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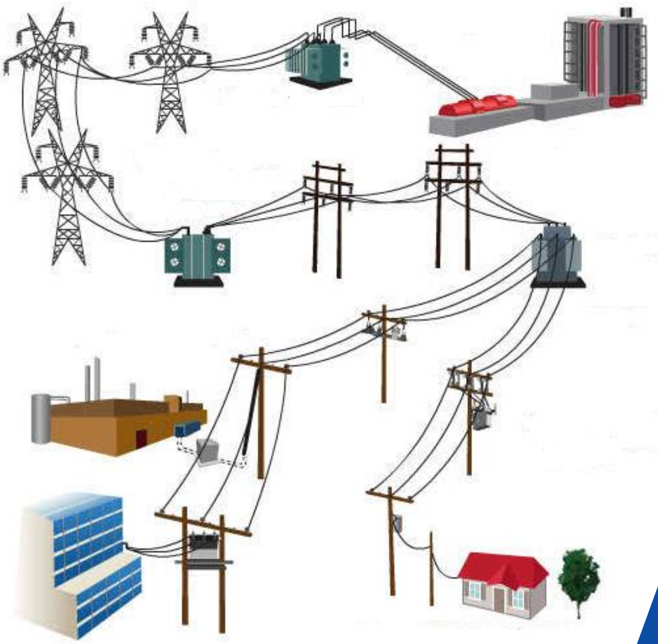


TRADE: IEL

MODULE CODE: IELEP 501

TEACHER'S GUIDE

Module name: ELECTRICAL POWER DISTRIBUTION SYSTEM DESIGN

Acronyms

AC: Alternating Current
DC: Direct Current
EDS: Electric Distribution System
UPS: An uninterruptible power supply
DG: Distributed Generation
SMPS: Switched-Mode Power Supply
PPS: Programmable Power Supply
IEL: Industrial electricity
BOQ: Bill of Quantity

LIST OF FIGURE

Figure 1: Picture/s reflecting the Learning unit 1 12
Figure 2: Breakdown of Building Demand and Energy 20
Figure 3: Feeder, distributor and service main 26
Figure 4: Customer service poles 27
Figure 5: Vegetation clearing 28
Figure 6: Deviation stays 28
Figure 7: No conductors inside 28
Figure 8: Compliance with ENA 28
Figure 9: Unipolar DC Distribution System (2-Wire DC System) 32
Figure 10: Bipolar DC Distribution System (3-Wire DC System) 32
Figure 11: Single phase, 2-wire system 33
Figure 12: Single phase, 3-wire system 33
Figure 13: Two phase, 4-wire system 34
Figure 14: Three phase, 3-wire system 34
Figure 15: Three phase, 4-wire system 34
Figure 16: Over-head system 35
Figure 17: Under-ground system 35
Figure 18: Radial system 36
Figure 19: Parallel Feeders Distribution System 37
Figure 20: Ring main system 37
Figure 21: Inter-connected system 37
Figure 22: Picture/s reflecting the Learning unit 2 40
Figure 23: Wooden poles 53
Figure 24: Tubular poles 53
Figure 25: Concrete Electric Pole 54
Figure 26: Lattice steel towers 54
Figure 27: Pin type insulators 55
Figure 28: Suspension type insulators. 55
Figure 29: Strain insulators 57
Figure 30: Shackle insulators 58
Figure 31: MS Channel or wooden cross arm 58
Figure 32: U- shape cross arm 58
Figure 33: V- shape cross arm 59
Figure 34: Zig- zag cross arm 59
Figure 35: Phase plate 59
Figure 36: Danger plate 60
Figure 37: Lightning arrestor 60
Figure 38: Anti-climb wire 60
Figure 39: Sag in over-head lines 62
Figure 40: Sag when measured vertically In the above overhead conductor AOB, S is the sag when measured vertically. 63
Figure 41: Sag calculation for supports are at equal levels 64
Figure 42: Sag calculation for supports are at unequal levels 64
Figure 43: Cable construction 66

Figure 44: Belted cables 68
Figure 45: H-type cables 69
Figure 46: Circuit breaker 73
Figure 47: Fuse 75
Figure 48: Relay 75
Figure 49: Relay construction 76
Figure 50: Isolators 76
Figure 51: Picture/s reflecting the Learning unit 3 88
Figure 52: Framework of the BOQ Sheet 94
Figure 53: Create a spreadsheet to organize your BOQ 122
Figure 54:1.Compile a list of materials needed for your project 122
Figure 55: Break down your project into categories 123
Figure 56:Provide the quantity you need of each material. 123
Figure 57:Estimate the labor needed in each category 124
Figure 58: Make an initial cost estimate for the project 124
Figure 59:Draft a project schedule based on your labor estimates 125
Figure 60:Solicit bids from contractors with your BOQ 125
Figure 61:Evaluate contractor bids for specific jobs 126
Figure 62:Refer to your BOQ throughout the project. 126

Table of contents

Acronyms **5**
LIST OF FIGURE **6**
Table of contents **8**
Introduction **10**
Module Code and Title: IELEP 501: ELECTRICAL POWER DISTRIBUTION SYSTEM DESIGN **11**
Learning Unit 1: Carry out a site survey **12**
Learning outcome 1.1 Collect data from the site **12**
Indicative content 1.1.1: load assessment 13
Indicative content 1.1.2: Distribution line route selection methodology 15
Learning outcome 1.2. Interpret data from the site **18**
Indicative content 1.2.1: load assessment 18
Indicative content 1.2.2: Distribution line route selection methodology 23
Learning out come 1.3. Lay-out the site **25**
Indicative content 1.3.1: Parts of electrical power distribution line 25
Indicative content 2: location of electrical power distribution line equipment 26
Learning outcome 1.4. Select wiring system **31**
Indicative content 1.4.1: Classification of distribution system 31
Learning Unit 2: Elaborate technical specifications **40**
Learning outcome 2.1. Calculate electrical design requirements **40**
Indicative content 2.1.1: Calculation of load power requirements 41
Indicative content 2.1.2: Design considerations of feeders, distributors and service main 44
Learning outcome 2.2. Calculate mechanical design requirements **52**
Indicative content 2.2.1: Main components of over-head lines 52
Indicative content 2.2.2: Corona effect 60
Indicative content 2.2.3: Sag in over-head lines 62
Indicative Content 2.2.4: Construction of under-ground cables 65
Learning outcome 2.3. Specify switching and protection equipment **73**
Indicative Content 2.3.1: Types of switching and protection equipmen 73
Indicative Content 2.3.2: Sizing of switching and protection equipment. 78
Learning outcome 2.4. Elaborate technical drawings **84**
Indicative Content 2.4.1. Symbols used in electrical power distribution 85
Indicative Content 2.4.2. Electrical power distribution line diagram 86

Learning Unit 3: Estimate cost **88**

Learning outcome 3.1 Determine quantity of materials **88**

Indicative content 3.1.1: Identification of purpose of preparation of bill of quantity 89

Indicative content 3.1.2: Identification of different methods used for elaboration of bill of quantity 91

Indicative content 3.1.3: Content of bill of quantity 94

Indicative content 3.1.4: Determination the way of laying out the table of bill of quantity 95

Learning outcome 3.2 Calculate materials cost **98**

Indicative content 3.2.1: Different methods of collecting information on the cost of materials 99

Indicative content 3.2.2: Compiling collected information on drafted bill of quantity .100

Indicative content 3.2.3: Identification of number of manpower needed to accomplish the task 101

Indicative content 3.2.4: Determination of an appropriate labor rate per man- hour 102

Indicative content 3.2.5: Determination of execution delay 104

Indicative content 3.2.6: Clarification of Job average labor rate 105

Indicative content 3.2.7: Clarification of labor Burden 105

Indicative content 3.2.8: Preparation of final document on bill of quantity include materials cost and labor cost. 106

Indicative content 3.2.9: Format of cost report 107

Learning outcome 3.3 Calculate labour cost **108**

Indicative content 3.3.1: Calculate labor cost 108

Indicative content 3.3.2: Techniques of controlling labour cost..........109

Theoretical learning Activity 117

Learning outcome 3.4. Elaborate cost report **118**

Indicative content 3.4.1: Purpose of cost reporting 118

Indicative content 3.4.2: Contract arrangement 119

Indicative content 3.4.3: Cost report..........120

Indicative content 3.4.4: Preparation of final document on bill of quantity include materials cost and labour cost 121

Theoretical learning Activity 127

Introduction

An electric power system is encompassing the electric power generation in power plants, electric power transmission system is to transmit the generated power from the power plant to load center (over several hundred kilo meters) where the actual load is located, power distribution and utilisation. The Electric Distribution System (EDS) is the final stage of electric power system where the generated power is converted into useful work through distribution lines and feeders. It deals with lower voltage magnitude as reverse of transmission system high voltage.

Based on the reliability requirement, type of distribution system to be selected based on both technical as well as economic considerations, power distribution systems are classified:

1. *Based on voltage level, power distribution systems are classified into primary distribution system and secondary distribution system*

Typically the various voltage levels of primary distribution systems are 6.6 kV, 11 kV, 22 kV and 33 kV.

Typically the various voltage levels of secondary distribution are 415 V three phase and 240 V single phase.

2. *Based on the type of consumer, power distribution systems are classified into:*
    - Residential
    - Commercial
    - Industrial distribution system
3. *Based on the location, power distribution systems are classified into urban distribution system and rural distribution system.*

Urban distribution system comprising the residential, commercial and industrial power systems.

Rural distribution system comprising the residential, commercial, industrial power systems and also comprising the agricultural usage.

4. *Based on the no of wires used, power distribution systems are classified into 1ϕ 2W system, 3ϕ 3W system and 3ϕ 4W system.*
    - Residential system loads are connected in 1ϕ 2W system and 3ϕ 4W system.
    - Commercial system loads are connected in 1ϕ 2W system, 3ϕ 3W system and 3ϕ 4W system.
    - Industrial system loads are connected in 1ϕ 2W system, 3ϕ 3W system and 3ϕ 4W system.

The concept of Distributed Generation (DG) introduced in last decade to generate the localised power nearer to the load center or end user loads to reduce the energy losses in transmission & distribution lines, improve the voltage profile across the distribution system.

Module Code and Title: IELEP 501: ELECTRICAL POWER DISTRIBUTION SYSTEM DESIGN

Learning Units:

1. Carry out a site survey
2. .Elaborate technical specifications
3. Estimate cost

Learning Unit 1: Carry out a site survey

Figure 1: Picture/s reflecting the Learning unit 1

STRUCTURE OF LEARNING UNIT

Learning outcomes:

1.1. Collect data from the site

1.2. Interpret data from the site

1.3. Layout the site

1.4. Select wiring system

Learning outcome 1.1 Collect data from the site

Duration: 2 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify types of loads
2. Differentiate types of power supply
3. Select the line route
4. Estimate customer evolution power consumption

Resources

Equipment	Tools	Materials
• Theodolite • Total station • Transit level • Chains and Tapes • Compasses and Clinometers • Transits and Theodolites	• Sprit Levels	• Sheet • Notebook

● Safety Gear ● Prisms and Reflectors ● Magnetic Locators ● Poles, Tripods, and Mounts		

Advance preparation:

Site surveys are inspections of an area where work is proposed, to gather information for a design or an estimate to complete the initial tasks required for an outdoor activity. It can determine a precise location, access, best orientation for the site and the location of obstacles. Route selection and detailed line design dimensions and arrangement as well as on climatic, topographic, infrastructure or legal aspects. The provision of suitable maps with a scale adjusted to the spatial expansion of the project to be designed is necessary for the contractor responsible for the design. The maps should be used for planning of new line route corridors. These maps can be acquired from companies in the internet, from the provincial surveying administrations or from local land register and surveying authorities. In countries without a completed land register system, ortho-photos can be used as well to determine at least crop borders which might indicate borders of plots as well. Before a first line route proposal will be presented to the licensing authority in charge, all the administrative and environmental concerns as well as the existing and planned land use have to be observed and considered.

Indicative content 1.1.1: load assessment

A. Data collection

Data collection is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes.

B. Data collection methods

Method	When to use	How to collect data
Experiment	To test a causal relationship.	Manipulate variables and measure their effects on others.
Survey	To understand the general characteristics or opinions of a group of people.	Distribute a list of questions to a sample online, in person or over-the-phone.
Interview/focus group	To gain an in-depth understanding of perceptions or opinions on a topic.	Verbally ask participants open-ended questions in individual interviews or focus group discussions.

Method	When to use	How to collect data
Observation	To understand something in its natural setting.	Measure or survey a sample without trying to affect them.
Ethnography	To study the culture of a community or organization first-hand.	Join and participate in a community and record your observations and reflections.
Archival research	To understand current or historical events, conditions or practices.	Access manuscripts, documents or records from libraries, depositories or the internet.
Secondary data collection	To analyze data from populations that you can't access first-hand.	Find existing datasets that have already been collected, from sources such as government agencies or research organizations.

C. Electrical Load

An electrical load is any electrical device or component that consumes electrical energy and converts that energy into another form. As part of any electrical circuit, the component transforms current into something useful, commonly motion, light, or heat.

D. Load assessment

Planning is necessary to design a system for optimum performance. While ensuring supply continuity, minimizing power losses, ensuring power quality, and obtaining trouble free operation by selecting appropriate sizing equipment based on surrounding influences.

Data required to be collected for power estimation

- List of Connections Loads and Locations
- Pattern of loading (process variations)
- Separating Critical Load from Non-Critical Loads
- Loads with High Harmonics
- Inclusion of Future Growth Plans
- Utility Interfacing

Types of Loads in power system

A device which taps electrical energy from the electric power system is called a **load on the system**. The load may be resistive (e.g., electric lamp), inductive (e.g., induction motor), capacitive or some combination of them. The various types of loads on the power system are:

(i) Domestic load
(ii) Commercial load
(iii) Industrial load
(iv) Municipal load
(v) Irrigation load
(vi) Traction load

E. Power supplies

A power supply is an electrical device that supplies electric power to an electrical load. The main purpose of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load.

Types of power supply

- Linear power supply
- Switched-mode power supply
- Capacitive (transformer less) power supply
- Linear regulator
- AC power supplies
- AC adapter
- Programmable power supply
- Uninterruptible power supply
- High-voltage power supply
- DC power supplies
- Bipolar power supply

Indicative content 1.1.2: Distribution line route selection methodology

Distribution line route selection methodology

The route selected for a distribution line should be such that the length of the line should be minimum. However, the line route should also be as close to the road as possible in order to ensure easy maintenance. While selecting the routes, natural obstacles e.g., hills, valleys, swamps or marshy places, rivers and thick forests are avoided as far as possible. The H.T. lines should also be kept as much away as possible from the residential area of villages, as a precaution for safety. The line should also be routed away from fire and chemical hazards, explosives, stores and away from play-grounds and cemetery.

a. Environmental and construction consideration

Environmental specifications depend on facility location for the distribution system design and equipment purchasing. Temperature and humidity are defining factors to determine distribution system equipment selection. Construction of overhead power lines, especially in wilderness areas, may have significant environmental effects. Environmental studies for such projects may consider the effect of brush clearing, changed migration routes for migratory animals, possible access by predators and humans along transmission corridors, disturbances of fish habitat at stream crossings, and other effects.

b. Public/Social considerations.

Involuntary resettlement

The master plan may propose the construction of a new primary substation near an urban area. It may require somewhere around 50m^2 of land, to a maximum of about 200m^2. For this reason, prior consideration is necessary to avoid dense residential areas and farmlands when constructing the substation. The actual impacts will remain unclear until the site is decided, but since it is comparatively likely for the site to be selected near urban areas that have residences and farmlands, impacts are expected to a certain extent.

