. It protects from electric shocks by flowing fault currents to the earth.

b. It prevents electrical fires by providing a safe path for fault currents to dissipate.

c. It prevents equipment damage by providing a low resistance path for fault current.

d. It protects buildings and equipment from damage caused by lighting strikes by providing a low resistance path for lightning current to flow into the earth.

e. It helps to stabilize the voltage levels in an electrical system, preventing excessive voltage fluctuations that can damage equipment.

4.2.2. Earthing Arrangements in Medium Voltage System

In medium voltage systems, earthing arrangements are crucial for safety and proper functioning of the electrical network. The earthing system provides a path for fault currents to flow safely to the ground, thus preventing electric shocks, equipment damage, and fires. Here are some common earthing arrangements used in medium voltage systems

a. Unearthed Neutral System

In an unearthed neutral system, also known as a floating neutral system or an isolated neutral system, the neutral point of the transformer or generator is not connected to the earth or ground. The neutral point is left isolated or floating, which means there is no direct electrical connection between the neutral point and the ground. This type of system is less common in medium voltage systems due to potential issues with insulation breakdown and difficulties in detecting ground faults. Unearthed neutral systems are mainly used in special applications where continuous operation without ground faults is critical, such as in some process industries.

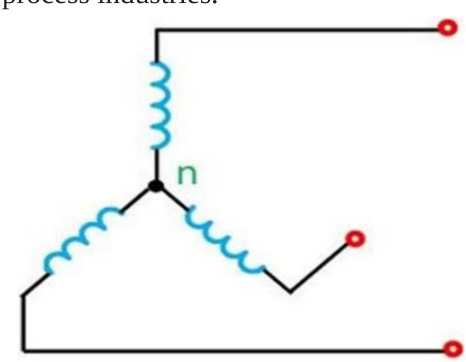


Fig.4.6: Unearthed Neutral System

Advantages

a. The system can continue operating even if a single-phase earth fault occurs, as there is no direct path for fault current.

b. Earth fault currents are minimal, reducing stress on equipment and protective devices.

c. Low fault current minimizes potential damage during earth faults.

Disadvantages

a. Locating and isolating faults is challenging due to the absence of significant fault currents.

b. The system may experience overvoltage due to resonant conditions or sustained earth faults, leading to insulation stress.

c. Equipment must have higher insulation levels to withstand transient overvoltage.

d. Since earth fault currents are low, they may go undetected, posing a safety risk.

b. Earthed Neutral System

In an earthed neutral system, the neutral point of the transformer or generator is connected to the earth or ground. This connection is typically achieved through a low-impedance path such as an earth electrode, grounding conductor, or neutral earthing transformer. The earthed neutral system provides a reference point for the system voltages and ensures that the system remains at or near ground potential. It also facilitates the detection and clearing of ground faults by providing a path for fault currents to flow to the ground, improving safety and system reliability. Earthed neutral systems are the most common in medium voltage distribution networks and are widely used in commercial, industrial, and residential applications

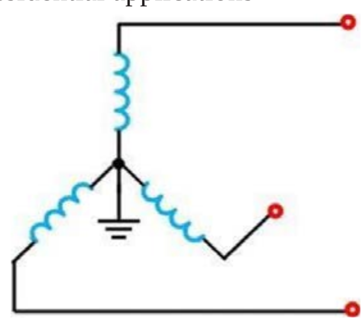


Fig.4.7: Earthed Neutral System

Advantages

a. Fault currents are directed to the ground, ensuring safer operation by quickly clearing faults.

b. Earth faults produce measurable fault currents, allowing for easier detection and isolation.

c. Earthed systems maintain a stable voltage profile under normal and fault conditions.

d. The risk of transient overvoltage is lower due to the direct connection of the neutral to the ground.

Disadvantages

a. Solidly earthed systems may experience large earth fault currents, leading to potential equipment damage.

b. Earth faults require immediate clearance, which may interrupt the supply.

c. Protective devices and cables must handle higher fault currents, potentially increasing costs.

d. Requires proper earthing infrastructure, which may increase installation costs.

Exercise

Choose the correct answer from the given alternatives.

1. What is the purpose of substation earthing?

   a. To reduce power loss

   b. To prevent electrical shock and equipment damage

   c. To improve voltage regulation

   d. To increase system reliability

2. Which of the following is a type of system earthing arrangement in medium voltage systems?

   a. Balanced Neutral System b. Unearthed Neutral System

   c. Overloaded Neutral System d. Grounded Fault System

3. What does Step and Touch Voltage Regulation aim to control?

   a. The voltage drop across transmission lines

   b. The voltage difference during faults in substations

   c. The resistance of earthing electrodes

   d. The current flow through transformers

4. Substation earthing mats are primarily used for...........

   a. Insulating electrical components b. Providing a common ground reference

   c. Reducing power consumption d. Storing electrical energy

5. Equipment and neutral earthing are classified under which category?

   a. System Earthing b. Protective Earthing

   c. Earthing of Electric Equipment d. Dynamic Earthing

6. Equipment earthing is mainly provided for…..

   a. Safety of equipment b. Safety of operating personnel

   c. Safety of starters and cables d. None

7. Earthing is necessary to ….

   a Protect human and machine b. Protect machine winding

   c. Protect birds form current d. All of above

8. Earth wire is made of:

a. Copper b. Aluminum c. Iron d. Galvanized steel

9. What is the advantage of an earthed neutral system?

a. Reduced fault currents b. Better voltage stability

c. Increased equipment cost d. Increased risk of arcing grounds

10. Which type of earthing is used to limit the magnitude of fault currents?

a. Equipment earthing b. Solid neutral earthing

c. Resistance earthing d. Unearthed neutral system

Write short answer to the following questions.

1. What is earthing? What are its types?
2. What is the purpose of system earthing in a distribution system?
3. What is the significance of substation earthing mats?

Write long answer to the following questions.

1. What are Step and Touch Voltage Regulations, and why are they important?
2. Compare and contrast the unearthed and earthed neutral systems in medium voltage system.

Project Works

1. Observation of different methods of earth electrodes.
2. To design and build a small-scale model of an earthing system.
3. To design an earthing mat for a substation, considering the size, grid spacing, and material requirements.
4. To research and report on the earthing standards and regulations used by their local electricity authority.

Unit 5 Inspection, Testing and Maintenance of Industrial Installations

5.1 Inspection of Industrial Installations

5.1.1 Inspection of industrial Wiring System

Periodic inspection and testing of internal wiring installations is necessary. Internal wiring should be checked every year for safe operations. While carrying out inspection and testing of internal wiring installations, following points should be checked:

1. Incoming Service Line Connection

Check and ensure the following:

a. Service line coming in to the premises is properly terminated and brought in

b. Check for fuse wire rating on each of the phases so as to ensure it is of correct rating

c. Check for wire sizes to be of correct size to carry the required current

d. Check for earthing to be properly maintained at the service line side

2. Main Switch Board

A main switch board exists at the point of termination of service line. Supply is provided through this board in to the premises.

a. Ensure that the main switch board is closer to the point of supply in the premises

b. Check for fuses / circuit breakers used of adequate sizes for all phases

c. Check for correct ON/OFF working of Main Switch. A main switch plays a very important role as it helps to switch off the complete supply of the premises in case of emergency / repairs. It should always be in good working condition. Check for any mechanical faults in switching operations that might cause it to remain continuously in ON state. This may be problematic in emergency cases when the electrician wants to switch the supply off

d. Ensure that the Switch board assembly is well covered to protect against rain/weather conditions

e. Inspect to see that you are clearly able to trace the neutral and earthing wires in different colour

f. Inspect the energy meter connections are properly fastened

3. Internal Wiring Circuits

Internal Wiring Circuits are to be checked for following points:

a. Ensure that each circuit branching out of Main Switch board has a connected load of not more than 800 watts or 10 points.

b. Test for Insulation resistance of conductor and earth to be as per IEC specifications.

c. Electrical resistance from connection with Earth electrode should not be more than 10 ohm

d. Ensure metallic covering of iron clad switches, distribution boards are properly earthed.

e. Test that that leakage current is less than 1/5,000 of maximum supply current.

5.1.2 Inspection of Industrial Equipment

5.1.2.1 Inspection of Industrial Equipment

Inspecting industrial wiring is essential to maintain electrical safety and prevent potential hazards in industrial facilities. During the inspection, a qualified electrician or technician should check for various issues, including:-

a. **Loose or Damaged Connections:** Ensure all connections are secure and free from any signs of damage or overheating.

b. **Insulation Integrity:** Verify that the insulation around wires and cables is intact to avoid electrical shorts and shocks.

c. **Proper Grounding:** Check the grounding system to ensure it is correctly installed and functional to protect against electrical faults.

d. **Overloading:** Make sure the wiring can handle the current load to prevent overheating and potential fires.

e. **Cable Protection:** Ensure that cables are appropriately protected from mechanical damage and environmental factors.

f. **Compliance with Regulations:** Confirm that the wiring follows relevant electrical codes and standards.

g. **Age and Wear:** Assess the condition of older wiring systems and replace or repair components as needed.

h. **Testing:** conduit electrical tests to verify the performance and safety of the wiring.

5.2 Testing of Industrial Installations

5.2.1 Test Instruments

- **Insulation Test Instruments**

  The instrument which is used to measure high resistance between conductors or conductor and earth is known as insulation test instrument. This instrument helps in detecting the insulation leakage between the conductors in a cable, conductor and earth etc.

  This instrument must be capable of producing high DC voltages like 500V, 1000V, 2000V etc. to measure the insulation resistance.

  Select the voltage double of installation. For 380V installation, select 1000V.

Fig.5.1: Megger

- **Continuity Test Instruments**

  The instrument which is used to measure resistance and detect whether it is open circuit or short-circuit is known as continuity test instrument. Generally Ampere Volt Ohm(AVO) meter or multimeter is used as continuity test instrument.

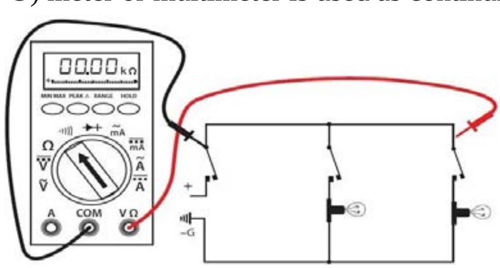


Fig.5.2: Multimeter

- **Phase sequence Test Instruments**

  Phase Sequence Test instruments are electrical testing devices used to determine the correct sequence of phases in a 3-φ electrical system. In 3-φ systems, there are three conductors, typically labelled as A, B, and C, which carry alternating currents with a 120° phase difference between them. The correct phase sequence is crucial for the proper operation of motors, generators and other three-phase equipment. Phase sequence test instruments are typically handheld devices that are easy to use. They are equipped with probes or clamps that are connected to the 3-φ conductors. When the instrument is activated, it analyzes the phase sequence and indicates whether it is correct or not. Some phase sequence testers use visual indicators, such as LEDs, while others may display the results on a digital screen. It is essential to check the phase sequence during the installation and maintenance of 3-φ system to avoid issues like potential equipment damage, and inefficient operation.

Fig.5.3: Phase sequence Tester

- **Earth resistance Test Instruments**

  The instrument which is used to test the earth resistance is known as earth electrode test instrument. This instrument is required to test resistance around the earth electrode.

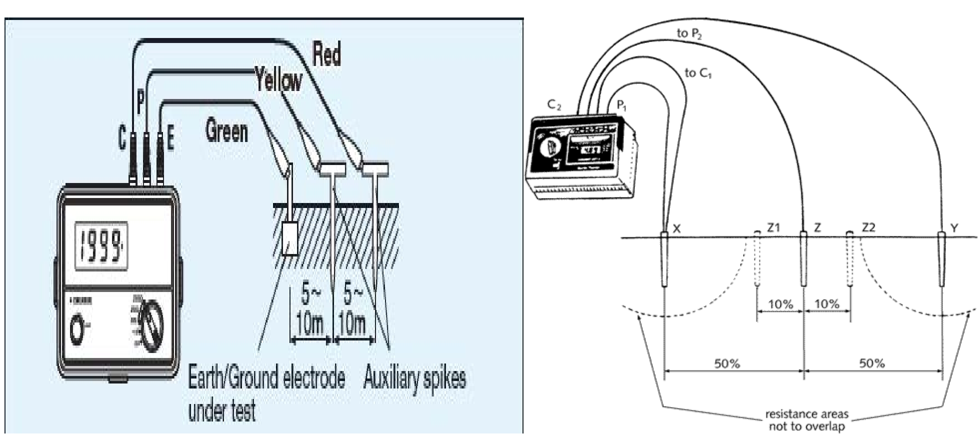


Fig.5.4: Earth Resistance Tester

5.2.2 Testing

- **Insulation Test**

1. Insulation Resistance Test between the Wiring and Earth

The test performed to know whether the cables or wires used in the wiring system are sufficiently insulated wire to wire, lines to neutral, and earth conductor is called Insulation Resistance Test. The values of insulation resistance are measured in terms of Mega ohms (MΩ).

Insulation Resistance Tester, also known as Megger, having test voltage most be double of installation is used to test the insulation resistance. Before making an insulation test, following things should be taken into consideration:-

i. Main switch is in OFF position.

ii. Main fuse has to be taken out or main MCB has to be made in OFF position.

iii. All other fuses are in position.

iv. All the switches are in ON position.

v. All the bulb and lamps are taken out from circuit.

vi. Line and neutral terminals are shorted on the installation side.

Procedure

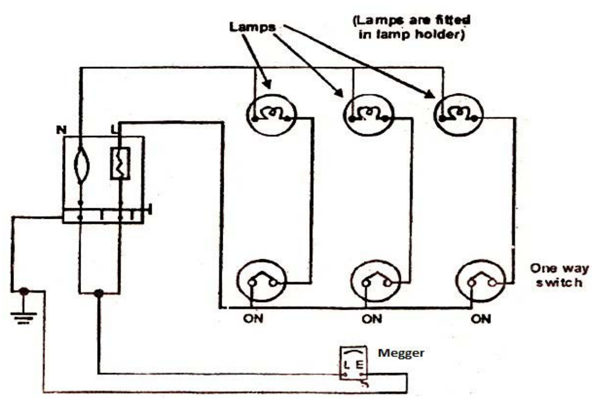


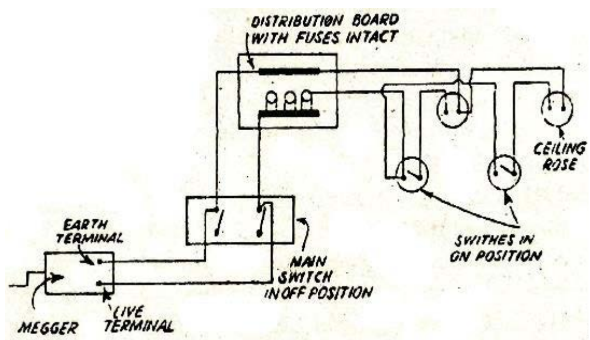
Fig.5.5: Insulation Resistance Test between the Wiring and Earth

The line terminal of the megger is connected to the point where the conductors have been shorted at the main switch and the earth terminal is connected to the earth. The handle of the megger is then rotated if it is analog hand driven megger. Then the readings are noted. The measured insulation resistance should not be less than 50 Mega Ohms (MΩ) divided by the number of outlets. If the ration is 1MΩ is more than unity, insulation resistance is considered sufficient but the insulation resistance should not be less than 0.5 MΩ. If the reading is zero, it means that there is short circuit in wiring which should be removed.

2. Insulation Resistance Test between the conductors

This test is conducted to ensure that the insulation between the conductors is sound so that there may not be appreciable leakage between them. In this test, megger is used to find out the insulation resistance between the conductors.

Before making an insulation test, following things should be taken into consideration:



Testing of insulation resistance between conductor

Fig.5.6: Insulation Resistance Test between the conductors

i. Main switch is in OFF position.

ii. Main fuse has to be taken out or main MCB has to be made in OFF position.

iii. All other fuses are in position.

iv. All the switches are in ON position.

v. All the lamps and all metallic connections between the two wires of the installation are removed from the lamp holders.
In this case, all the things to be considered are same as above except the loop at the main switch is removed and the all the lamps and all metallic connections are removed from the lamp holders.

Procedure: The terminals of the megger are connected to the two poles or lines of the installation and insulation resistance is measured between two conductors (i.e phase and neutral). The insulation resistance so measured should not be less than 0.5 MΩ and need not be more than 1MΩ

- **Continuity Test**

  Continuity test is conducted to ensure that each conductor in the circuit has continuity. Multimeter or Ohmmeter is used to perform continuity tests.

Procedures

a. Using Continuity Mode

The steps for continuity test using continuity mode is given below:

a. De-energize the circuit, if it has any power input.

b. Set the dial of the multimeter in continuity mode (continuity mode is shown by the symbol of sound)

c. Insert the black probe into the COM port.

d. Insert the red probe into the V, Ω port.

e. Now touch the probes with each other. If the meter beeps or gives reading 0 that means the meter works fine.

f. Now connect the probes to both ends of the component or wire that you want to test.

g. If the meter shows 0 and beeps, it means the path is complete (close) or the component allows the flow of current.

h. If the meter does not beep & show 1 or OL, it means the path is broken (open) or the component does not allow the flow of current.

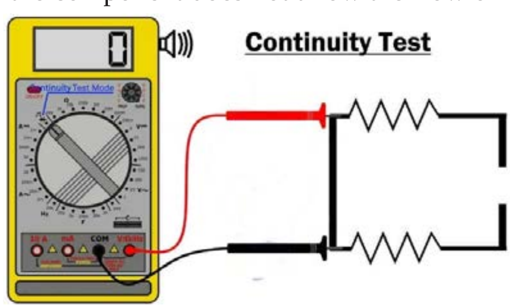


Fig.5.7: Continuity Test

b. Using Ohm-Meter

An Ohmmeter can also be used to determine the circuit whether it is a closed or open circuit, which is the main purpose of a continuity test.