The poor, indigenous and ethnic people

As native settlements have been confirmed, due consideration needs to be given to prevent these areas from being selected as the sites of power facilities, as well as from social impacts on their traditional culture. At the present stage, there does not appear to be any system for designating areas such as native settlements, but it is necessary to confirm that no problems are foreseen.

Misdistribution of benefit and damage

Depending on the type and location of the planned facilities, the possibility of social inequality, such as in the access to public facilities, cannot be denied. A feeling of unfairness may also occur between electrified and un-electrified areas.

Cultural heritage

If there is a possibility of constructing a primary substation nears a designated cultural heritage, measures need to be taken to avert the construction of the primary substation or to divert distribution lines and interconnected lines away from the cultural heritage.

c. Engineering/Construction considerations

There is a lot to consider when designing new structures. Engineers need to keep in mind their designs' functionality, cost, safety, and environmental impact. We also need to develop new materials that are eco-friendlier and less expensive than traditional ones like steel or concrete.

Electrical designs should include detailed information such as panel schedules circuit designations, conduit routing, wire types and sizes, conduit types and sizes, enclosure and equipment classifications, switch and receptacle grades, and circuit breaker types.


Theoretical learning Activity

- ✓ Discuss on the methods used to collect data
- ✓ **Choose the letter corresponding with the right answer:**

1. The method of collecting first-hand data includes-

- **A.** Mailed questionnaire
- **B.** Personal interview
- **C.** Telephonic interview
- **D.** All of the above

Answer- (D)

2. An individual trained in gathering data from the source is called-

(A). Investigator
(B). Respondent
(C). Enumerator
(D). None of the above

Answer- (C)

3. What are types of loads used in power system?

Answer:

- Domestic (Residential) Load.
- Commercial Load.
- Industrial Load.
- Municipal Load.

Practical learning Activity

✓ Perform data collection of site A located in rural area having 30 houses.

Points to Remember (Take home message)

-Data collection is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes.

Reference:

1. **https://www.simplilearn.com/what-is-data-collection-article**
2. **https://www.energy.gov.za/EEE/Projects/Building%20Energy%20Audit%20Training/Training%20Modules/Building%20Energy%20Auditing%20Module%206_Final.pdf**
3. **https://electricalengineering123.com/overhead-power-transmission-line-route-selection-considerations/#:~:text=The%20line%20route%20shall%20be,obtained%20before%20energizing%20the%20line.**

Learning outcome 1.2. Interpret data from the site

Duration: 3 hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Determine the line route
2. Estimate distance of the line route
3. Calculate the load assessment
4. Interpret the load assessment

Resources

Equipment	Tools	Materials
• Theodolite • Total station • Transit level • Chains and Tapes • Compasses and Clinometers • Safety Gear • Magnetic Locators	• Sprit Levels	• Sheet • Notebook

Advance preparation:

Data interpretation refers to the process of using diverse analytical methods to review data and arrive at relevant conclusions. The interpretation of data helps researchers to categorize, manipulate, and summarize the information in order to answer critical questions.

Indicative content 1.2.1: load assessment

Electrical Load

An electrical load is any electrical device or component that consumes electrical energy and converts that energy into another form. As part of any electrical circuit, the component transforms current into something useful, commonly motion, light, or heat.

Load assessment

Planning is necessary to design a system for optimum performance. While ensuring supply continuity, minimizing power losses, ensuring power quality, and obtaining trouble free operation by selecting appropriate sizing equipment based on surrounding influences.

Types of Loads in power system

A device which taps electrical energy from the electric power system is called a **load on the system**. The load may be resistive (e.g., electric lamp), inductive (e.g., induction motor), capacitive or some combination of them. The various types of loads on the power system are:

1. **Domestic load.** Domestic load consists of lights, fans, refrigerators, heaters, television, small motors for pumping water etc. Most of the residential load occurs only for some hours during the day (i.e., 24 hours) e.g., lighting load occurs during night time and domestic appliance load occurs for only a few hours. For this reason, the load factor is low (10% to 12%).

2. **Commercial load**. Commercial load consists of lighting for shops, fans and electric appliances used in restaurants etc. This class of load occurs for more hours during the day as compared to the domestic load. The commercial load has seasonal variations due to the extensive use of air conditioners and space heaters.

3. **Industrial load**. Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load up to 25 kW, medium scale industry between 25kW and 100 kW and large-scale industry requires load above 500 kW. Industrial loads are generally not weather dependent.

4. **Municipal load.** It consists of street lighting, power required for water supply and drainage purposes. Street lighting load is practically constant throughout the hours of the night. For water supply, water is pumped to overhead tanks by pumps driven by electric motors.

Pumping is carried out during the off-peak period, usually occurring during the night. This helps to improve the load factor of the power system.

5. **Irrigation load.** This type of load is the electric power needed for pumps driven by motors to supply water to fields. Generally, this type of load is supplied for 12 hours during night.

6. **Traction load.** This type of load includes tram cars, trolley buses, railways etc. This class of load has wide variation. During the morning hour, it reaches peak value because people have to go to their work place. After morning hours, the load starts decreasing and again rises during evening since the people start coming to their homes.

Load inventory

How to Compile a Load Inventory?

Organizations use inventories to keep track of many items. An inventory of the uses of electricity will help to develop a baseline that will allow you to focus your energy management efforts upon the areas of greatest opportunity.

Making a list or inventory of all loads in a facility answers two important questions:

- Where is the electricity used?
- How much and how fast is electricity used in each category?

Often the process of identifying categories of use allows sources of waste to be easily identified, and this often leads to low cost savings opportunities. Identifying the high consumption loads lets you consider the best savings opportunities first. Because the inventory also quantifies the demand (or "how fast") associated with each load or group of loads, it is invaluable in further interpretation of the demand profile.

Sample Load Inventory Calculations

Data-entry Item	Units	Description
Quantity	(a number)	The quantity of this particular item.
Unit Load	kW	The load in kW for one of this particular load.
Total kW	kW	Quantity x Unit Load.
Hrs/Period	hours	The estimated hours of use per period
kWh/Period	kWh	Total kW x Hrs/Period
On - Peak	Yes/No	Is this load on during the peak period identified in the demand profile?
Diversity Factor (Div'ty Factor)	0 - 100%	That fraction of the total load that this particular item contributed to the peak demand.
Peak kW	kW	If the load is on peak, then this value equal to the Total kW x Diversity Factor

Finally, the load inventory data can be represented graphically to show the distribution of demand and energy consumption. The difference between the graphs reveals that any given load may have a greater impact upon demand or energy depending upon its size and mode of operation.

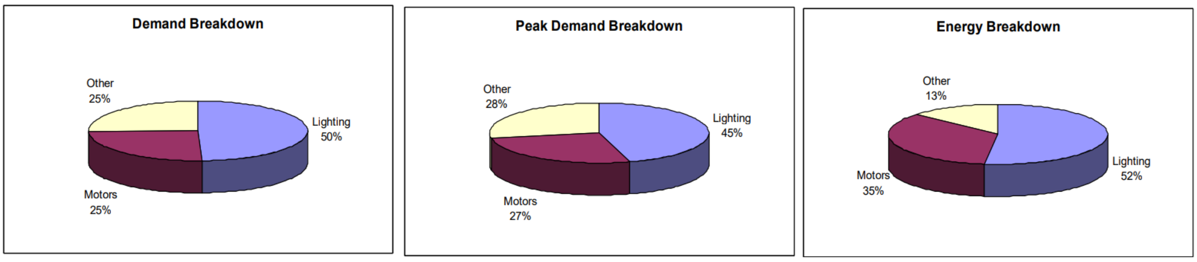


Figure 2: Breakdown of Building Demand and Energy

This section outlines a method for compiling a load inventory using a set of forms, samples of which are given in the next few pages and which are also included as worksheets at the end of this Section. Each form is accompanied by instructions for its use. In addition to these forms, a clipboard, pencil and calculator are required. Instrumentation is not a necessity; a simple clip-on ammeter is probably adequate in most situations.

STEP 1: To begin, three pieces of information are required: A period of time on which the inventory will be based. Usually this would be a month—corresponding to the utility billing period—but it could also be a day, week or year. Select a period which is typical of operations in your facility. The actual demand in kilowatts (kW) and the energy consumption in kilowatt-hours (kWh) for the period selected. If the period selected is a month, then this information is available from the utility bill. If the facility demand is measured in kVA, then this will require a calculation based on the peak power factor to convert kVA to kW. See Module 2: Energy Basics for details. Record the actual values on the Summary Form LD1, as Actual Demand and Energy.

STEP 2: Identify each of the major categories of electricity use in the facility. This may require that you take a walk through, and list categories as you notice them. Record each category on FORM LD1. When identifying the various categories of use, it is useful to consider both the type of electricity use and the activity in each area. Selecting categories with similar operation patterns is a good approach. The example on the sample form separates the motor use from the lighting use in each of the office, production (multiple categories), and exterior areas.

STEP 3: Guess the percentage of demand attributable to each category. This may be based on prior knowledge, a rough idea of the size of the loads, the size of the distribution wiring, etc. Also, use any information available from the demand profile when preparing this estimate. Record the demand percentages on Form LD1 and calculate the estimated demand for each category of use based on the actual demand.

STEP 4: Guess the percentage of energy used in each category. This should be based on occupancy, production, or other such factors relating to the intensity of use in each category. Record the energy percentages on Form LD1 and calculate the estimated energy for each category of use based on the actual energy.

STEP 5: Select the category of use in which the largest amount of demand and/or energy is used.

STEP 6: Use Forms LD3, LD4 and LD5 to list each and every load in the category selected. Only record nameplate and kW load information up to and including the Total kW. Each form is designed for a different type of information.

For each load, select one method of recording information according to the following criterion:

LD3: Simple Load Information Use this form for such things as lighting, electric heat, office equipment, or any load for which the load in kW is known.

LD4: Current Voltage Method Use this form to record detailed nameplate data from loads such as coolers, small motors, appliances, etc. when kW load data is not known. This form should also be used for any device that actual measurements are conducted upon.

LD5: Motor Load Method This form should only be used for motors. It provides a method of estimating kW load based upon motor horsepower, loading and efficiency. Do not use this method if actual motor currents and voltages have been measured; use Form LD4.

STEP 7: For each load, estimate the hours of operation for the period selected. Also indicate if this load is on during the peak demand period and/or at night. At this point, do not attempt to estimate the diversity factor.

STEP 8: Repeat Steps 6 and 7 for each category of use working down from the categories of highest energy use and demand to the lowest. If the estimated energy use and/or demand in a category is relatively small (less than 5%) then performing a detailed inventory is probably not worthwhile.

Type of power supply

i. **Power supplies**

An AC-to-DC power supply operates on an AC input voltage and generates a DC output voltage. Depending on application requirements the output voltage may contain large or negligible amounts of AC frequency components known as ripple voltage, related to AC input voltage frequency and the power supply's operation. A DC power supply operating on DC input voltage is called a DC-to-DC converter. This section focuses mostly on the AC-to-DC variant.

ii. Linear power supply

An AC adapter disassembled to reveal a simple, unregulated linear DC supply circuit: a transformer, four diodes in a bridge rectifier arrangement, and an electrolytic capacitor to smooth the waveform.

iii. Switched-mode power supply

In a switched-mode power supply (SMPS), the AC mains input is directly rectified and then filtered to obtain a DC voltage. The resulting DC voltage is then switched on and off at a high frequency by electronic switching circuitry, thus producing an AC current that will pass through a high-frequency transformer or inductor.

iv. Capacitive (transformer less) power supply

A capacitive power supply (transformer less power supply) uses the reactance of a capacitor to reduce the mains voltage to a smaller AC voltage. Typically, the resulting reduced AC voltage is then rectified, filtered and regulated to produce a constant DC output voltage.

v. Linear regulator

The function of a *linear voltage regulator* is to convert a varying DC voltage to a constant, often specific, lower DC voltage. In addition, they often provide a current limiting function to protect the power supply and load from *overcurrent* (excessive, potentially destructive current).

vi. AC power supplies

An AC power supply typically takes the voltage from a wall outlet (mains supply) and uses a transformer to step up or step down the voltage to the desired voltage. Some filtering may take place as well.

vii. AC adapter

An AC adapter is a power supply built into an AC mains power plug. AC adapters are also known by various other names such as "plug pack" or "plug-in adapter", or by slang terms such as "wall wart". AC adapters typically have a single AC or DC output that is conveyed over a hardwired cable to a connector, but some adapters have multiple outputs that may be conveyed over one or more cables.

viii. Programmable power supply

A **programmable power supply** (PPS) is one that allows remote control of its operation through an analog input or digital interface such as RS-232 or GPIB. Controlled properties may include voltage, current, and in the case of AC output power supplies, frequency.

ix. Uninterruptible power supply

An uninterruptible power supply (UPS) takes its power from two or more sources simultaneously. It is usually powered directly from the AC mains, while simultaneously charging a storage battery.

x. High-voltage power supply

A **high-voltage power supply** is one that outputs hundreds or thousands of volts. A special output connector is used that prevents arcing, insulation breakdown and accidental human contact. Federal Standard connectors are typically used for applications above 20 kV, though other types of connectors (e.g., SHV connector) may be used at lower voltages.

xi. Bipolar power supply

A bipolar power supply operates in all four quadrants of the voltage/current Cartesian plane, meaning that it will generate positive and negative voltages and currents as required to maintain regulation.

DC power supplies

An AC-to-DC power supply operates on an AC input voltage and generates a DC output voltage. Depending on application requirements the output voltage may contain large or negligible amounts of AC frequency components known as ripple voltage, related to AC input voltage frequency and the power supply's operation. A DC power supply operating on DC input voltage is called a DC-to-DC converter. This section focuses mostly on the AC-to-DC variant.

When choosing a power supply, there are several requirements that need to be considered.

The power requirements of the load or circuit, including:

- Voltage
- Current
- Safety features such as voltage and current limits to protect the load.
- Physical size and efficiency.
- Noise immunity of the system

Indicative content 1.2.2: Distribution line route selection methodology

Transmission line route selection and acquisition is one of the most important steps in planning of transmission line projects. In selecting the final route, alternatives.

1. Impact of length, terrain, angles, obstacles, and special crossings on the cost and strength of the line
2. Ease and cost of maintenance, including maintenance of tree trimming.
3. vegetables managements. Can tree be cut, trimmed, or avoided?
4. Impact of existing overhead and underground utilities paralleling or crossing the route. This refers to electric, telecommunications, gas, oi;, water, sewer system, drainage, and irrigation.
5.Availability,restrictions, or limitations on the use of public rights of way.
6. Impact of line on land use, environment, and on historical, archaeological, or biologically sensitive sites or areas.

distribution line selected route must be mapped and identified in detail to have a smooth proceeding during coordination with other involved parties, may it be utilities, government agencies, owners, etc. This very important during acquisition of rights of way and application of necessary permits.

There will be times wherein our probable routes will lie on areas or points which set limit or prohibit the setting of supporting structures. Cases as such, there are factors in determining locations and alignment of structures and are commonly called control point.

These point include:

1. location where it is necessary for the line to change direction.
2. Man-made structures, facilities, and land use.
3. topographic and geographic land features.

The limitations imposed by the control points may be the following:

1. Define the general alignment of the route
2. Require special supporting structures
3. Prohibit use of the route.

These control points must be identified since they are critical to the selection of final route.

Theoretical learning Activity

✓ Discuss on the methodology used while selecting distribution line route

✓ Discuss on various types of power supply

✓ Discuss on the type of load used in the power system

Assessment

1. List the type of power supply

Answer:

- DC power supplies.
- AC power supplies.
- Programmable power supply.
- Uninterruptible power supply.
- High-voltage power supply.
- Bipolar power supply.

2. Place a T on the line if you think a statement it TRUE. Place an F on the line if you think the statement is FALSE.

A. The power supply has a circuitboard inside?

Answer: False

B. Switched mode power supply is used for obtaining controller DC supply?

Answer: True

Practical learning Activity

✓ Perform load assessment of site **B** located in rural area having 50 houses.

Points to Remember (Take home message)

-The various types of loads on the power system are: Domestic load, Commercial load, Industrial load, Municipal load Irrigation load

Reference:

1. **https://electricalengineering123.com/overhead-power-transmission-line-route-selection-considerations/#:~:text=The%20line%20route%20shall%20be,obtained%20before%20energizing%20the%20line.**
2. **https://www.simplilearn.com/what-is-data-collection-article**

Learning out come 1.3. Lay-out the site

Duration: 5 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify feeder, distributor and service main
2. Locate poles
3. Locate service entrance and distribution equipment and unit substation

Resources

Equipment	Tools	Materials
• Theodolite • Total station • 3D scanners • GPS/GNSS	• Measuring tape	• Sheet • Notebook

Advance preparation:

A site layout plan, sometimes called a block plan, shows a detailed layout of the whole site and the relationship of the proposed works with the boundary of the property, nearby roads, and neighbouring buildings.

Indicative content 1.3.1: Parts of electrical power distribution line

1. **Feeders** – A feeder is a conductor which connects the distribution sub-station to the area where power is to be distributed. The current in a feeder remains the same throughout its length because no tapings are taken from it. The main consideration in the design of a feeder being its current carrying capacity.
2. **Distribution Transformers** – The distribution transformer is a step-down transformer in which primary and secondary are delta and star connected respectively. It is also termed as *service transformer*. The output voltage of distribution transformer is 440 V in 3-phase system whereas 230 V in 1-phase system in India.

3. **Distributor** – A distributor is a conductor from which tapings are taken for supply to the consumers. Due to the taping is done at various places in a distributor, the current being not same throughout its length. The main design consideration of a distributor is the voltage drop across its length because the statutory limit of voltage variations is ± 6 % of rated voltage at the consumer's terminals.
4. **Service Mains** – Service Mains is a small cable which connects the distributor to the consumer's meter.

It generally consists of three main parts namely, feeders, distributors and the Service mains. *Feeders, Distributor* and *Service mains.*

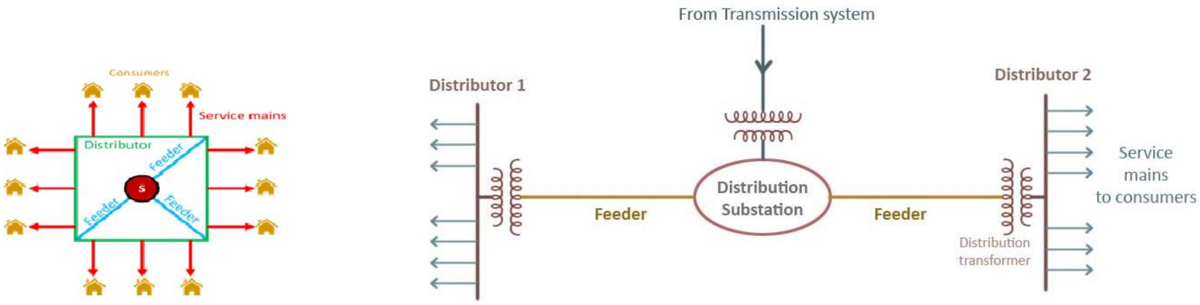


Figure 3: Feeder, distributor and service main

Indicative content 2: location of electrical power distribution line equipment

1. Location of feeder

Power stations may be located near a fuel source, at a dam site (to take advantage of renewable energy sources), and are often located away from heavily populated areas. The electric power which is generated is stepped up to a higher voltage at which it connects to the electric power transmission net.

2. Electrical substation location

An electrical substation is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or the reverse using transformers. Electric power may flow through several substations between generating plant and consumer, and may be changed in voltage in several steps.

A substation that has a step-up transformer increases the voltage while decreasing the current, while a step-down transformer decreases the voltage while increasing the current for domestic and commercial distribution. Substations may be on the surface in fenced enclosures underground, or located in special-purpose buildings.

3. Service entrance, service entrance equipment

The equipment needed at the point where electrical service enters a building. Refers to equipment related to the point of entry for electrical service, not electrical equipment at a building's service entrance. This equipment normally consists of the main junction box, circuit breakers and/or fuses, and any additional equipment located between the main junction and the service drop, including meters.

Service entrance equipment is rated by size, and its size is a measure of the total current capacity of the equipment. Older homes typically have 100-amp service; newer homes commonly offer twice this capacity. Service entrance equipment size for commercial establishments may be measured in thousands of amps.

4. Location of poles

Distance between two electric poles

They are typically spaced about *125 ft (38 m) apart in urban areas, or about 300 ft (91 m) in rural areas,* but distances vary widely based on terrain and clearance needs. Joint-use poles are usually owned by one utility, which leases space on it for other cables.

The rule for determining the setting depth for a pole to be installed in soil

A rule often followed for determining the setting depth in soil is to *take 10 percent of the pole length and add 2 ft, with a minimum of 5 ft.*

The following policies detail location and set back requirements for poles near roads:

- Guidelines for placement of power poles within road reserves in built up areas Placement of distribution poles along roads with speed limits not exceeding 70 kmh.
- Placement of rigid distribution poles along roads with speed limits exceeding 70 kmh.
- Placement of frangible distribution poles along roads with speed limits exceeding 70 kmh.

As well as meeting the requirements of the Code, poles should be installed according to the following guidelines:

1) **Maximum number of customer services**: In order to minimize costs, poles should be positioned so as to maximize the number of customers serviced from one pole.
2) **Street lighting:** distribution poles are used to carry streetlights. Therefore, they should be positioned to take into Account Street lighting design requirements.
3) **Future extensions:** In order to minimize future costs, consideration should be given to the likelihood/possibility of extensions to the existing/proposed distribution network (for example requirements for “tee-offs”, ground/aerial stays etc.)
4) **Customer service poles:** consideration should also be given to any advantage that may be achieved by positioning poles on the side of a street that will minimize the number of customer service poles required when service connections are run across the road.

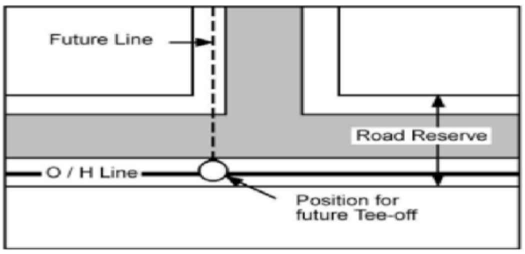


Figure 4: Customer service poles

A) Vegetation clearing: it is important to minimize the impact Western Power’s assets have on the environment. Therefore, consideration should be given to positioning poles on the side of the road that will minimize the need for vegetation-clearing.

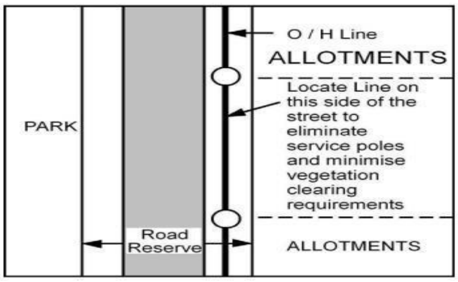


Figure 5: Vegetation clearing

B) Deviation stays: stays can restrict land use and obstruct pedestrian traffic. Therefore, conductor deviation angles should be avoided or installed in a way that eliminates or reduces the need for deviation stays.

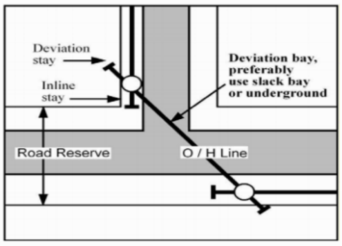


Figure 6: Deviation stays

C) No conductors inside property: In built-up areas it is not acceptable for new overhead power lines to be located inside property boundaries.

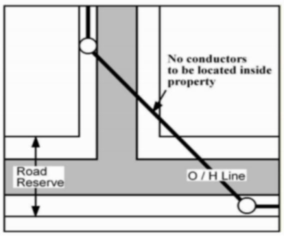


Figure 7: No conductors inside

D) Compliance with ENA C (b) 1, Section 9: bare overhead power lines can be built only on the 2.7m alignment in areas zoned for building setbacks of 6m, or in areas with special dispensation setbacks of 3m. If zoning allows properties to be built along the front property boundary, bare overhead line construction should not be used.

The distance between a building and the closest conductor could be reduced to 1.3m as a result of blowout caused by strong wind. The required minimum clearance from the wall is 1.5m and from the window it is 2.1m.

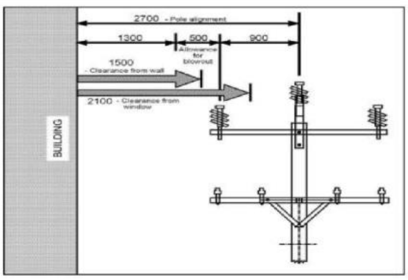


Figure 8: Compliance with ENA

Theoretical learning Activity

- ✓ Differentiate feeder, distributor and service main
- ✓ Discuss on policies detail location and set back requirements for poles near roads
- ✓ Discuss on where Locate electrical feeder
- ✓ List the main parts of electrical power distribution line

Answer:

- Feeder
- Distributor
- Service main

1. Which of the following statement are true or false?

A. The electrical power from 11 kv line is deliver to distribution sub-station

Answer: True

B. Distribution substation step down the voltage to 400V(L-L)

Answer: True

Practical learning Activity

- ✓ Perform a layout of site **B** located in urban area having 1000m^2 using a scale of 1:1000000.

Points to Remember (Take home message)

-A feeder is a conductor which connects the distribution sub-station to the area where power is to be distributed. The current in a feeder remains the same throughout its length because no tapings are taken from it. The main consideration in the design of a feeder being its current carrying capacity.

REFERENCE

1. https://www.myelectrical2015.com/2020/12/difference-between-distributor-feeder.html
2. https://en.wikipedia.org/wiki/Electrical_substation

Learning outcome 1.4. Select wiring system

Duration: 5 hrs

Learning outcome 4 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify electrical power distribution systems according to nature of current, according to construction, and according to construction
2. Identify Types of AC wiring systems
3. Select the wiring system

Resources

Equipment	Tools	Materials
•		•

Advance preparation:

The part of the power system that distributes electric power for local use is called as ***distribution system***. Generally, a distribution system is the electrical system between the substation fed by transmission system and the consumer's meters.

Indicative content 1.4.1: Classification of distribution system

Classification of Electric Power Distribution Network Systems

- **Classification According to Nature of Supply**
  - AC Distribution System
    - Primary Distribution System
    - Secondary Distribution System
  - DC Distribution System
    - Two-wire DC Distribution System
    - Three-wire DC Distribution System
- **Classification of Distribution System According to Type of Construction**
  - Underground Distribution System
  - Overhead Distribution System
- **Classification According to Method of Connection**
  - Radial System
  - Ring Main System
  - Interconnected Distribution System

1. **Classification based on the *nature of current*** –

A. DC distribution system

The DC distribution system is simply an extension of the multiple DC links that already exist in all propulsion and thruster drives, which usually account for more than 80 percent of the electrical power consumption on electric propulsion vessels.

<u>Types of DC power distribution</u>

Wherever DC power distribution is required, AC power from the transmission network can be rectified at a substation using converting equipment and then fed to the dc distribution system. AC consumers can also be connected to DC system using a DC to AC inverter.

A **low voltage DC distribution system is of two types**:

i. <u>Unipolar DC Distribution System (2-Wire DC System)</u>

As the name suggests, this system uses two conductors, one is positive conductor and the other one is negative conductor. The energy is transmitted at only one voltage level to all the consumers using this system. A typical unipolar dc power distribution system is as shown in the following figure.

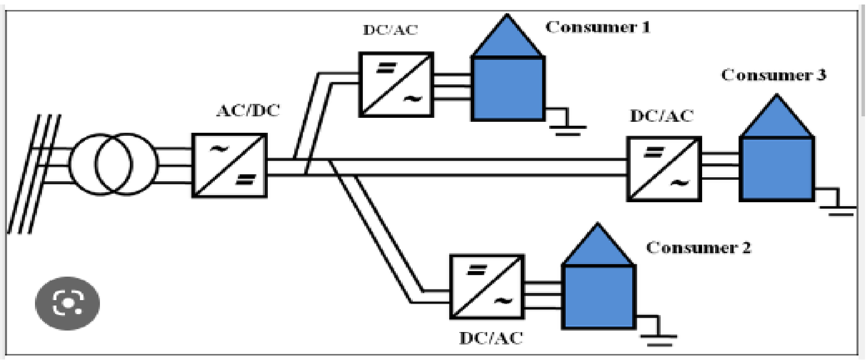


Figure 9: Unipolar DC Distribution System (2-Wire DC System)

ii. <u>Bipolar DC Distribution System (3-Wire DC System)</u>

This is basically a combination of two series connected unipolar DC systems. It consists of three conductors, two outer conductors (one is positive and the other is negative) and one middle conductor which acts as neutral.

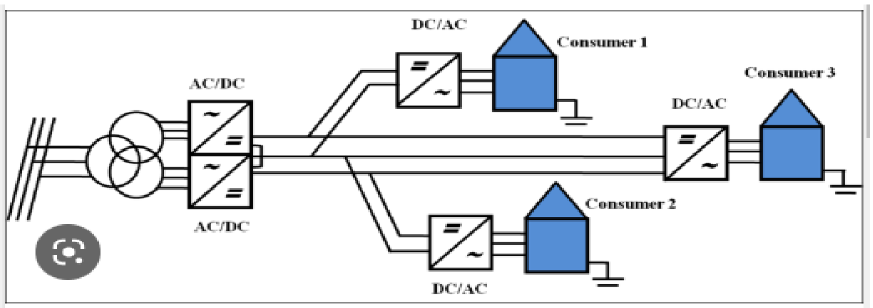


Figure 10: Bipolar DC Distribution System (3-Wire DC System)

This system leaves following connection choices to a consumer

- Between positive conductor and neutral
- Between negative conductor and neutral
- Between positive and negative conductor (double voltage)
- Positive to negative with neutral connected

B. AC distribution system

B.1. **<u>Types of AC Distribution System</u>**

i. ***Primary Distribution System***

The primary distribution system is the part of AC distribution system which operates at voltages slightly higher than general utilization. The voltage used for primary distribution depends upon the amount power to be transferred and distance of substation required to be fed. The commonly used primary distribution voltages are 11 kV, 6.6 kV and 3.3 kV. The primary distribution is done by 3-phase 3-wire system because of economic considerations.

ii. Secondary Distribution System

The secondary distribution system includes those ranges of voltage at which consumer utilises the electrical energy. In India, the secondary distribution employs 440V (3-phase) & 230V (1-phase), 3-phase 4-wire system.

According to phases and wires involved, an AC distribution system can be classified as:

i. Single phase, 2-wire system

This system may be used for very short distances. The following figure shows a single phase two wire system with - fig (a) one of the two wires earthed and fig. (b) mid-point of the phase winding is earthed.