Steps for continuity test using an ohmmeter

a. First de-energize the circuit, if it has any power source.

b. Set the dial of the multimeter to resistance mode Ω. If it has many ranges, set the dial to the minimum range.

c. Insert the black probe into the COM socket of multi-meter.

d. Put the red probe into the V, Ω socket.

e. Connect the probes to both ends of the wire or component you want to test.

f. If the meter reads 0 Ohm or near to 0 Ohm, the path is complete and close.

g. If the meter reads 1 or OL, the wire connection is broken (open).

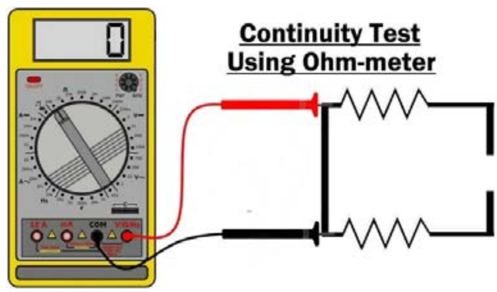


Fig.5.8: Continuity Test

- **Earth Resistance Test**

This test is carried out to check that the earth resistance is within permissible limits. The permissible earth resistance of domestic purpose is 5Ω. Earth resistance is checked by using an instrument called Earth Resistance Tester.

The earth tester is a special type of ohmmeter which sends AC through earth and DC through the measuring instrument. It has got four terminals, P1, C1, P2 and C2 outside. Two terminals P1 and C1 are sorted to form a common point which is connected to the earth electrode (E) under test. The other two terminals P2 and C2 are connected to the auxiliary electrodes P and C respectively. The value of the earth resistance is indicated by the instrument directly.

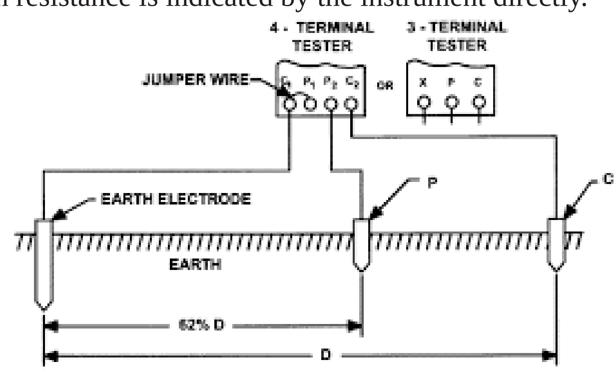


Fig.5.9: Earth Resistance Test

- **Earth Continuity Test**

This test is carried out to check that the resistance of the earth continuity conductor between its connection to the earth electrode and any other metal pieces in the installations does not exceed 1Ω. In a properly designed wiring system, there are a number of earth points located different positions throughout the wiring. For example each plug socket will have a third earthing point. The metallic body of each electrical appliance is connected to the earth through these earth points. This test ensures the continuity between an earth point and the actual earth.

In this test, main switch should be opened, main fuse withdrawn, all other switches in ON position and lamps in their respective holders. One terminal of Earth Resistance tester is connected to the earth point whose continuity is to be checked and other terminal of the tester is connected to the main earthing system of the building. The pointer of earth continuity tester will give the resistive value between the said earth point and actual earth. In any case, the value must not be greater than 1 ohm. If it is greater than 1 ohm, then the earthing connection should be physically rechecked and properly rectified \to achieve desired minimum earth resistance.

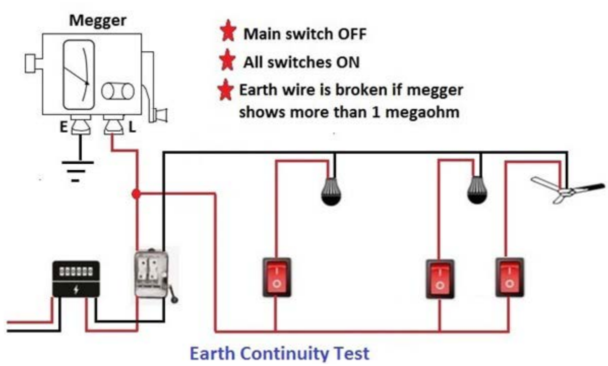


Fig.5.10: Earth Continuity Test

Ewcrcise

Choose the correct answer from the given alternatives.

1. What is the primary purpose of an insulation test?

   a. To measure power consumption

   b. To check the integrity of insulation in a system

   c. To identify the phase sequence

   d. To test earth resistance

2. Which test instrument is used to measure the resistance of the earth connection?

   a. Phase Sequence Test Instrument   b. Continuity Test Instrument

   c. Earth Resistance Test Instrument   d. Insulation Test Instrument

3. What is inspected during the inspection of industrial installations?

   a. Wiring systems and industrial equipment

   b. Transformer connections only

   c. Switchgear alignment only

   d. Load distribution

4. Which of the following tests ensures proper connections in electrical circuits?

   a. Insulation Test   b. Continuity Test

   c. Earth Resistance Test   d. Phase Sequence Test

5. Phase sequence test instruments are used to:

   a. Check insulation resistance

   b. Verify the order of phases in a three-phase system

   c. Measure the continuity of circuits

   d. Determine earth continuity

6. The permissible earth resistance of domestic purpose is…

   a. 5 Ω   b. 1 MΩ   c. 0.5 Ω   d. 1 Ω

7. The insulation resistance test is performed using a/an ………

   a. Ammeter   b. Megger   c. Galvanometer   d. Voltmeter

8. In an earth continuity test, which of the following values is typically considered an acceptable range for the earth continuity resistance of a grounding conductor in a standardhousehold electrical system?

a. 10–20-ohm
b. Greater than 100 ohms
c. Exactly 50 ohms
d. Less than 1 ohm

9. What is the purpose of a visual inspection?

a. To measure voltage
b. To identify visible defects and damages
c. To test insulation resistance
d. To check phase sequence

10. What is the function of a clamp meter?

a. To measure voltage
b. To measure current without interrupting the circuit
c. To measure resistance
d. To measure insulation resistance

Write short answer to the following questions.

1. Write any five points of main switch board that should be checked in wiring installation.
2. How can we perform test between conductors using megger?
3. What does the reading of megger zero and infinity represent?
4. How the inspection of industrial equipment is carried out?
5. What are the functions of different test instruments used in industrial installations?

Write long answer to the following questions.

1. How can we perform the insulation resistance test between wiring and earth? Why the insulation test is necessary?
2. How the earth resistance test and earth continuity test is carried out?.
3. What points should be checked during the inspection of industrial wiring system?

Project Works

1. To create a comprehensive inspection checklist for industrial wiring systems, covering visual checks, continuity tests, insulation tests, and safety aspects.
2. To conduct a simulated inspection of a piece of industrial equipment (e.g., a motor,

a control panel), using the inspection checklist they developed.

3. To demonstrate the use of different test instruments.
4. To develop a step-by-step testing procedure for industrial installations, covering insulation tests, continuity tests, earth resistance tests, and earth continuity tests.
5. To conduct a simulated testing of an industrial installation (e.g., a wiring system, a motor control circuit), using the testing procedure they developed.

Unit 6 Three Phase Induction Motor Controls

6.1. Control of Three Phase Induction Motor Using Drum Switches

Drum Type Switch

A switch in which the electrical contacts are made on pins, segments, or surfaces on the periphery of a rotating cylinder is called drum type switch. This switch has stationary contacts called finger contacts and a rotating drum which carries copper contacts in the form of segments . The crank type operating handle is moved in 'steps' by a star wheel and a pivoted arm. It is a manual switch that lets one manually change the function.

Fig.6.1: On-Off Drum type switch

Types of Drum Type Switch

- ON/OFF Drum type Switch
- Forward/Reverse Drum type Switch
- Star/Delta Drum type Switch

a. ON/OFF Drum Type Switch

This switch helps to turn ON and OFF simply by rotating the handle. It helps in starting up three phase induction motor in which stator windings of the motor are connected directly to the main supply.

b. Forward/Reverse Drum Type Switch

This switch helps the three phase induction motor to rotate in either forward direction or in reverse direction. When the handle of the switch is turned in the forward direction, motor terminals A,B,C are connected to L1, L2,L3 respectively at one step. Again, when the handle is turned in the reverse direction, the motor terminals A,B,C are connected to L2,L1,L3 respectively thus reversing the direction of motor.

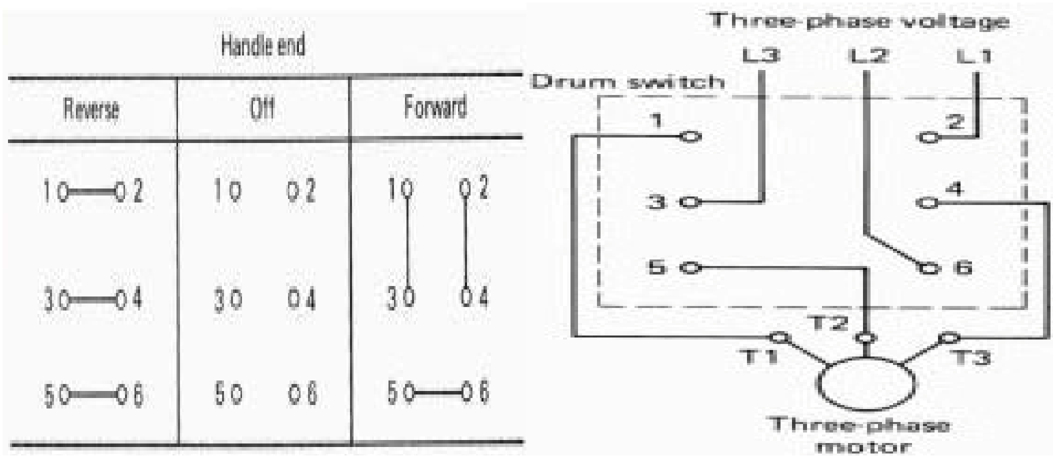


Fig.6.2: Forward/Reverse Drum type Switch

c. Star/Delta Drum Type Switch

This switch is used for starting motors of higher ratings (normally greater than 5HP). The motor can be started with star connection and can be manually changed into delta connection once it attains full speed. When starting up large AC motors directly on the grid, a high starting current is temporarily generated for the relevant systems. This can cause fuses to trip and thus lead to unwanted production downtime. In order to avoid this, star/delta changeover switches are used.

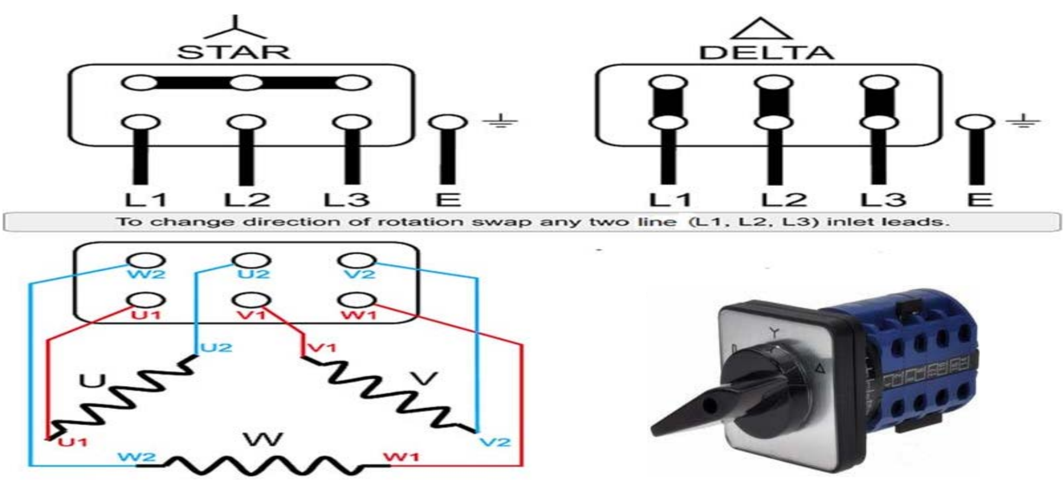


Fig.6.3: Star/Delta Drum type Switch

6.1.1 Control of Three Phase Induction Motor Using Simple Drum Type ON/ OFF Switch

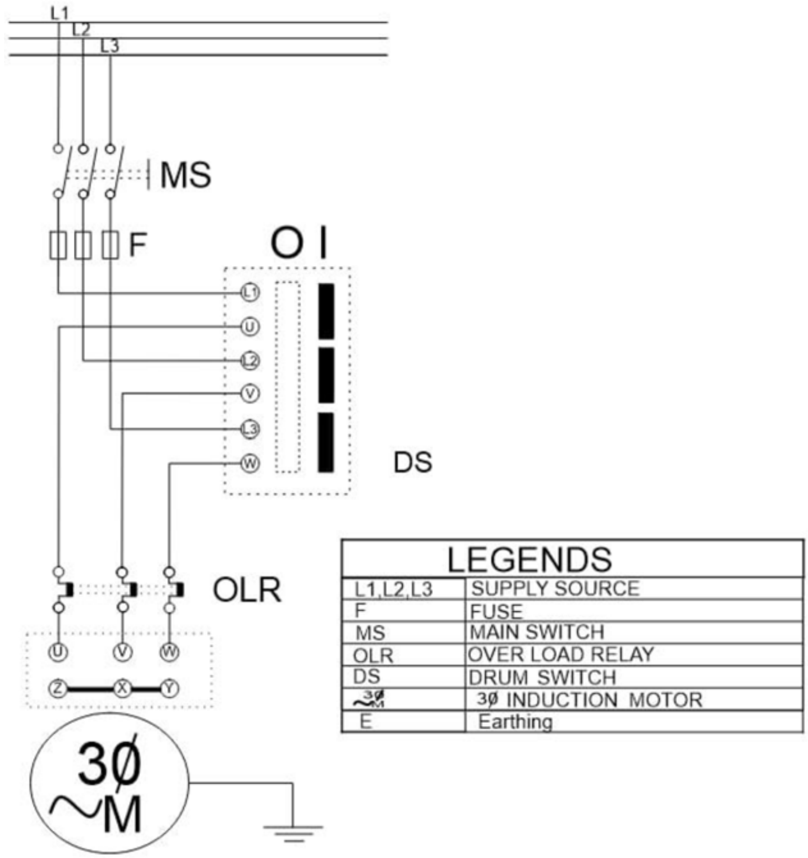


Fig.6.4: Control circuit diagram of three phase induction motor using simple drum type ON/ OFF switch

Working Principle

The switch is often connected to the motor's starter circuit (typically including components like fuses, overload relays, and contactors).

i. **ON Position:** In this position, the three-phase current is supplied to the motor. The motor will start running when the switch closes the circuit.

ii. **OFF Position:** The switch opens the circuit, cutting off the power to the motor, which stops the motor from running.

This is a very basic form of control, suitable for situations where the motor is required to be operated manually or where simple ON/OFF functionality is needed without the need for advanced automation or speed control.

6.1.2 Control of Three Phase Induction Motor Using Simple Drum Type forward/Reverse Switch

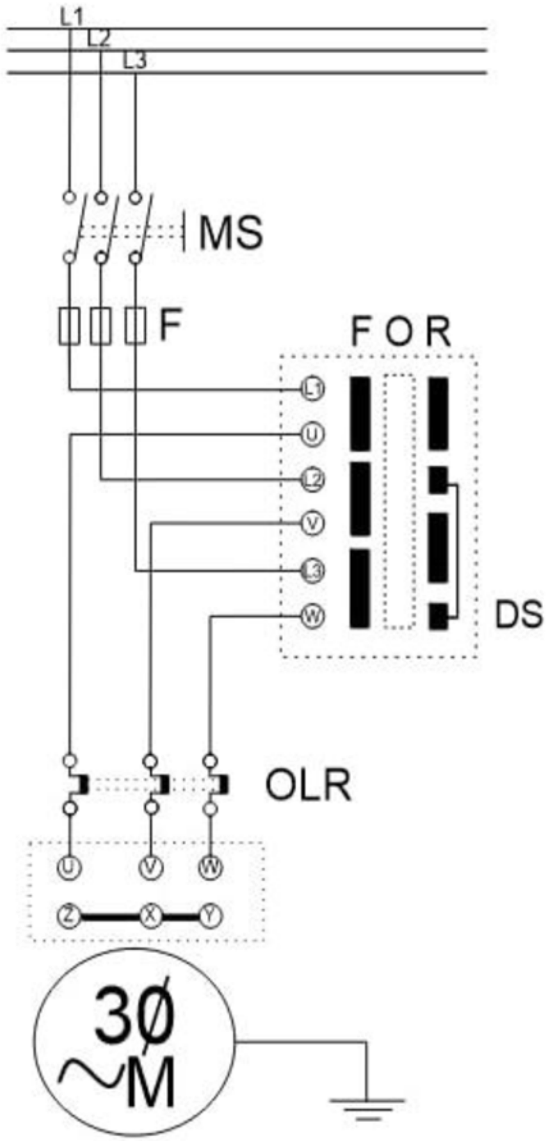


Fig.6.5: Control circuit diagram of three phase induction motor using simple drum type forward/reverse switch

Working Principle

i. **Forward Position (ON - Forward):** The drum-type switch closes specific electrical contacts, providing the correct phase sequence to the motor, resulting in forward rotation.

ii. **Reverse Position (ON - Reverse):** The drum-type switch rotates and connects different contacts, reversing the phase sequence of the motor's supply, causing the motor to rotate in the opposite direction.

Interlocking: A critical feature of forward/reverse control is interlocking. The switch should be designed to ensure that both forward and reverse cannot be engaged simultaneously. This prevents short circuits or damage to the motor and other components.