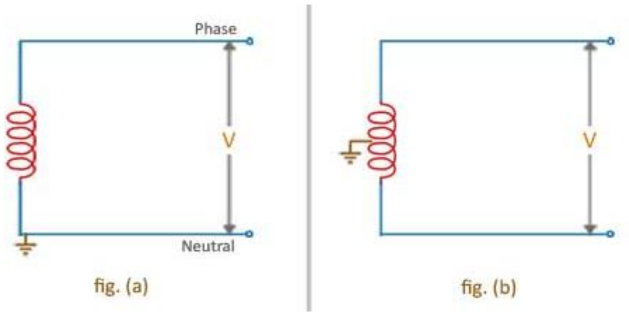


Figure 11: Single phase, 2-wire system

ii. Single phase, 3-wire system

In this system, the neutral wire is taken from the junction of two phase windings whose voltages are in quadrature with each other. The voltage between neutral wire and either of the outer phase wires is V. Whereas, the voltage between outer phase wires is √2V. As compared to a two-phase 4-wire system, this system suffers from voltage imbalance due to unsymmetrical voltage in the neutral.

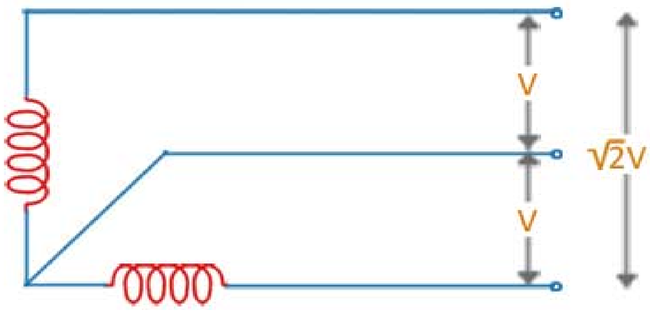


Figure 12: Single phase, 3-wire system

iii. Two phase, 3-wire system

In this system, 4 wires are taken from two phase windings whose voltages are in quadrature with each other. Mid-point of both phase windings are connected together. If the voltage between the two wires of a same phase is V, then the voltage between two wires of different phase would be 0.707V.

iv. Two phase, 4-wire system

In this system, 4 wires are taken from two phase windings whose voltages are in quadrature with each other. Mid-point of both phase windings are connected together. If the voltage between the two wires of a same phase is V, then the voltage between two wires of different phase would be 0.707V.

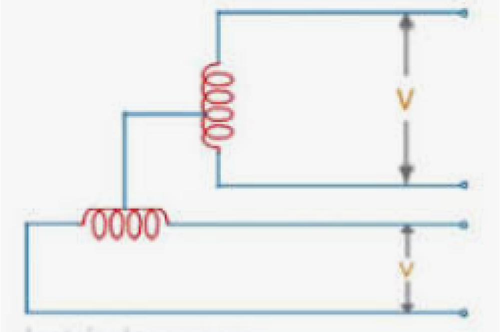


Figure 13: Two phase, 4-wire system

v. Three phase, 3-wire system

Three phase systems are very widely used for **AC power distribution**. The three phases may be delta connected or star connected with star point usually grounded. The voltage between two phases or lines for delta connection is V, where V is the voltage across a phase winding. For star connection, the voltage between two phases is √3V.

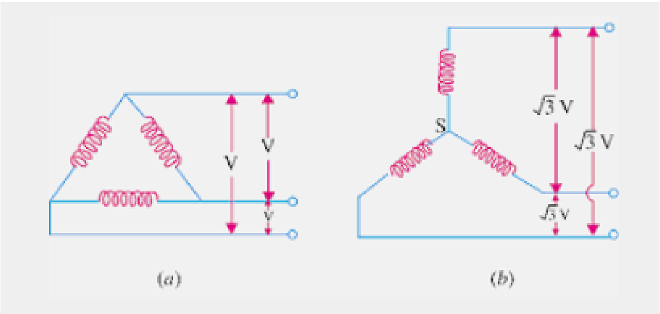


Figure 14: Three phase, 3-wire system

vi. Three phase, 4-wire system

This system uses star connected phase windings and the fourth wire or neutral wire is taken from the star point. If the voltage of each winding is V, then the line-to-line voltage (line voltage) is √3V and the line-to-neutral voltage (phase voltage) is V. This **type of distribution system** is widely used in India and many other countries. In these countries, standard phase voltage is 230 volts and line voltage is √3x230 = 400 volts. Single phase residential loads, single phase motors which run on 230 volts etc. are connected between any one phase and the neutral. Three phase loads like three-phase induction motors are put across all the three phases and the neutral.

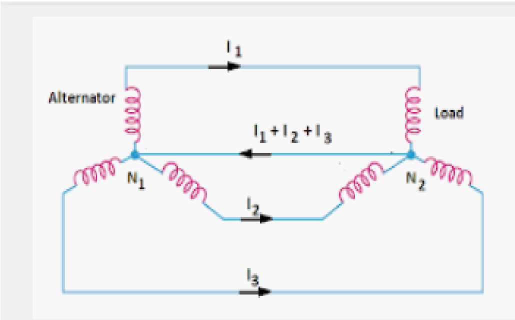


Figure 15: Three phase, 4-wire system

2. Classification based on the *type of construction*

i. <u>Over-head system</u>

The traditional method of distributing electricity to customers has been on wires attached to poles high above the ground, referred to as overhead distribution. Transformers and other equipment in the overhead system are mounted on poles or other supporting structures.

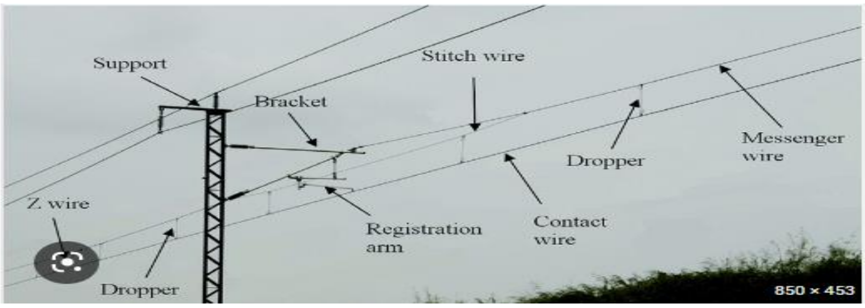


Figure 16: Over-head system

ii. <u>Under-ground system</u>

Underground lines are the alternative type of distribution lines. They are buried in trenches, ducts, or tunnels, and run under the ground, water, or buildings. They are more expensive and complex to install and repair than overhead lines, and they require more equipment and protection, such as insulation, junction boxes, and manholes.

Figure 17: Under-ground system

<u>OVERHEAD VERSUS UNDERGROUND SYSTEM</u>

The distribution system can be overhead or underground.

a) **Overhead lines** are generally mounted on wooden, concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors**.**

b) **The underground system** uses conduits, cables and manholes under the surface of streets and sidewalks.

The choice between overhead and underground system depends upon a number of widely differing factors such as:

- **Public safety**: The underground system is safer than overhead system because all distribution wiring is placed underground and there are little chances of any hazard.
- **Initial cost**: The underground system is more expensive due to the high cost of trenching, conduits, cables, manholes and other special equipment. The initial cost of an underground system may be five to ten times than that of an overhead system.
- **Flexibility***:* The overhead system is much more flexible than the underground system.

- ❖ **Faults:** The chances of faults in underground system are very rare as the cables are laid underground and are generally provided with better insulation.
- ❖ **Appearance**: The general appearance of an underground system is better as all the distribution lines are invisible. This factor is exerting considerable public pressure on electric supply companies to switch over to underground system.
- ❖ **Fault location and repairs**: In general, there are little chances of faults in an underground system. However, if a fault does occur, it is difficult to locate and repair on this system. On an overhead system, the conductors are visible and easily accessible so that fault locations and repairs can be easily made.
- ❖ **Current carrying capacity and voltage drop:** An overhead distribution conductor has a considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than that of an overhead conductor because of closer spacing of conductors.
- ❖ **Useful life:** The useful life of underground system is much longer than that of an overhead system. An overhead system may have a useful life of 25 years, whereas an underground system may have a useful life of more than 50 years.
- ❖ **Maintenance cost:** The maintenance cost of underground system is very low as compared with that of overhead system because of fewer chances of faults and service interruptions from wind, ice, and lightning as well as from traffic hazards.

❖ **Interference with communication circuits**: An overhead system causes electromagnetic interference with the telephone lines. The power line currents are superimposed on speech currents, resulting in the potential of the communication channel being raised to an undesirable level. However, there is no such interference with the underground system.

3. Classification based on the *scheme of connection*

i. Radial system

This system is used only when substation or generating station is located at the center of the consumers. In this system, different feeders radiate from a substation or a generating station and feed the distributors at one end. Thus, the main **characteristic of a radial distribution system** is that the power flow is in only one direction. Single line diagram of a typical radial distribution system is as shown in the figure below. It is the simplest system and has the lowest initial cost.

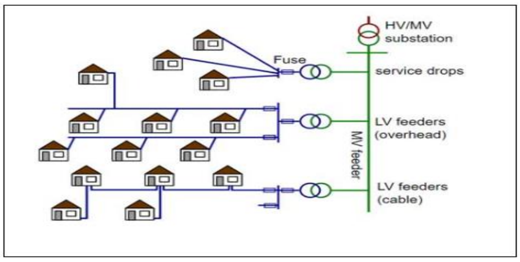


Figure 18: Radial system

Although this system is simplest and least expensive, it is not highly reliable. A major **drawback of a radial distribution system** is, a fault in the feeder will result in supply failure to associated consumers as there won't be any alternative feeder to feed distributors.

ii. Parallel Feeders Distribution System

The above-mentioned disadvantage of a radial system can be minimized by introducing parallel feeders. The initial cost of this system is much more as the number of feeders is doubled. Such system may be used where reliability of the supply is important or for load sharing where the load is higher.

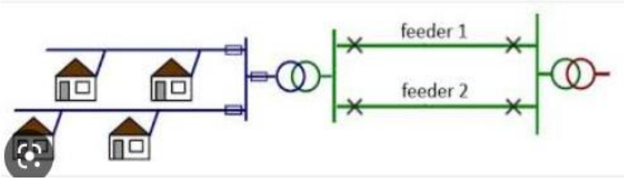


Figure 19: Parallel Feeders Distribution System

iii. <u>Ring main system</u>

A similar level of system reliability to that of the parallel feeders can be achieved by using **ring distribution system**. Here, each distribution transformer is fed with two feeders but in different paths. The feeders in this system form a loop which starts from the substation bus-bars, runs through the load area feeding distribution transformers and returns to the substation bus-bars. The following figure shows a typical single line diagram of a ring main distribution system.

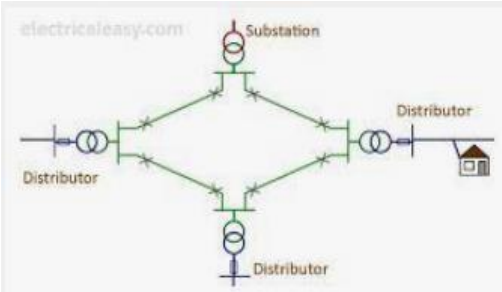


Figure 20: Ring main system

Ring main distribution system is the most preferred due to its following advantages.

Advantages of ring main distribution system

There are fewer voltage fluctuations at consumer's terminal.

The system is very reliable as each distribution transformer is fed with two feeders. That means, in the event of a fault in any section of the feeder, the continuity of the supply is ensured from the alternative path.

iv. <u>Inter-connected system</u>

When a ring main feeder is energized by two or more substations or generating stations, it is called as an interconnected distribution system. This system ensures reliability in an event of transmission failure. Also, any area fed from one generating stations during peak load hours can be fed from the other generating station or substation for meeting power requirements from increased load.

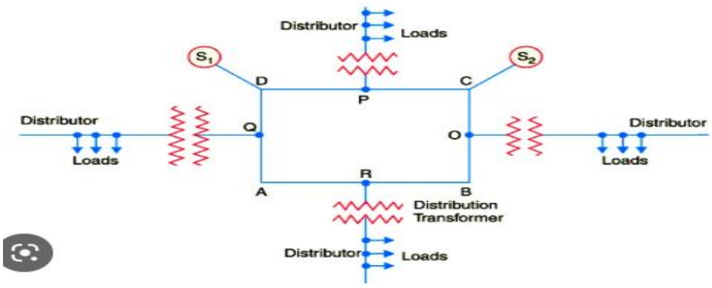


Figure 21: Inter-connected system

Requirements of a distribution system

Some of the requirements of a good distribution system are –

- **Proper Voltage** – The voltage variations at consumer's terminals should be as low as possible. The statutory limit of voltage variations is ± 6 % (India) of the rated voltage at consumer's terminals.
- **Availability of Power on Demand** – The electric power must be available to the consumers in any amount that they may require from time to time.
- **Reliability** – The modern industry is almost dependent on electric power for its operation. This calls for reliable service as much possible.


Theoretical learning Activity

✓ Classify electrical power distribution system

✓ Discuss on types of AC wiring system

✓ **Choose the letter corresponding to the right answer:**

1. A transmission and distribution engineer needed to design the sub transmission substation. The tapping component needed will be _______________
   a) feeder
   b) distributor
   c) transmitter
   d) tap-changing transformer

Answer: a

2. While designing the distribution to locality of one lac population with medium dense load requirement, we can employ ___________
   a) radial system
   b) parallel system
   c) ring main system
   d) any of the mentioned

Answer: a

3. List the classification of electrical distribution system

Answer:

Electrical distribution system is classified according to:

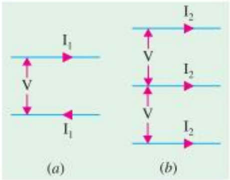
- Nature of current
- Connection scheme
- Construction

✓


Practical learning Activity

A d.c. 2-wire distribution system is converted into a.c. 3-phase, 3-wire system by adding a third conductor of the same size as the two existing conductors. If voltage between conductors and percentage power loss remain the same, calculate the percentage additional balanced load which can now be carried by the conductors at 0.95 p.f.

Solution:



If R is the resistance per conductor, then power transmitted is $P = VI_1$ and power loss $= 2I_1 2R$. Percentage power loss

$$= 2I_1^2 R \times 100/VI_1$$
$$= 2I_1 R \times 100/V$$

(b) as 3-phase, 3-wire system [Fig. 40.11 (b)]

$$P_2 = \sqrt{3}\, VI_2 \cos\phi, \text{ power loss} = 3I_2^2 R$$
$$\%\text{ power loss} = 3I_2^2 R/P_2 = \sqrt{3} I_2 R \times 100\ V \cos\phi$$

Since losses in the two cases are the same

$$\therefore \quad 2I_1 R \times 100/V = \sqrt{3} I_2 R \times 100/V \cos\phi \text{ or } I_2 = 2\cos\phi \times I_1/\sqrt{3}$$
$$\therefore \quad P_2 = \sqrt{3}.V.2\cos^2\phi \times I_1/\sqrt{3} = 2VI_1 \cos^2\phi = 2VI_1 (0.95)^2 = 1.8\ VI_1$$

Percentage additional power transmitted in a 3-phase, 3-wire system

$$= \frac{P_2 - P_1}{P_1} \times 100 = \frac{1.8\,VI_1 - VI_1}{VI_1} \times 100 = \mathbf{80\%}$$

Points to Remember (Take home message)

Classification of Electric Power Distribution Network Systems

- Classification According to Nature of Supply
  - AC Distribution System
    - Primary Distribution System
    - Secondary Distribution System
  - DC Distribution System
    - Two-wire DC Distribution System
    - Three-wire DC Distribution System
- Classification of Distribution System According to Type of Construction
  - Underground Distribution System
  - Overhead Distribution System
- Classification According to Method of Connection
  - Radial System
  - Ring Main System
  - Interconnected Distribution System

REFERENCE

1. Classification of Distribution Systems (brainkart.com)
2. Overhead vs. Underground Residential Distribution Circuits. Which One Is 'Better'? | EEP (electrical-engineering-portal.com)

Learning Unit 2: Elaborate technical specifications

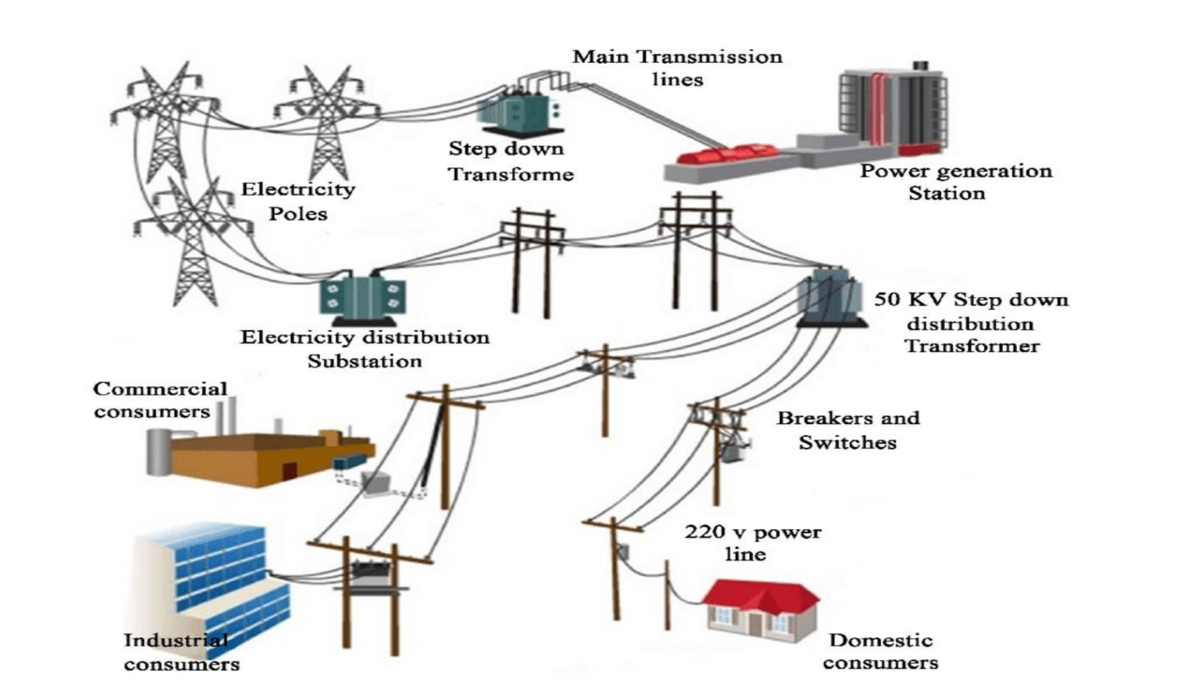


Figure 22: Picture/s reflecting the Learning unit 2

STRUCTURE OF LEARNING UNIT

Learning outcomes:

2.1. Calculate electrical design requirements

2.2. Calculate mechanical design requirements

2.3. Specify switching and protection equipment

2.4. Elaborate technical drawings

Learning outcome 2.1. Calculate electrical design requirements

Duration: 6 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Calculation of the demand and diversity factors of loads, distribution and utilization voltages, current carrying capacity of cables, voltage drop and insulation resistance of under-ground cables
2. Identify line spacing of conductors

Resources

Equipment	Tools	Materials

• Calculator • Laptop	• Pen	• Sheet • Notebook

Advance preparation:

The electrical design criteria is a document that:

- State design decisions throughout the design process.
- List any special features and alternatives that were considered.
- Provide a written narrative accurately addressing the electrical
- Describe the design approach to all electrical systems.
- Include the method used for sizing conductors, conduit, protective devices, and other equipment.
- When tables from industry standards are used in the design, it indicates the title, source, and date of the document.
- Include a complete list of all design standards and references used for the design.

Indicative content 2.1.1: Calculation of load power requirements

1. Demand factor and diversity factor

- ***Demand factor*** is the ratio of the maximum demand of a system, or part of a system, to the total connected load on the system, or part of the system under consideration. Demand factor is always less than one.

Demand Factor = Maximum demand of a system / Total connected load on the system

Example: if a residence having 6000W equipment connected has a maximum demand of 300W, Then demand factor = 6000W / 300W = 20%.

The lower the demand factor, the less system capacity required to serve the connected load

- ***Diversity factor*** is the ratio of the sum of the individual maximum demands of the various subdivisions of a system, or part of a system, to the maximum demand of the whole system, or part of the system, under consideration. Diversity factor is usually more than one.

For example, these terms, when used in an electrical design, should be applied as follows: **The sum of the connected loads supplied by a feeder-circuit can be multiplied by the demand factor to determine *the load* used to size the components of the system**.

The sum of the maximum demand loads for two or more feeders is divided by the diversity factor for the feeders to derive the maximum demand load

Given: Consider four individual feeder-circuits with connected loads of 250 kVA, 200 kVA, 150 kVA and 400 kVA and demand factors of 90%, 80%, 75% and 85% respectively. Use a diversity factor of 1.5.

Solution: Calculating demand for feeder-circuits

- 250 kVA x 90% = 225 kVA
- 200 kVA x 80% = 160 kVA
- 150 kVA x 75% = 112.5 kVA
- 400 kVA x 85% = 340 kVA

The sum of the individual demands is equal to 837.5 kVA

If the main feeder-circuit were sized at unity diversity: kVA = 837.5 kVA ÷ 1.00 = 837.5 kVA the main feeder-circuit would have to be supplied by an 850 kVA transformer.

However, using the diversity factor of 1.5, the kVA = 837.5 kVA ÷ 1.5 = 558 kVA for the main feeder. For diversity factor of 1.5, a 600 kVA transformer could be used. Note that a 600 kVA transformer can be used instead of an 850 kVA when applying the 1.5 diversity factor.

Although feeder-circuit conductors should have an ampacity sufficient to carry the load, the ampacity of the feeder-circuit need not always be equal to the total of all loads on all branch-circuits connected to it. Remember*, **the demand factor*** permits a feeder-circuit ampacity to be less than 100% of the sum of all branch-circuit loads connected to the feeder.

"Demand factor" is a percentage by which the total connected load on a service or feeder is multiplied to determine the greatest probable load that the feeder will be called upon to carry. In hospitals, hotels, apartment complexes, and dwelling units, it is not likely that all of the lights and receptacles connected to every branch-circuit served by a service or feeder would be "on" at the same time. Therefore, instead of sizing the feeder to carry the entire load on all of the branches, a percentage can be applied to this total load, and the components sized accordingly.

Calculation:

- ✓ A Residence Consumer has 10 No's Lamp of 400 W but at the same time It is possible that only 9 No's of Bulbs are used at the same time. Here Total Connected load is 10×40=400 W. Consumer maximum demand is 9×40=360 W. Demand Facto of this Load = 360/400 =0.9 or 90%.
- ✓ One Consumer have 10 lights at 60 kW each in Kitchen, the load is 60 kW x 10 = 600 KW. This will be true only if All lights are Turns ON the same time (Demand factor=100% or 1)
- ✓ For this Consumer it is observed that only half of the lights being turned ON at a time so we can say that the demand factor is 0.5 (50%). The estimated load = 600 kW X 0.5 = 300 kW.

Use of demand factors:

- Feeder conductors should have sufficient Ampere Capacity to carry the load. The Ampere Capacity does not always be equal to the total of all loads on connected branch-circuits.
- This factor must be applied to each individual load, with particular attention to electric motors, which are very rarely operated at full load.
- As per National Electrical Code (NEC) demand factor may be applied to the total load. The demand factor permits a feeder ampacity to be less than 100 percent of all the branch-circuit loads connected to it.
- Demand factor can be applied to calculate the size of the sub-main which is feeding a Sub panel or a fixed load like a motor etc. If the panel have total load of 250 kVA, considering a Demand factor of 0.8, we can size the feeder cable for 250 x 0.8= 200 kVA.

- Demand factors for buildings typically range between 50 and 80 % of the connected load.
- In an industrial installation this factor may be estimated on an average at 0.75 for motors.
- For incandescent-lighting loads, the factor always equals 1.

Diversity Factor = Sum of Individual Maximum Demands / Maximum Demand of the System.

- The diversity factor is always >= 1.
- Diversity Factor is always >1 because sum of individual max. Demands >Max. Demand.
- In other terms, Diversity Factor (0 to 100%) is a fraction of Total Load that is particular item contributed to peak demand
- It is expressed as a percentage (%) or a ratio more than 1.

If we use diversity value in % than it should be multiply with Load and if we use in numerical value (>1) than it should be divided with Load.

- Diversity occurs in an operating system because all loads connected to the System are not operating simultaneously or are not simultaneously operating at their maximum rating. The diversity factor shows that the whole electrical load does not equal the sum of its parts due to this time Interdependence (i.e. diverseness).
- In general terms we can say that diversity factor refers to the percent of time available that a machine. 70% diversity means that the device operates at its nominal or maximum load level 70% of the time that it is connected and turned ON.
- Consider two Feeders with the same maximum demand but that occur at different intervals of time. When supplied by the same feeder, the demand on such is less the sum of the two demands. In electrical design, this condition is known as diversity.
- Diversity factor is an extended version of demand factor. It deals with maximum demand of different units at a time/Maximum demand of the entire system.

Greater the diversity factor, lesser is the cost of generation of power.

- Many designers prefer to use unity as the diversity factor in calculations for planning conservatism because of plant load growth uncertainties. Local experience can justify using a diversity factor larger than unity, and smaller service entrance conductors and transformer requirements chosen accordingly.
- The diversity factor for all other installations will be different, and would be based upon a local evaluation of the loads to be applied at different moments in time. Assuming it to be 1.0 may, on some occasions, result in a supply feeder and equipment rating that is rather larger than the local installation warrants, and an over-investment in cable and equipment to handle the rated load current. It is better to evaluate the pattern of usage of the loads and calculate an acceptable diversity factor for each particular case.

Calculation:

- ✓ One Main Feeder have two Sub feeder (Sub Feeder A and Sub Feeder B), Sub Feeder-A have demand at a time is 35 KW and Sub Feeder-B have demands at a t
- ✓ ime is 42 KW, but the maximum demand of Main Feeder is 70 KW.

✓ Total individual Maximum Demand =35+42=77 KW.

✓ Maximum Demand of whole System=70 KW

- So Diversity factor of The System= 77/70 =1.1
- Diversity factor can shoot up above 1.

Use of diversity factor

❖ The Diversity Factor is applied to each group of loads (e.g. being supplied from a distribution or sub distribution board).

❖ Diversity factor is commonly used for a complete coordination study for a system. This diversity factor is used to estimate the load of a particular node in the system.

❖ Diversity factor can be used to estimate the total load required for a facility or to size the Transformer

❖ Diversity factors have been developed for main feeders supplying a number of feeders, and typically 1.2 to 1.3 for Residence Consumer and 1.1 to 1.2 for Commercial Load. 1.50 to 2.00 for power and lighting loads

Diversity factor for distribution network

Elements of System	Diversity Factors			
	Residential	Commercial	General Power	Large Industrial
Between individual users	2.00	1.46	1.45	
Between transformers	1.30	1.30	1.35	1.05
Between feeders	1.15	1.15	1.15	1.05
Between substations	1.10	1.10	1.10	1.10
From users to transformers	2.00	1.46	1.44	
From users to feeder	2.60	1.90	1.95	1.15
From users to substation	3.00	2.18	2.24	1.32
From users to generating station	3.29	2.40	2.46	1.45

Indicative content 2.1.2: Design considerations of feeders, distributors and service main

a. Voltage drop in Cables

The voltage drop of any insulated cable is dependent upon the route length under consideration (in meters), the required current rating (in amperes) and the relevant total impedance per unit length of the cable. The maximum impedance and voltage drop applicable to each cable at maximum conductor temperature and under a.c. conditions is given in the tables. For cables operating under dc conditions, the appropriate voltage drops may be calculated using the formula.

2 x route length x current x resistance x 10^{-3}.

Limit of Voltage drop

The values detailed in the tables are given in m/V/Am, (volts/100 per ampere per metre), and the nominal maximum acceptable volt drop specified by the IEE Regulations is 2.5% of the system voltage, i.e. 0.025 x 415
= 10.5 volts for 3 phase working or 0.025 x 240 = 6.0 volts for single phase working.

The resistance is directly proportional to the length and inversely proportional to the diameter of conductor $R \propto L/a$

- Laws of resistance R = ρ (L/A)
- Whenever current flows through a conductor, a voltage drop occurs in that conductor.
- Generally, voltage drop may be neglected for low length conductors but in a lower diameter and long length conductors, we cannot neglect that voltage drops.

Tables & Charts for Suitable Cable & Wire Sizes

English unit and Metric unit

SI System or Metric (Decimal) system			English System (British)		
Current Carrying Capacity (in Amp)	Number of wires and Thickness of each wire	Area (in mm^2)	Current Carrying Capacity (in Amp)	Number of wires and Thickness of each wire	Area (in $Inch^2$)
11	1/1.13	1	11	1/.044	0.0015
13	1/1.38	1.5	13	3/.029	0.002
18	1/1.78	2.5	16	3/.036	0.003
24	7/0.85	4	21	7/.029	0.0045
31	7/1.04	6	28	7/.036	0.007
42	7/1.35	10	34	7/.044	0.01
56	7/1.70	16	43	7/.052	0.0145
73	7/2.14	25	56	7/.064	0.0225
90	19/1.53	35	66	19/.044	0.03
145	19/1.78	50	77	19/.052	0.04
185	19/2.14	70	105	19/.064	0.06
230	19/2.52	95	180	19/0.83	0.1

Table (1) current rating of Copper cables at 86°F or 30°C

SI System or Metric (Decimal) system			English System		
Current Carrying Capacity (in Amp)	Number of wires and Thickness of each wire	Area (in mm^2)	Current Carrying Capacity (in Amp)	Number of wires and Thickness of each wire	Area (in $Inch^2$)
3	16/0.20	0.5	3	14/0.0076	0.0006
6	24/0.20	0.75	6	23/0.0076	0.001
10	32/0.20	1	13	40/0.0076	0.00017
13	40/0.20	1.25	18	70/0.0076	0.003
15	48/0.20	1.5	24	110/0.0076	0.004
20	80/0.20	2.5	31	162/0.0076	0.007

Table (2) current rating of flexible cords Copper cables at 86°F or 30°C

Temperature factors

Temp Factor	1.02	1	0.97	0.94	0.91	0.88	0.77	0.63
Temp F°	77	86	95	104	113	122	1131	140
Temp C°	25	30	35	40	45	50	55	60
Temp K°	298.15	303.15	308.15	313.15	318.15	323.15	328.15	333.15

Table (3) Temperature Factor

English and Metric units.

Inside Trunking & Conduit				Conductor	
Single Phase One Cable AC & DC		Three Phase Three or four Core Cable		Number & Diameter of Wires (in Inch)	Cross Section Area (in Inch²)
Current Rating	Volt Drop / 100 feet	Current Rating	Volt Drop / 100 feet		
Amp	Volt	Amp	Volt		
11	14	9	9.8	1/.044	0.0015
13	12	11	9.1	3/.029	0.002
16	11	14	7.7	3/.036	0.003
21	8.4	18	6.4	7/.029	0.0045
28	7	23	5.3	7/.036	0.007
34	5.7	28	4.1	7/.044	0.01
43	5.5	36	4	7/.052	0.0145
56	4.8	48	3.5	7/.064	0.0225
66	4.3	56	3.2	19/.044	0.03
77	3.6	65	2.7	19/.052	0.04
105	3.4	88	2.5	19/.064	0.06

Table (4) Cable Size, Current Rating with voltage drop (English / British System)

Inside Trunking & Conduit				Conductor	
Single Phase One Cable AC & DC		Three Phase Three or four Core Cable		Number & Diameter of Wires (mm)	Cross Section Area (mm²)
Current Rating	Volt Drop / Amp-meter	Current Rating	Volt Drop / Amp-meter		
Amp	mVolt	Amp	mVolt		
11	41	9	35	1/1.13	1
13	28	12	24	1/1.38	1.5
18	17	16	15	1/1.78	2.5
24	11	22	9.1	7/0.85	4
31	7	27	6	7/1.04	6
40	4.1	37	3.6	7/1.35	10
53	2.6	47	2.2	7/1.70	16
60	1.7	53	1.5	7/2.14	25
74	1.2	65	1	19/1.53	35

Table (5) Cable Size, Current Rating with voltage drop (SI / Metric / Decimal System)

b. Determine the proper Cable Size for Given Load (with Examples)

Determining the size of cable for a given load, take into account the following rules:

1. For a given load except the known value of current, there should be 20% extra scope of current for additional, future or emergency needs.