6.1.3 Control of Three Phase Induction Motor Using Simple Drum Type Star/ Delta Switch

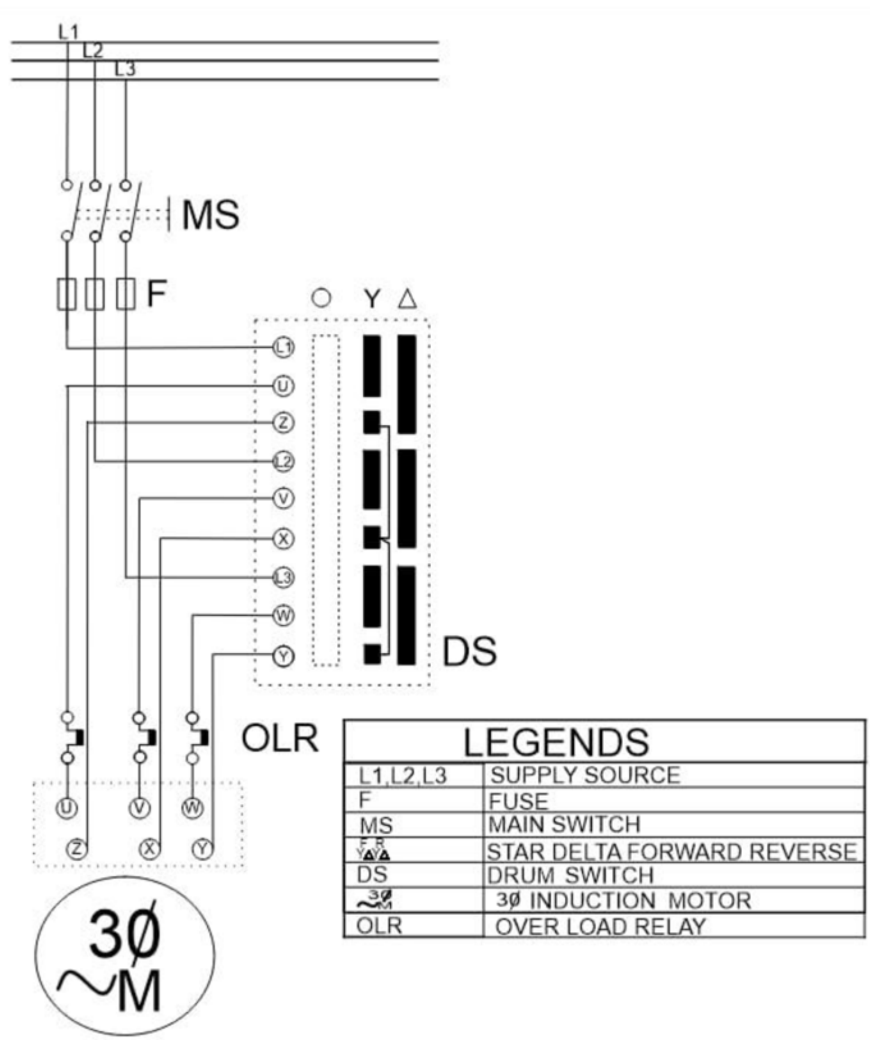


Fig.6.6: Control circuit diagram of three phase induction motor using simple drum type star/ delta switch

Working Principle of Star/Delta Switching

i. **Start (Star Configuration):** When the motor is first started, it is connected in the Star (Y) configuration. This reduces the voltage across each winding, causing the motor to start with a lower current (approximately one-third of the current compared to the Delta connection). This helps in reducing the starting inrush current, which is beneficial for preventing electrical stress and damage to the motor.

ii. **Run (Delta Configuration):** After the motor reaches a certain speed (usually around 70-80% of its rated speed), the Star/Delta switch is activated, and the motor is switched to the Delta configuration. This applies full line voltage across the windings, enabling the motor to operate at full torque and speed.

Automatic or Manual Switching: The drum switch can either be manually operated or automated with a time-delay relay. This ensures the motor is first started in Star and then switched to Delta after a short delay..

6.2 Functions and Applications of Motor Control Accessories

6.2.1 Functions and Applications of Motor Control Accessories : Contactor, Motor Protection Circuit Breaker (MPCB), Over Load Relay (OLR), Push Button Switches, Timers etc.

1. **Contactor**

A contractor is an electromechanical switch. It is used for high power applications. It operates when it's coil is energized and attracts other contact towards it. It has two types and size of contacts main and auxiliary. Auxiliary contact is also divided into Normally open (NO) and Normally Closed (NC)

Coil voltage may be DC: 12V, 24V, 48V or AC: 110V, 220V, 500V..

Function: It is an electrically controlled switch used for switching on electrical power circuit. It is designed to control motors and other high-power loads.

Application: It is commonly used in motor starters, lighting control, and heating applications. They can handle high currents and voltages, making them suitable for industrial settings. It can be operate from remote.

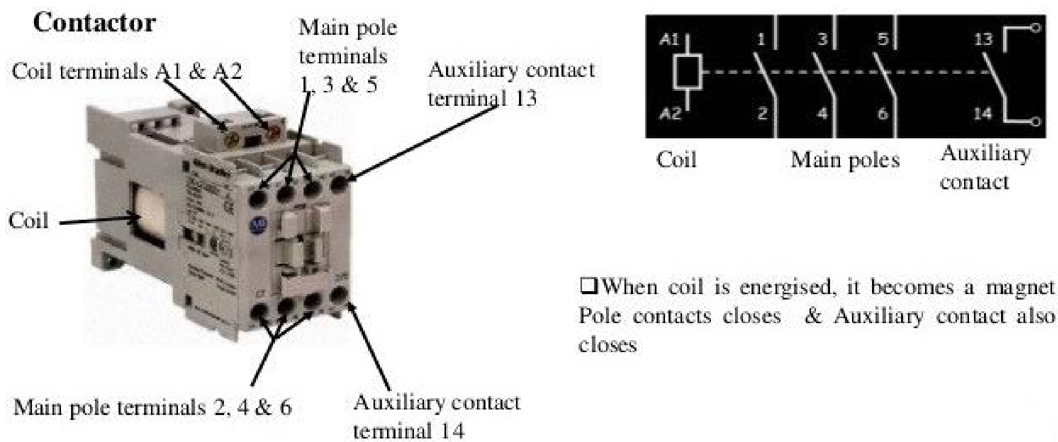


Fig.6.7: Contactor

2. **Motor Protection Circuit Breaker (MPCB)**

   Motor protection circuit breaker (MPCB) helps to protects electric motors from overloads, short circuits, and phase failures (combining circuit breaker, overload relay, phase failure relay).

   Function: It is a device that does the job of both contactor and (OLR) Over Load Relay. It protects motor from overload and short-circuit.

   Application: It is used in motor control panels to protect motors from damage due to overloads or electrical faults.

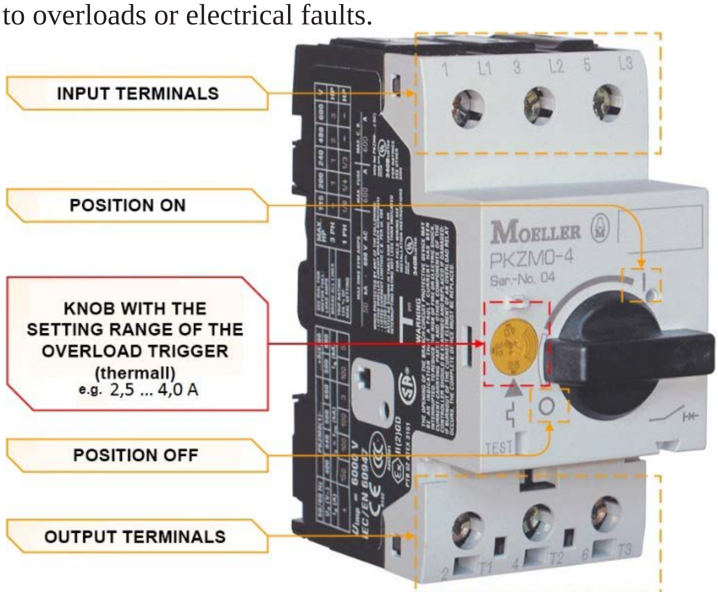


Fig.6.8: Motor Protection Circuit Breaker (MPCB)

3. **Over-Road Relay (OLR)**

A relay is a device that senses and controls the circuits. An OLR senses overload and disconnect the circuit for protection. It consists of bimetallic strip which expands when overload current flows, then disconnects the circuit.

Function: It protects motors for from overheating by disconnecting the Power supply when current et. - seeds a preset level.

Application: It is typically used in conjunction with contactors in motor starters.