2. From Energy meter to Distribution board, Voltage drop should be 1.25% and for final sub circuit, voltage drop should not exceed 2.5% of Supply voltage.
3. Consider the change in temperature, when needed, use temperature factor (Table 3)
4. When determining the cable size, consider the wiring system i.e. in open wiring system, temperature would be low but in conduit wiring, temperature increases due to the absence of air
5. Keep in mind Diversity Factor in Electrical Wring Installation while selecting the proper size of cable for electrical wiring installation

Solved Examples of Proper Wire & Cable Size

For Electrical wiring installation in a building, total load is 5.8 kW and total length of cable from energy meter to sub-circuit distribution board is 35 m. Supply voltages are 230V and temperature is 35°C (95°F). Find the most suitable size of cable from energy meter to sub circuit if wiring is installed in conduits.

Solution:

- Load = 5.8kW = 5800W
- Voltage = 230V
- Current = I = P/V = 5800 / 230 = 25.2A
- 20% additional load current = (20/100) x 5.2A = 5A
- **Total Load Current = 25.2A + 5A = 30.2A**

Now select the size of cable for load current of 30.2A (from Table 1) which is 7/1.04 (31 Amperes) it means we can use 7/0.036 cable according **table 1**.

Now check the selected (7/1.04) cable with temperature factor in Table 3, so the temperature factor is 0.97 (in table 3) at 35°C (95°F) and current carrying capacity of (7/1.04) is 31A, therefore, current carrying capacity of this cable at 35°C (104°F) would be;

- **Current rating for 35°C (95°F) = 31 x 0.97 = 30 Amp.**
- Since the calculated value (30 Amp) at 35°C (95°F) is less than that of current carrying capacity of (7/1.04) cable which is 31A, therefore this size of cable (7/1.04) is also suitable with respect to temperature.

Now find the voltage drop for per ampere meter for this (7/1.04) cable from (Table 5) which is 7mV, But in our case, the length of cable is 35 meter.

- Actual Voltage drop for 35meter = mV x I x L= (7/1000) x 31×35 = 7.6V
- And Allowable voltage drop = (2.5 x 230)/100 = 5.75V

Here the actual Voltage drop (7.6 V) is greater than that of maximum allowable voltage drop of 5.75V. Therefore, this is not suitable size of cable for that given load.

So we will select the next size of selected cable (7/1.04) which is 7/1.35 and find the voltage drop again. According to Table (5) the current rating of 7/1.35 is 40Amperes and the voltage drop in per ampere meter is 4.1 mV (See table (5)).

- Therefore, the actual voltage drop for 35 meter cable would be;

- Actual Voltage drop for 35meter ***= mV x I x L*** = (4.1/1000) x 40×35 = 7.35V = 5.74V This drop is less than that of maximum allowable voltage drop. So this is the **most appropriate and suitable cable or wire size**.

Exercise

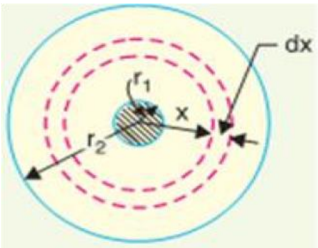
A 10H.P (7.46kW) three phase squirrel cage induction motor of continuous rating using Star-Delta starting is connected through 400V supply by three single core PVC cables run in conduit from 250feet (76.2m) away from multi-way distribution fuse board. Its full load current is 19A. Average summer temperature in Electrical installation wiring is 35°C (95°F). Calculate the size of the cable for motor?

c. Calculation of insulation resistance of under-ground cables

The cable conductor is provided with a suitable thickness of insulating material in order to prevent leakage current. The path for leakage current is radial through the insulation. The opposition offered by insulation to leakage current is known as insulation resistance of the cable. For satisfactory operation, the insulation resistance of the cable should be very high.

Consider a single-core cable of conductor radius r_1 and internal sheath radius r_2 as shown in Fig. 11.12. Let l be the length of the cable and ρ be the resistivity of the insulation.

Consider a very small layer of insulation of thickness dx at a radius x. The length through which leakage current tends to flow is dx and the area of X-section offered to this flow is $2\pi x\, l$.



∴ Insulation resistance of considered layer

$$= \rho \frac{dx}{2\pi x\, l}$$

Insulation resistance of the whole cable is

$$R = \int_{r_1}^{r_2} \rho \frac{dx}{2\pi x\, l} = \frac{\rho}{2\pi l} \int_{r_1}^{r_2} \frac{1}{x} dx$$

$$\therefore \quad R = \frac{\rho}{2\pi l} \log_e \frac{r_2}{r_1}$$

This shows that insulation resistance of a cable is inversely proportional to its length. In other words, if the cable length increase, its insulation resistance decrease and vice-versa

Example:

$$A\ single - core\ cable\ has\ a\ conductor\ diameter\ of\ 1cm\ and\ insulation\ thickness\ of\ 0.4cm.$$
$$If\ the\ specific\ resistace\ of\ insulation\ is\ 5 \times 10^{14} \Omega - cm, calculate\ the\ insulation\ resistance$$
$$for\ a\ 2km\ length\ of\ the\ .$$

Solution:

Length of the cable, L= 2km= $2000m$, $specific\ resistace\ of\ insulation = 5 \times 10^{14} \Omega - cm$

Conductor radius, $r_1 = \frac{1}{2} cm = 0.5cm$

$$insulation\ thickness\ r_1 = 0.4cm$$

Internal shealth radius, $r_2 = 0.5cm + 0.4cm = 0.9cm$

$$the\ insulation\ resistance\ of\ a\ cable\ is:$$

$$R = \frac{\rho}{2\pi L} \frac{r_2}{r_1} = \frac{5 \times 10^{14}}{2\pi * 2000} \frac{0.9}{0.5} = 234M\Omega$$

Theoretical learning Activity

- ✓ Differentiate the demand factor and diversity factor
- ✓ Discuss on the rules used for determining the size of cable for a given load

Practical learning Activity

We plan to install 1-unit induction motor 75 hp for running a water pump. Power factor value is 0.8 and motor efficiency is 0.85. Power supply for this motor is 415 volt 3 phase 50Hz.Distance from panel to motor is 75 meter. This panel and pump is located at outside of factory. Please sizing the suitable circuit breaker, electrical cable and also type of cable for this application.

Solution:

Calculation

Ib ≤ In ≤ Iz

Where

Ib: Calculated current

In: Current rated

Iz: current in the table refer to the table

- Ib = (hp x 746) / (√3 x Volt x PF x Efficiency)
- Ib = (75 x 746) / (√3 x 415 x 0.8 x 0.85)
- Ib = 114.5 Amperes
- In = Ib ≤ breaker sizing
- Iz = In ≤ Iz
- Iz = 150 ≤ Iz

Iz = 187 ampere (carried capacity for 50mm^2 cable size)

So we decide to used cable size = 50 mm^2 with 4 core cable and clipped direct to cable tray. To confirm this cable size, we need to calculate the voltage drop.

Below is a voltage drop calculation that i made for cable power supply from panel to induction motor.

From Panel to Induction motor = 75 meter

mV = 0.87 (refer table above)

Formula voltage drop: Vd = Ib x length(meter) x mV / 1000

Vd = (114.5 x 75 x 0.87) / 1000

Vd = 7.47v

* Voltage drop acceptable value is 2.5% x 415 volt = 10.375 Volts

From this calculation, we fully confident to laying cable size **$50mm^2$** with **150 amperes** of MCCB, using **multicore PVC Armored cable** (due to outdoor wiring application) and also cable laying with cable tray.

In = 114 ≤ 150 ampere

In = 150 ampere (we decide to used MCCB 3 pole with 150 ampere rating)

Points to Remember (Take home message)

-The voltage drop of any insulated cable is dependent upon the route length under consideration (in meters), the required current rating (in amperes) and the relevant total impedance per unit length of the cable.

Learning outcome 2.2. Calculate mechanical design requirements

Duration: 6 hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify types of over-head conductors, types of overhead line insulators, types underground cable insulation and types of over-head line supports
2. Differentiate phase plates, danger plates, lightning arrestors, cross arms and anti-climbing wires
3. Classify under-ground cables

Resources

Equipment	Tools	Materials
• Calculator • Laptop	Pen	• Sheet • Notebook

Advance preparation:

Mechanical design is **to design parts, components, products, or systems of mechanical nature**. For example, designs of various **<u>components of over-head lines</u>** such as conductor, line insulator, support, cross arm and miscellaneous items fall into the scope of mechanical design.

Indicative content 2.2.1: Main components of over-head lines

An overhead line may be used to transmit or distribute electric power. The successful operation of an overhead line depends to a great extent upon the mechanical design of the line. While constructing an overhead line, it should be ensured that mechanical strength of the line is such so as to provide against the most probable weather conditions.

In general, the main components of an overhead line are:

- **(i)** **Conductors:** which carry electric power from the sending end station to the receiving end station.
- **(ii)** **Supports:** which may be poles or towers and keep the conductors at a suitable level above the ground?
- **(iii)** **Insulators:** which are attached to supports and insulate the conductors from the ground.
- **(iv)** **Cross arms:** which provide support to the insulators.
- **(v)** **Miscellaneous items** such as phase plates, danger plates, lightning arrestors, anti-climbing wires etc.

Conductor
The conductor is one of the important items as most of the capital outlay is invested for it. Therefore, proper choice of material and size of the conductor is of considerable importance. The conductor material used for transmission and distribution of electric power should have the following properties:

- **i)** High electrical conductivity.
- **ii)** High tensile strength in order to withstand mechanical stresses.
- **iii)** Low specific gravity so that weight per unit volume is small.

Commonly used conductor materials.
The most commonly used conductor materials for overhead lines are copper, aluminum, steel-cored aluminium, galvanized steel and cadmium copper. The choice of a particular material will depend upon the cost, the required electrical and mechanical properties and the local conditions.
Line Supports
The supporting structures for overhead line conductors are various types of poles and towers called line supports.
In general, the line supports should have the following properties:

- **i)** High mechanical strength to withstand the weight of conductors and wind loads etc.
- **ii)** Light in weight without the loss of mechanical strength.
- **iii)** Cheap in cost and economical to maintain.
- **iv)** Longer life.
- **v)** Easy accessibility of conductors for maintenance

The line supports used for transmission and distribution of electric power are of various types including:

1. **Wooden poles**

Wooden pole means the stem of a tree which has the proper natural characteris- tics to meet the engineering and design standards to support a utility line; and has been harvested, shaped, treated, and certified to meet that need.

Figure 23: Wooden poles

2. **Tubular poles**

Is a strong metal that is a mixture of iron and carbon, used for making things that need a strong structure, especially vehicles.

Figure 24: Tubular poles

There are two types of tubular poles:

a. Stepped Pole
b. Swaged Pole

Concrete Electric Pole

The reinforced concrete electrical pole is a major innovation from NPD Ltd. It comes as a substitute to the traditional wooden pole that has been used for decades in the power distribution lines.

There are two types of concrete poles:

- R.C.C. Poles(reinforced concrete: useful for weight and stability)
- P.C.C. Poles(Prestressed concrete useful for strength and lateral capacity)

The main disadvantages of concrete poles are that if not made on-site, the cost of transporting them is considerable.

Figure 25: Concrete Electric Pole

3. **Lattice steel towers.**

A structure which consists of vertical and horizontal supports and metal crossed strips or bars to support antennae and connecting appurtenances.

Figure 26: Lattice steel towers

The choice of supporting structure for a particular case depends upon:

- Line span
- X-sectional area
- Line voltage
- Cost
- Local conditions.

Insulators

The overhead line conductors should be supported on the poles or towers in such a way that currents from conductors do not flow to earth through supports i.e., line conductors must be properly insulated from supports. This is achieved by securing line conductors to supports with the help of insulators. The insulators provide necessary insulation between line conductors and supports and thus prevent any leakage current from conductors to earth.

Properties of insulators

i) High mechanical strength in order to withstand conductor load, wind load etc.
ii) High electrical resistance of insulator material in order to avoid leakage currents to earth.
iii) High relative permittivity of insulator material in order that dielectric strength is high.
iv) The insulator material should be non-porous; free from impurities and cracks otherwise the permittivity will be lowered.
vi) High ratio of puncture strength to flashover.

Types of Insulators

The successful operation of an overhead line depends to a considerable extent upon the proper selection of insulators. There are several types of insulators but the most commonly used are pin type, suspension type, strain insulator and shackle insulator.

a) Pin type insulators

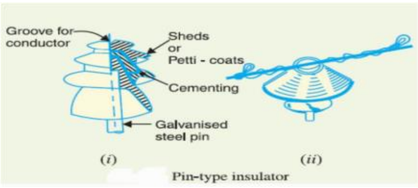


Figure 27: Pin type insulators

As the name suggests, the pin type insulator is secured to the cross-arm on the pole. There is a groove on the upper end of the insulator for housing the conductor. Pin insulators are used for transmission and distribution of electrical power at voltages up to 33kV. Beyond operating voltage of 33kV, the pin type insulators become too bulky and hence uneconomical.

b) Suspension type insulators.

The cost of pin type insulator increases rapidly as the working voltage is increased. Therefore, this type of insulator is not economical beyond 33kV. For high voltage (> 33kV), it is a usual practice to use suspension type insulators.

Suspension insulator

Figure 28: Suspension type insulators.

They consist of a number of porcelain connected in series by metal links in the form of a string. The conductor is suspended at the bottom end of this string while the other end of the string is secured to the cross-arm of the tower. Each unity or disc is designed for low voltage, say 11kV. The number of discs in series would obviously depend upon the working voltage. For instance, if the working voltage is 66kV, then six discs in series will be provided on the string.

Advantages

i) Suspension type insulators are cheaper than pin type insulators for voltage beyond 33kV.
ii) Each unit or disc of suspension type insulator is designed for low voltage, usually 11kV. Depending upon the working voltage, the desired number of discs can be connected in series.
iii) If anyone disc is damaged, the whole string does not become useless because the damaged disc can be replaced by the sound one.

iv) The suspension arrangement provides greater flexibility to the line. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

v) In case of increased demand on the transmission line, it is found more satisfactory to supply the greater demand by raising the line voltage than to provide another set of conductors. The additional insulation required for the raised voltage can be easily obtained in the suspension arrangement by adding the desired number of discs

vi) The suspension type insulators are generally used with steel towers. As the conductors run below the earthed cross-arm of the tower, therefore, this arrangement provides partial protection from lightning.

Calculation of Voltage Distribution along Different Units

String Efficiency

If there are n units in the string, then its efficiency is given by

$$\%\text{ string } \eta = \frac{\text{total voltage across the string}}{n \times \text{voltage across unit adjacent the line}} \times 100$$

Let, C = capacitance to ground

kC = mutual capacitance between units

The current and voltage distribution is as shown in Fig. 41.59. It is seen that

$$I_1 = \frac{V_1}{1/\omega kC} = \omega kCV_1 \text{ ; Similarly } i_1 = \frac{V_1}{1/\omega C} = \omega CV_1$$

Now, $I_2 = I_1 + i_1 = \omega CV_1(1+k)$ and $V_2 = \dfrac{I_2}{\omega kC} = \dfrac{V_1(1+k)}{k}$

The current i_2 is produced by the voltage combination of $(V_1 + V_2)$

Now, $V_1 + V_2 = V_1\left(1 + \dfrac{1+k}{k}\right) = V_1\left(1 + \dfrac{1+2k}{k}\right)$; $\therefore\ i_2 = \omega CV_1\left(1 + \dfrac{1+2k}{k}\right)$

At junction B, we have

$$I_3 = I_2 + i_2 = \omega CV_1\left\{1 + k\,\frac{(1+2k)}{k}\right\}$$

$$= \omega CV_1\,\frac{(1+3k+k^2)}{k}$$

However, $I_3 = \omega kCV_3$; $\therefore\ V_3 = \dfrac{V_1(1+3k+k^2)}{k^2} = V_1\left(1 + \dfrac{3}{k} + \dfrac{1}{k^2}\right)$

The current i_3 is produced by the voltage combination of $(V_1 + V_2 + V_3)$

Now, $V_1 + V_2 + V_3$

$$= V_1\left[1 + \frac{(1+k)}{k} + \frac{(1+3k+k^2)}{k^2}\right]$$

$$\therefore\ i_3 = \omega C V_1\left(\frac{1+4k+3k^2}{k^2}\right)$$

At junction C, we have

$$I_4 = I_3 + i_3 = \omega C V_1 \left[\frac{(1+3k+k^2)}{k^2} + \frac{(1+4k+3k^2)}{k^2}\right]$$

Now, $I_4 = \omega k C V_4$,

$$\therefore\ V_4 = V_1\left[\frac{(1+3k+k^2)}{k^2} + \frac{(1+4k+3k^2)}{k^2}\right]$$

$$= V_1\left(1 + \frac{6}{k} + \frac{5}{k^2} + \frac{1}{k^2}\right)$$

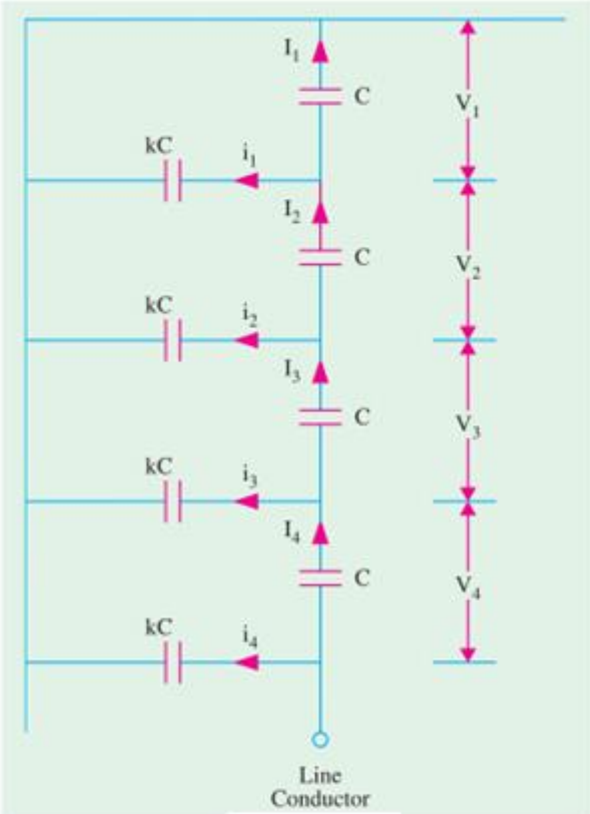
For the fifth insulator from the top, we have

$$V_5 = \left(1 + \frac{10}{k} + \frac{15}{k^2} + \frac{7}{k^3} + \frac{1}{k^4}\right)$$

and so on.

If the string has n units, the total voltage is given by

$$V = (V_1 + V_2 + V_3 + V_4 + \ldots\ldots\ldots\ldots\ldots + V_n)$$



c) Strain insulators

When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve (lift up) the line of excessive tension, strain insulators are used. The disc of strain insulators are used in the vertical plane. When the tension in lines is exceedingly high, as at long river spans, two or more strings are used in parallel.

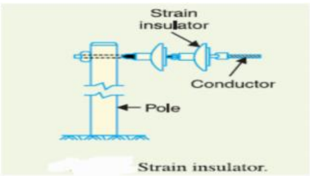


Figure 29: Strain insulators

d) Shackle insulators

In early days, the shackle insulators were used as strain insulators. But now-a-days, they are frequently used for low voltage distribution lines. Such insulators can be used either in a horizontal position or in a vertical position. They can be directly fixed to the pole with a bolt or to the cross arm. The conductor in the groove is fixed with a soft binding wire.

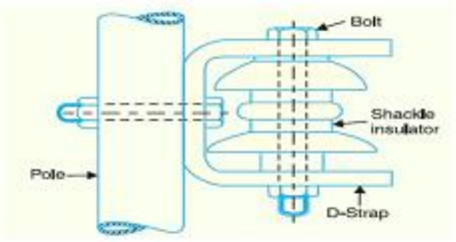


Figure 30: Shackle insulators

Cross Arm

Cross Arm is an arm fastened at right angles to an upright (as the horizontal member of a cross or a traverse on a telephone pole)

The cross arm is fixed to the pole in such a manner that the load of the conductors is taken by the cross arm and not the clamp or bolt that fixes the cross arm to the pole.

The function of line support (pole) is to support the line conductors at a safe distance from the ground whereas the function of cross arms is to keep the conductors at a safe distance from each other and from the pole. Cross Arm is a cross-piece fitted to the pole top end portion by means of brackets, known as pole brackets, for supporting insulators.

Types of Cross arms

1. **MS Channel or wooden cross arm**

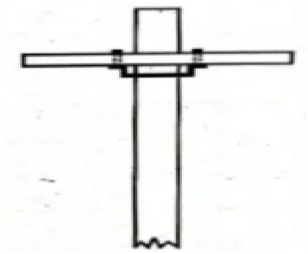


Figure 31: MS Channel or wooden cross arm

2. **U- shape cross arm**

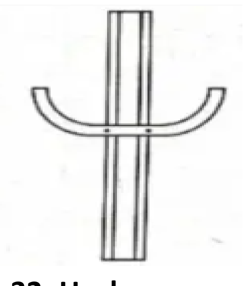


Figure 32: U- shape cross arm

3. **V- shape cross arm**

Figure 33: V- shape cross arm

4. **Zig- zag cross arm**

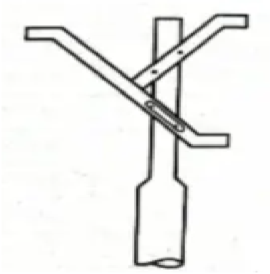


Figure 34: Zig- zag cross arm

These cross arm are made in:

A) Wooden cross arms are commonly employed on 11kv And 33 kV lines. These are made of sal wood, seasoned Sheridan wood, or creosoted firewood. Grains of wood cross arms should be length-wise and completely free from knots. Wooden cross arms are preferred owing to their insulating property which provides safety to line staff and minimizes flash-over due to bridcage.

The usual lengths and x-sections of wooden cross arms in use are 1.5m×125mm×125mm for 11 KV lines and 2.1m×125mm×125mm for 11 KV lines and 2.1m×125m×125mm for 33 KV lines. Wooden cross arms need replacement owing to decay after 5-7 years depending upon weather conditions.

B) Steel cross arms are stronger and are generally used on steel poles. For lv distribution, the angle iron or channel iron cross arms shall be of a size not less than 50mm×50mm×6.4mm and 76mm×38mm. The length of the cross arms shall be suitable for the spacing of the conductors.

Cross arms shall be suitable and strong enough to withstand the resultant forces caused by insulators, their pins, the dead weight of insulator attachments, etc. To avoid birdcage on HT lines, V-shaped cross arms are used with pin insulators while straight cross arms are used with disc insulators.

Miscellaneous items

a) Phase plate

Phase plates are electro-optical elements placed in the beam path to modulate the phase of the electron wave. Their primary function is to increase the contrast when imaging weak phase objects, thereby reducing the irradiation damage needed to detect these objects.

Figure 35: Phase plate

Phase plates provided in order to distinguish the various phases.

1. Lightning Arrestors Discharge excessive voltages built upon the line to earth due to lightning.
2. Barbed Wire Installed over some portion of the pole at anti climbing device.
3. Guard Wires provided above or below power lines whole crossing telephone or telegraph lines.

b) Danger plate

Danger Plate or Board are signage used for installing on Low Tension and High Tension Poles & Substations for restricted movement in the high voltage electrical areas.

Figure 36: Danger plate

c) Lightning arrestor

A lightning arrestor provides a path to ground for over-voltages caused by lightning and other power surges to protect equipment and help prevent outages.

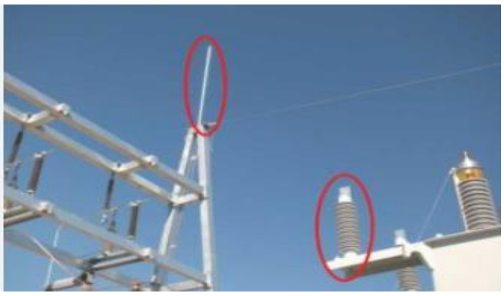


Figure 37: Lightning arrestor

d) Anti-climb wire.

Anti-climb devices is generally wrapped on the poles or tower to protect against the climbing of unauthorized persons. Barbed wire is wrapped on poles at a height of about 2.5 m from the ground for at least 1 meter.

Figure 38: Anti-climb wire

Indicative content 2.2.2: Corona effect

When an alternating potential difference is applied across two conductors whose spacing is large as compared to their diameters, there is no apparent charge in the condition of atmospheric air surrounding the wires if the applied voltage is low. However, when the applied voltage exceeds a certain value, called critical disruptive voltage, the conductors are surrounded by a faint violet glow called corona.
The phenomenon of corona is accompanied by a hissing sound, production of ozone, power loss and radio interference. The higher the voltage is raised, the larger and higher the luminous envelope becomes, and greater are the sound, the power loss and the radio noise. If the applied voltage is increased to breakdown value, a flash over will occur between the conductors due to the breakdown of air insulation.
The phenomenon of violet glow hissing noise and production of ozone gas in an overhead transmission line is known as corona.

Factors affecting corona

The phenomena of corona is affected by the physical state of the atmosphere as well as by the conditions of the line. The following are the factors upon which corona depends:

1. **Atmosphere:** As corona is formed due to ionization of air surrounding the conductors, therefore, it is affected by the physical state of atmosphere.
2. **Conductor size:** The corona effect depends upon the shape and conditions of the conductors.
3. **Spacing between conductors:** If the spacing between the conductors is made very large as compared to their diameters, there may not be any corona effect.
4. **Line voltage:** The line voltage greatly affects corona. If it is low, there is no chance in the condition of air surrounding the conductors and hence no corona is formed.

Advantages and disadvantages of corona effect

Mainly transmission line has been designed in a way to minimize corona discharge. However, some advantages of corona discharge were also observed along with various disadvantages.

The advantages of corona discharge are:

1. Due to corona phenomena, surrounding air becomes conductive and it will increase the virtual diameter of the conductor. After increasing the virtual diameter of the conductor, the maximum potential gradient also reduced
2. In corona phenomena, the charge dissipated to the surrounding air. During a voltage surge, partial energy will dissipate in the form of corona discharge and it will reduce the transient effect of the voltage surge.

The Disadvantages of corona discharge are:

1. As the corona phenomena discharge the electric charge, it will create power loss in the transmission line, and the overall efficiency of the transmission line is also reduced.
2. Corona effects generate Ozone and it will deteriorate the conductor due to chemical reaction.
3. Under corona phenomena, non-sinusoidal voltage and current produced and will affect the power quality of the transmission line. It may also cause inductive interference in the neighboring communication medium.

4. In the transmission line, only power frequency (50/60 Hz) travel and it will not create any disturbance in the radio, TV, and other communication frequency. Under the corona effect, discharge current or voltage does not follow any particular frequency. Due to this the radio, TV, or another communication medium can be affected by the corona discharge.

Methods of reducing corona effect

Reducing the corona effect is the most important part for the design of a high voltage transmission line or substation. Corona effect cannot eliminate fully, however it can be significantly reduced by **using the following steps**.

1. **Size of the conductor:** Corona effect depends on the surface area of the conductor. By increasing the size or cross-sectional area of the conductor, the corona effect can be minimized. Further use of a bundle conductor instead of a single conductor also increases the effective diameter of the conductor and it will help to reduce the corona effect.
2. **Increasing Conductor spacing**: by increasing the distance between the conductors, the corona effect can be minimized. However, spacing cannot increase after a certain distance due to the huge construction costs and requirements of a larger area.
3. **Reducing of sharp points**: At a sharp point, the surface area is very low and due to this high corona produce. By reducing sharp points, the corona effect can reduce.
4. **Using corona ring**: Generally, the corona effect is high at the start or end points and any sharp points of the transmission line. After the installation of corona rings, the effective surface area will increase at those points. By using of corona ring we can reduce the corona effects at those points.

Indicative content 2.2.3: Sag in over-head lines

In a transmission line, **sag** is defined as the vertical difference in level between points of support (most commonly transmission towers) and the lowest point of the conductor. The calculation of sag and tension in a transmission line depends on the span of the overhead conductor.

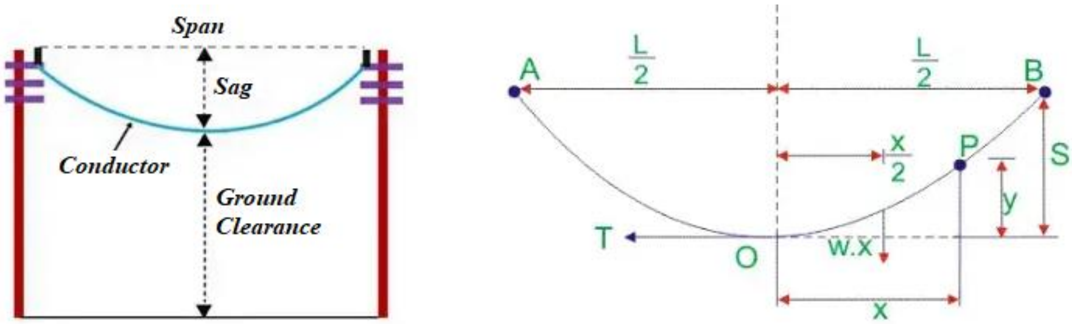


Figure 39: Sag in over-head lines

Span having equal level supports (i.e. towers of the same height) is called **level span**. Conversely, when the span has unequal levels of support, this is known as **unequal level span**.

Consider a transmission line conductor AOB suspended freely between level supports A and B at the same level (equal span). The shape of the conductor is a parabola and the lowest point of the conductor is O.

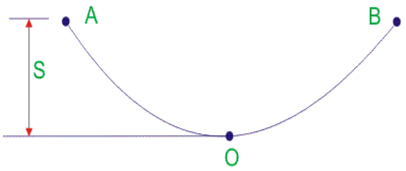


Figure 40: Sag when measured vertically

In the above overhead conductor AOB, S is the sag when measured vertically.

Why is Sag Mandatory in Transmission Line Conductors?

Sag is mandatory in transmission line conductor suspension. The conductors are attached between two supports with the perfect value of sag.

This is because it protects the conductor from excessive tension. In order to permit a safe level of tension in the conductor, conductors are not fully stretched; rather they are allowed to have sagged.