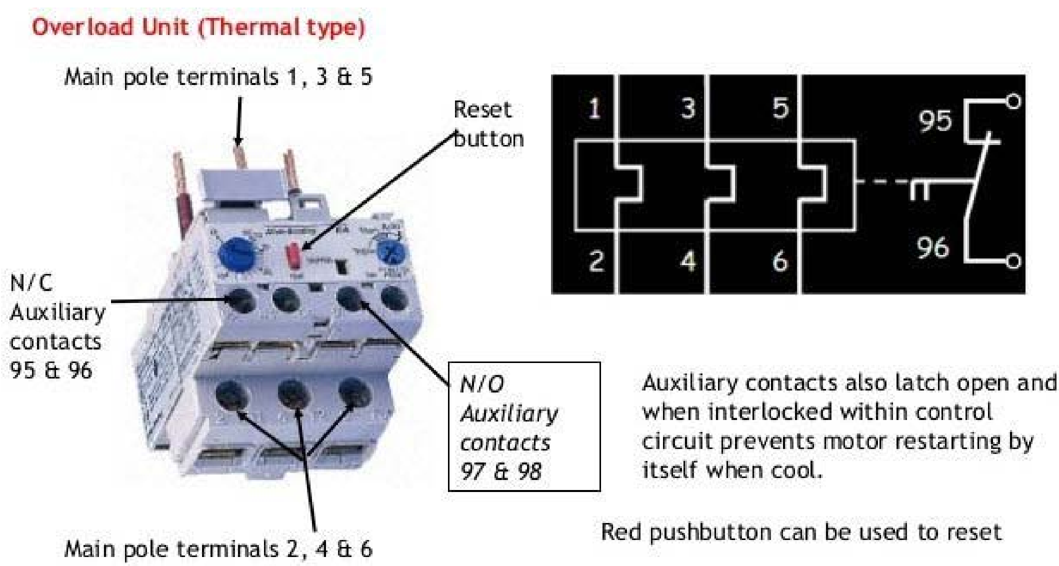


Fig.6.9: Over-Road Relay (OLR)

4. **Push Button Switches**

The switch which momentarily switch OFF or switch ON is called Push button switch. There are two types of push button START and STOP. Start push button switch is normally open and closes the circuit when pressure is applied. Stop push button switch is normally closed and opens the circuit when pressure is applied.

Function: Push button switches are manual controls that allow operators to start or stop a motor or other equipment.

Application: They are widely used to control panels for machinery and equipment.

Fig.6.10: Push button Switches

5. **Timer**

A timer is an electrical or electronic device used to control the timing of operations in circuits. It allows predefined time-based control of processes, enabling precise management of machinery and systems.

Function: Controls the operation of a circuit based on time delays (on or off delay).

Application: Used in motor control for delayed start/stop sequences, interlocks, and process timing in automation systems.

Fig.6.11: Timer

6.3 Power and Control Diagrams of Simple Motor Control System

6.3.1 Power and Control Diagrams of Simple Motor Control System (inching and Holding system)

a) **Inching System**

Working

In inching system, the motor will run till the start push button is pressed i.e. the motor will be stopped after releasing the start push button.

Start Mode: The circuit receives power from the main supply, which is typically a 3-phase AC source. The operator presses the start button. The contactor coil (K1) is energized, closing the contacts of the main contactor. The motor windings are directly connected to the power supply, allowing full line voltage to be applied to the motor.

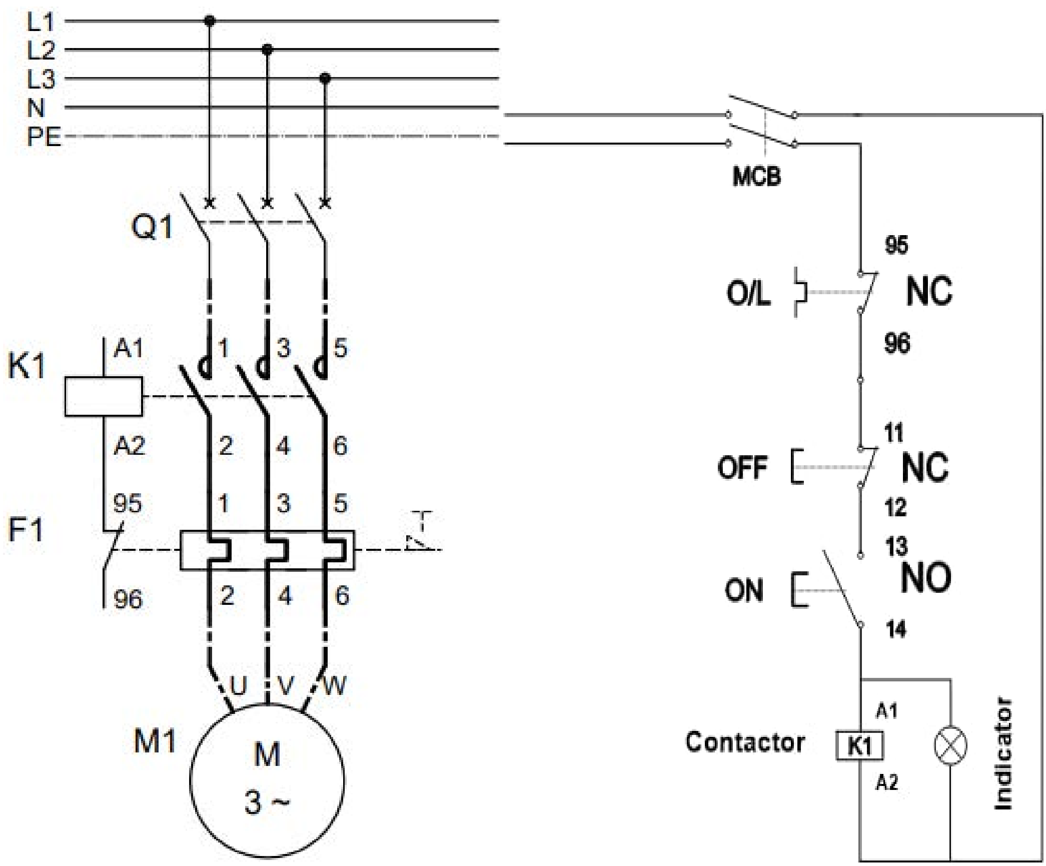


Fig.6.12: Power and control circuit diagrams of simple motor control system (Inching System)

Running Mode: With the main contactor closed, the motor receives full voltage and starts rotating. The motor accelerates and reaches its rated speed. The overload relay continuously monitors the motor's current. If the current exceeds the set limit, it trips, de-energizing the contactor and stopping the motor.

Stop Mode: When the start button is released, the contactor coil (K1) is de-energized. The main contactor opens, disconnecting the motor from the supply. The motor comes to a complete stop.

b) Holding System

Working

In holding system, the motor will run after start button is pressed and the motor will stop after stop push button is pressed.

As start and running mode is already discussed in 6.3.1 (a)

Stop Phase: When the stop button is pressed, the contactor coil (K1) is de-energized. The main contactor opens, disconnecting the motor from the supply. The motor comes to a complete stop.

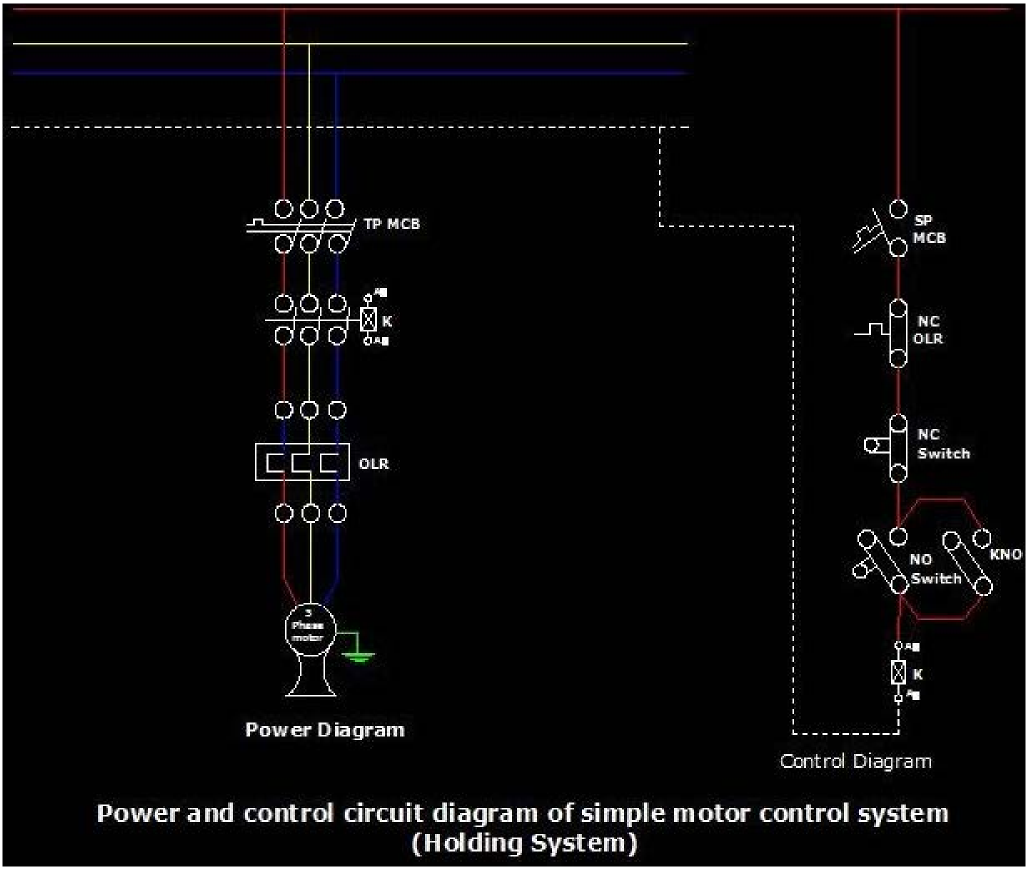


Fig.6.13: Power and control circuit diagrams of simple motor control system (Holding System)

6.3.2 Power and Control Circuit Diagrams of Simple Motor Control System From Two Places

Working

In this method, the motor can be controlled from two or more than places. When the ON button is pressed at any location, the corresponding coil in the contactor is energized. If the OFF button is pressed at any location, the contactor coil is de-energized.

As start, running and stop mode is already discussed in 6.3.1 (a)

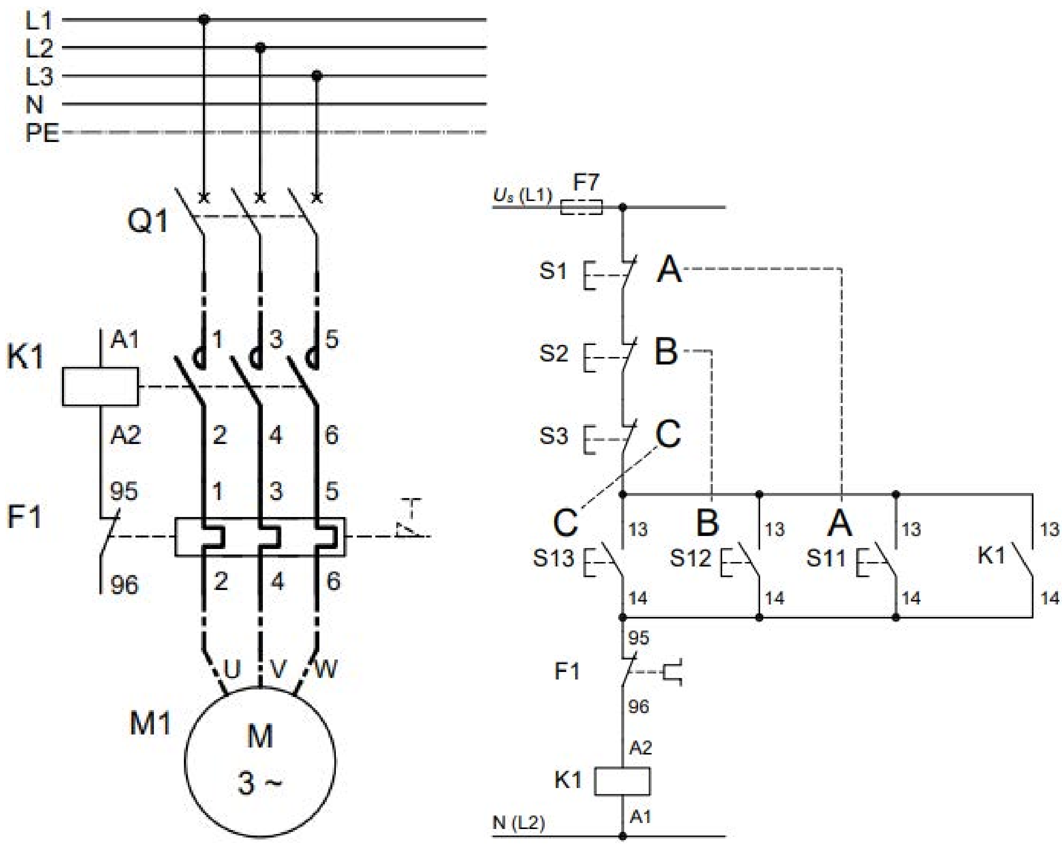


Fig.6.14: Power and control circuit diagrams of simple motor control system from two places

6.3.3 Power and Control Circuit Diagrams of Simple Motor Control System in Two Directions

The circuit receives power from the main supply, which is typically a 3-phase AC source The reverse forward direction of a motor can be achieved using two contactor (K1 & K2) and relay. The K1 contactor is used to switch the three-phase power supply to the motor and run in clockwise direction. The K2 contactor is used to run the motor in anti-clock wise direction. The relay is used to control the direction of rotation i.e. it changes the two lines supply out of three lines to the motor which is must to use for changing the direction of rotation of the motor.

Working

When the forward operation contacts of the relay are energized, they close, and the contactor K1 is activated, causing the motor to run in the forward direction. The three-phase power supply (via L1, L2 & L3) is applied to the motor's U, V, and W terminals, causing the motor to rotate in the clockwise direction.

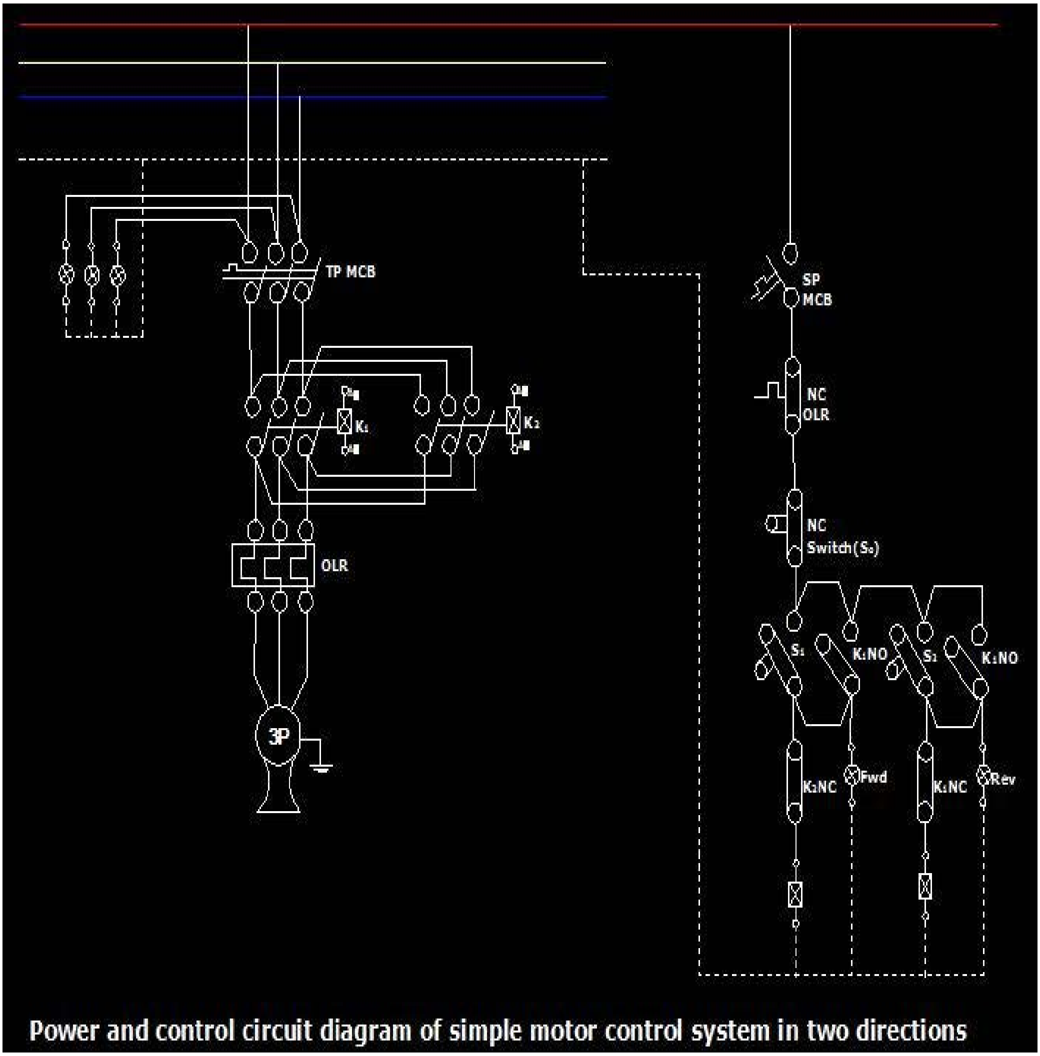


Fig.6.15: Power and control circuit diagrams of simple motor control system in two directions

When the reverse operation contacts of the relay are energized, they close, and the normally closed auxiliary contact of the contactor opens. This activates the reverse contactor K2 coil, causing the motor to run in the reverse direction. The three-phase power supply is now applied to the motor's U, W, and V terminals, causing the motor to rotate in the counterclockwise direction.

6.3.4 Power and Control Circuit Diagram of Motor Sing Star Delta Starter

The star-delta starter without timer follows a basic principle: the motor starts in a star configuration, and after a predefined time, it switches to the delta configuration.

Star Connection

During the starting process, the motor windings are initially connected in a star (Y) configuration. In the star connection, each winding receives the full line voltage (VL) across them. This configuration allows the motor to draw reduced current compared to a direct-on-line start.

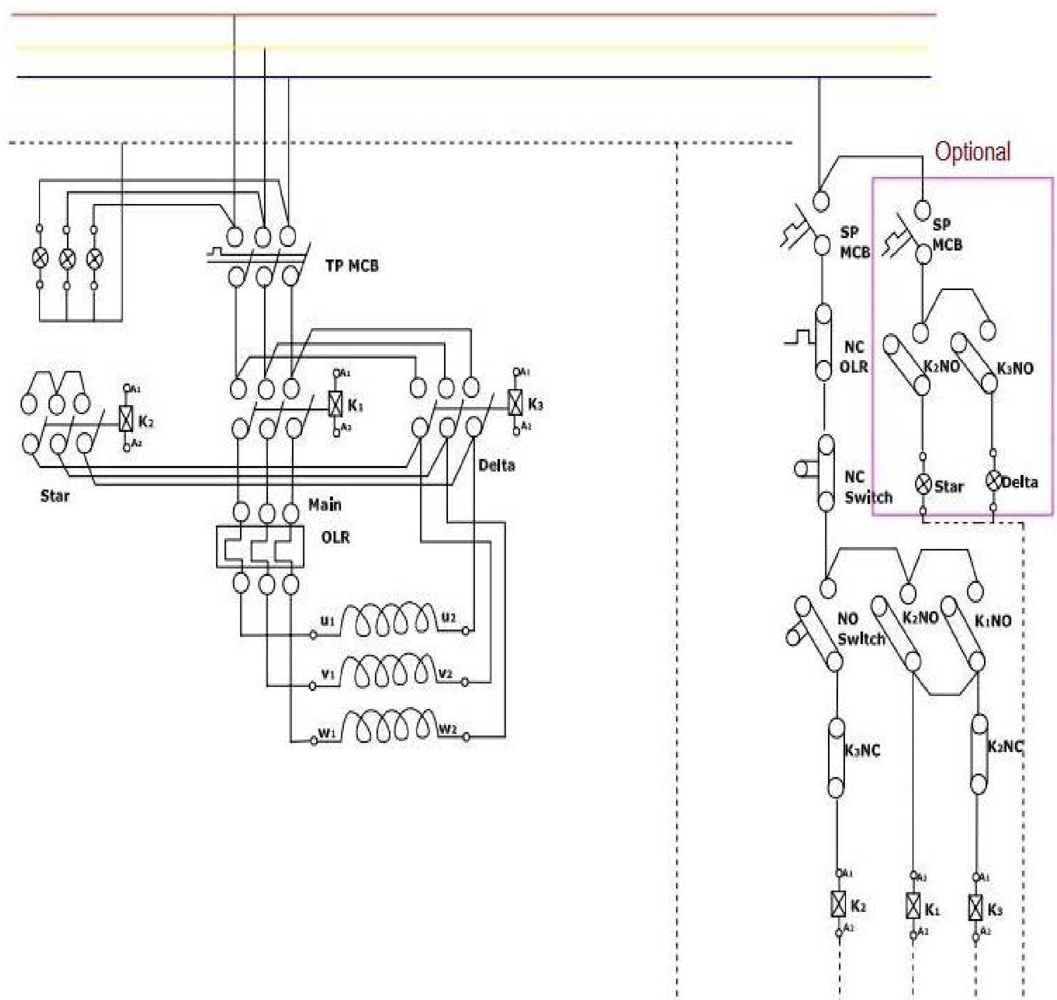


Fig.6.16: Power and control circuit diagram of motor sing star delta starter

Delta Connection

After a specific period (usually a few seconds) of running in star mode, the motor windings are switched to a delta (Δ) configuration. In the delta connection, each winding receives the line voltage divided by the square root of 3 (√3) across them. This results in an increase in the current but provides higher torque, allowing the motor to reach its full speed.

Working

Start mode: The circuit receives power from the main supply, which is typically a 3-phase AC source. The operator presses the start button. The star contactor (K2) coil is energized, closing the contacts and connecting the motor windings in a star configuration. The motor starts with reduced voltage, minimizing inrush current.

Delay mode: After a predefined time, the operator manually switches the delta contactor (K3). The motor windings switch from star to delta connection, operating at full voltage. The motor achieves full speed and continues running in the delta configuration.

Stop mode: The overload relay continuously monitors the motor's current. If the current exceeds the set limit, it trips, de-energizing the contactor and stopping the motor. When the stop button is pressed, both the star (K2) and delta (K3) contactors open.

The motor is disconnected from the power supply and comes to a stop.

Exercise

Choose the correct answer from the given alternatives.

1. Which type of drum switch is used for forward and reverse control of a three-phase induction motor?

   a. ON/OFF switch b. Star/Delta switch

   c. Forward/Reverse switch d. Timer switch

2. What is the purpose of a motor protection circuit breaker (MPCB)?

   a. To change the motor's speed

   b. To protect the motor from overloads and faults

   c. To reverse the motor's direction

   d. To control the star/delta transition

3. Which motor control accessory is used to prevent overloading in motors?

   a. Contactor b. Overload Relay (OLR)

   c. Push Button Switch d. Timer

4. What does a star/delta switch control in a three-phase motor?

   a. Voltage regulation b. Starting current and torque

   c. Motor temperature d. Direction of rotation

5. What is the function of an inching and holding system in motor control?

   a. To control the motor from two locations

   b. To enable precise positioning and maintain operation

   c. To protect the motor from short circuits

   d. To reverse the motor's rotation

6. When a contactor is de-energized, it is in the……… position.

   a. Normally closed b. Normally open

   c. Latched d. Semi-closed

7. In a DOL starter, what happens when a start push button is pressed?

   a. The motor starts with a reduced voltage

   b. The motor starts at full voltage

c. The motor stops

d. None of the above

8. Which type of the motors are typically started using the Star-Delta starter?

   a. DC motors
   b. Synchronous motors
   c. Single phase motor
   d. Three phase induction motors

9. What function is controlled using a simple drum-type forward/reverse switch?

   a. Speed control
   b. Starting and stopping the motor
   c. Direction of motor rotation
   d. Star-delta starting

10. What is the full form of MPCB?

   a. Motor Protection Circuit Breaker
   b. Main Power Control Board
   c. Motor Protection Control Board
   d. Main Power Circuit Breaker

Write short answer to the following questions.

1. What is drum type switch? What are its types?
2. How the control of three phase induction motor using simple drum type ON/OFF switch is achieved?
3. Draw and explain power and control circuit diagrams of simple motor control system (Inching System)
4. Draw and explain power and control circuit diagrams of simple motor control system (Holding System)

Write long answer to the following questions.

1. What are the functions and applications of motor control accessories, including contactors, MPCB, OLR, push-button switches, and timers?
2. How the control of three phase induction motor using simple drum type forward/reverse switch and drum type star/delta switch is achieved?
3. Draw and explain a power and control circuit diagram for a simple motor control system in two directions.
4. Illustrate and explain the power and control circuit diagram of a motor control system that operates from two location.
5. Draw and explain a power and control circuit diagram of motor using star delta starter

Project Works

1. Connect and run three phase induction motor using simple drum type ON/OFF switch.
2. Connect and run three phase induction motor in both directions using simple drum type forward/reverse switch.
3. Connect and run three phase induction motor using simple drum type Star/Delta switch.
4. Draw power and control circuit diagram of simple motor control system. And run using following accessories.

   a. Air break contactor - 1 No

   b. OLR – 1 NOs

   c. TPMCB32A – 1 Nos

   d. SPMCB6A – 1Nos

   e. Push Button switch(start/stop) – 2 Nos
5. Draw power and control circuit diagram of simple motor control system from two places. And run using following accessories.

   a. Air break contactor - 1 Nos

   b. OLR – 1 NOs

   c. TPMCB32A – 1 Nos

   d. SPMCB6A – 1Nos

   e. Push Button switch(start/stop) – 3 Nos
6. Draw power and control circuit diagram of simple motor control system in two directions. And run using following accessories.

   a. Air break contactor - 2 Nos

   b. OLR – 1 Nos

   c. TPMCB32A – 1 Nos

   d. SPMCB6A – 1Nos

   e. Push Button switch(start/stop) – 3 Nos
7. Draw power and control circuit diagram of star delta motor stator. And run using following accessories.

   a. Air break contactor - 3 Nos

b. OLR – 1 NOs

c. TPMCB32A – 1 Nos

d. SPMCB6A – 1Nos

e. Push Button switch(start/stop) – 3 Nos

5. To research and create a display showcasing different motor control accessories (contactors, MPCB, OLR, push buttons, timers).
6. To design a motor control panel for a specific industrial application.
7. To create a troubleshooting guide for common problems in motor control circuits.

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