If the conductor is stretched fully during installation, wind exerts pressure on the conductor, hence the conductor gets a chance to be broken or detached from its end support. Thus **sag** is allowed to have during conductor suspension.

Some important points to note:

1. When the same leveled two supports hold the conductor, a bent shape arises in the conductor. Sag is very small with respect to the span of the conductor.
2. The Sag span curve is parabolic.
3. The tension in each point of the conductor acts always tangentially.
4. Again the horizontal component of the tension of the conductor is constant throughout conductor length.
5. The tension at supports is nearly equal to the tension at any point in the conductor.

Calculate Sag in a Transmission Line

When calculating sag in a transmission line, two different conditions need to be considered:

1. When supports are at equal levels
2. When supports are not at equal levels

The formula to calculate sag changes based on whether the support levels (i.e. the transmission towers holding up the overhead conductor) are at the same level.

1. **Sag calculation for supports are at equal levels**

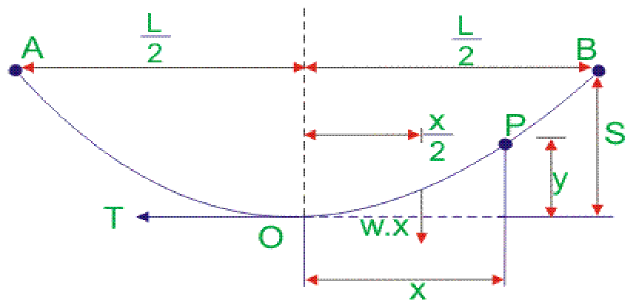


Figure 41: Sag calculation for supports are at equal levels

Suppose, AOB is the conductor. A and B are points of supports. Point O is the lowest point and the midpoint.

Let,

L = length of the span, i.e. AB

w is the weight per unit length of the conductor

T is the tension in the conductor.

We have chosen any point on the conductor, say point **P**.

The distance of point P from the Lowest point **O** is **x**.

y is the height from point **O** to point **P**.

Equating two moments of two forces about point O as per the figure above we get,

$$Ty = wx \times \frac{x}{2}$$

$$Now, y = \frac{wx^2}{2T},\ when\ y = S\ and\ x = L/2$$

$$Then\ S = \frac{wL^2}{8T}$$

2. **Sag calculation for supports are at unequal levels**

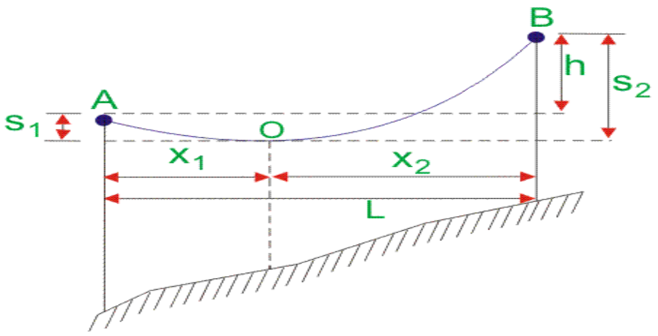


Figure 42: Sag calculation for supports are at unequal levels

Suppose **AOB** is the conductor that has point O as the lowest point.

L is the Span of the conductor.

h is the difference in height level between two supports.

x_1 is the distance of support at the lower level point **A** from **O**.

x_2 is the distance of support at the upper-level point **B** from **O**.

T is the tension of the conductor.

w is the weight per unit length of the conductor.

Now,

$$Sag\ S_1 = \frac{wx_1^2}{2T}\ \ And\ Sag\ S_2 = \frac{wx_2^2}{2T}$$

$$Also,\ x_1 + x_2 = L \ldots\ldots\ldots equation(1)$$

$$Now,\ S_2 - S_1 = \frac{w}{2T}(x_2^2 - x_1^2) = \frac{w}{2T}(x_2 - x_1)(x_2 + x_1)$$

$$So,\ S_2 - S_1 = \frac{wL}{2T}(x_2 - x_1)$$

$$Again, S_2 - S_1 = h$$

$$So, h = \frac{wL}{2T}(x_2 - x_1)$$

$$Or,\ (x_2 - x_1) = \frac{2Th}{wL} \ldots\ldots\ldots equation(2)$$

$$Solving\ equation\ (1)\ and\ (2),\ we\ get$$

$$x_1 = \frac{L}{2} - \frac{Th}{wL}\ and\ x_2 = \frac{L}{2} + \frac{Th}{wL}$$

So, having calculated the value of x_1 and x_2, we can easily find out the value of sag S_1 and sag S_2. The above formula is used to calculate sag when the conductor is in still air and ambient temperature is normal. Hence the weight of the conductor is its own weight.

Some of the effects of ice and wind on sag include:

- The weight per unit length of the conductor is changed when the wind blows at a certain force on the conductor and ice accumulate around the conductor.
- Wind force acts on the conductor to change the conductor self-weight per unit length horizontally in the direction of the airflow.
- Ice loading acts on the conductor to change the conductor self-weight per unit length vertically downward.
- Considering wind force and ice loading both at a time, the conductor will have a resultant weight per unit length.
- The resultant weight will create an angle with the ice loading down ward direction.

Indicative Content 2.2.4: Construction of under-ground cables

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

Although several types of cables are available, the type of cable to be used will depend upon the working voltage and service requirements.

In general, a cable must fulfill the following necessary requirements:

(i) The conductor used in cables should be tinned stranded copper or aluminum of high conductivity. Stranding is done so that conductor may become flexible and carry more current.

(ii) The conductor size should be such that the cable carries the desired load current without overheating and causes voltage drop within permissible limits.

(iii) The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.

(iv) The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.

(v) The materials used in the manufacture of cables should be such that there is complete chemical and physical stability throughout.

Material (like jute) similar to bedding is provided over the armouring. This is known as **serving.**

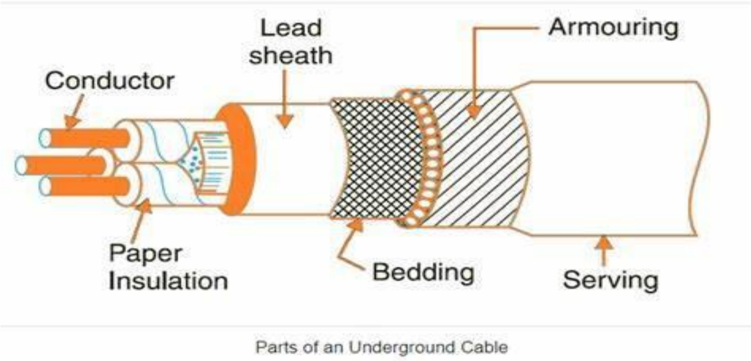


Figure 43: Cable construction

A. Cores or Conductors

A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended. For instance, the 3-conductor cable shown in figure is used for 3-phase service.

The conductors are made of tinned copper or aluminium and are usually stranded in order to provide flexibility to the cable.

The aluminium or copper conductor carries the electrical current.

The conductor behavior is characterized by two particularly noteworthy phenomena:

1. The skin effect and
2. The proximity effect.

The skin effect is the concentration of electric current flow around the periphery of the conductors. It increases in proportion to the cross-section of conductor used.

The short distance separating the phases in the same circuit generates the proximity effect.

In practice, the proximity effect is weaker than the skin effect and rapidly diminishes when the cables are moved away from each other.

The proximity effect is negligible when the distance between two cables in the same circuit or in two adjacent circuits is at least 8 times the outside diameter of the cable conductor.

B. Insulation

Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable.

The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound.

C. Metallic sheath

In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalies) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Figure.

D. Bedding

Over the metallic sheath is applied a layer of bedding which consists of fibrous material like jute or hessian tape.

The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armoring.

E. Armoring

Over the bedding, armoring is provided which consist of one or two layers of galvanized steel wire or steel tape.

Its purpose is to protect the cable from mechanical injuries while laying it or handling it. Armoring may not be done in the case of some cables.

F. Serving

In order to protect armoring from atmospheric conditions, a layer of fibrous material like jute similar to bedding is provided over the armoring. This is known as serving.

Classification of Underground Cables :
The **classification of Underground cables** can be done on the basis of several criteria.

Various aspects are taken into account while classification and these include:

1. Number of conductors in the cable
2. Voltage rating of the cable
3. Construction of cable
4. Type and thickness of insulation used
5. Installation and Laying of the cables

1. **Classification Based Upon Number of Conductors In The Cable**
   - Single-core

- Two-core
- Three-core
- Four-core etc

2. **Classification based upon voltage rating of the cable**
    - **Low tension cables**: These have a maximum voltage handling capacity of 1000 V (1 kV)
    - **High tension cables**: These have a maximum voltage handling capacity of 11 kV.
    - **Super tension cables**: These have a maximum voltage handling capacity of 33 kV.
    - **Extra high tension cables**: These have a maximum voltage handling capacity of 66 kV.
    - **Extra super voltage cables**: These are used for applications with voltage requirement above 132 kV.
3. **Classification based upon construction of the cable**
    - **Belted cables — upto 11 kV**
    - **Screened cables — from 22 kV to 66 kV**
    - **Pressure cables — beyond 66 kV**

A. Belted cables: These cables are used for voltages upto 11kV but in extraordinary cases, their use may be extended upto 22kV. Fig. 11.3 shows the constructional details of a 3-core, belted cable. The cores are insulated from each other by layers of impregnated paper. Another layer of impregnated paper tape, called paper belt is wound round the grouped insulated cores. The gap between the insulated cores is filled with fibrous insulating material (jute etc.) so as to give circular cross-section to the cable. The cores are generally stranded and may be of non-circular shape to make better use of available space. The belt is covered with lead sheath to protect the cable against ingress of moisture and mechanical injury. The lead sheath is covered with one or more layers of armouring with an outer serving (not shown in the figure).

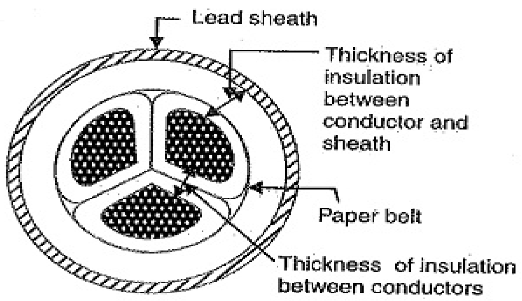


Figure 44: Belted cables

The belted type construction is suitable only for low and medium voltages as the electrostatic stresses developed in the Three Phase Service Cable for these voltages are more or less radial i.e., across the insulation. However, for high voltages (beyond 22 kV), the tangential stresses also become important. These stresses act along the layers of paper insulation. As the insulation resistance of paper is quite small along the layers, therefore, tangential stresses set up leakage current along the layers of paper insulation. The leakage current causes local heating, resulting in the risk of breakdown of insulation at any moment. In order to overcome this difficulty, screened cables are used where leakage currents are conducted to earth through metallic screens.

B. Screened cables: These cables are meant for use upto 33 kV, but in particular cases their use may be extended to operating voltages upto 66 kV. Two principal types of screened cables are H-type cables and S.L. type, cables.

(i) H-type cables: This type of Three Phase Service Cable was first designed by H. Hochstadter and hence the name. Fig. 1.1.4 shows the constructional details of a typical 3-core, H-type cable. Each core is insulated by layers of impregnated paper. The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminium foil. The cores are laid in such a way that metallic screens make contact with one another. An additional conducting belt (copper woven fabric tape) is wrapped round the three cores. The Three Phase Service Cable has no insulating belt but lead sheath, bedding,armouring and serving follow as usual. It is easy to see that each core screen is in electrical contact with the conducting belt and the lead sheath. As all the four screens (3 core screens and one conducting belt) and the lead sheath are at tearth potential, therefore, the electrical stresses are purely radial and consequently dielectric losses.

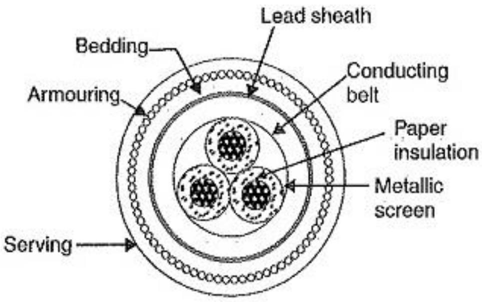


Figure 45: H-type cables

Two principal advantages are claimed for H-type cables. Firstly, the perforations in the metallic screens assist in the complete impregnation of the Three Phase Service Cable with the compound and thus the possibility of air pockets or voids (vacuous spaces) in the dielectric is eliminated. The voids if present tend to reduce the breakdown strength of the cable and may cause considerable damage to the paper insulation. Secondly, the metallic screens increase the heat dissipating power of the cable.

(ii) S.L. type cables: Fig. 11.5 shows the constructional details of a 3-core S.L. (separate lead) type cable. It is basically H-type cable but the screen round each

core insulation is covered by its own lead sheath. There is no overall lead sheath but only armouring and serving are provided. The S.L. type cables have two main advantages over H-type cables. Firstly, the separate sheaths minimize the possibility of core-to-core breakdown. Secondly, bending of cables becomes easy due to the elimination of overall lead sheath. However, the disadvantage is that the three lead sheaths of S.L. cable are much thinner than the single sheath of H-cable and, therefore, call for greater care in manufacture.

Classification based upon insulation of the cable

Various insulating materials used in cable construction are Rubber, Paper, PVC, XLPE (Cross linked Polyethene) etc. Such classification is based upon operating temperature limitations. Following are some insulating materials used and their maximum operating temperatures.
A comparison of common insulating materials is as follows:

Material	Advantages	Disadvantages
PVC	▪Cheap ▪Durable ▪Widely available	▪Highest dielectric losses ▪Melts at high temperatures ▪Contains halogens ▪Not suitable for MV / HV cables
PE	▪Lowest dielectric losses ▪High initial dielectric strength	▪Highly sensitive to water treeing ▪Material breaks down at high temperature
XLPE	▪Low dielectric losses ▪Improved material properties at high temperatures ▪Does not melt but thermal expansion occurs	▪Medium sensitivity to water treeing (although some XLPE polymers are water-tree resistant)
EPR	▪Increased flexibility ▪Reduced thermal expansion (relative to XLPE) ▪Low sensitivity to water treeing ▪Low-Medium dielectric losses	▪Medium-High dielectric losses ▪Requires inorganic filler additive ▪High weight ▪High cost
Paper / Oil	▪Not harmed by DC testing ▪Known history of reliability	▪Requires hydraulic pressure / pumps for insulating fluid ▪Difficult to repair ▪Degrades with moisture

4. **Classification based upon installation and laying of the cable**

- **Direct Buried**: As the name suggests, the conductors are buried underground in a trench without additional accessories. Sometimes cooling pipes are added if required. Once the cables are installed, there's no visible sign above the ground.
- **Trough**: Concrete troughs are dug and cables are installed in them. They're visible on the surface. Maintenance is easier.
- **Tunnels**: Sometimes, tunnels are dug up for this purpose. Such construction is mainly employed if a river needs to be crossed or if the intended power distribution is to a major city. Maintenance and future expansion is easier, but initial cost is higher.
- **Gas Insulated Lines**: This is a relatively new technology. For cables operating at higher voltages and currents, and handling high power, such gas insulated line construction is safer. It is being employed nowadays for advanced projects.

Theoretical learning Activity

1. Discuss on main components of overhead lines
2. Discuss on classification of underground cable
3. Choose the letter corresponding to right answer:

I. The sag produced in the conductor of a transmission wire depends on:
(a) weight of the conductor per unit length
(b) tension in the conductor
(c) length of the conductor
(d) all of the above
(e) none of the above.

Answer is(b)

II. Solid grounding is adopted for voltages below
(a) 100 V
(b) 200 V
(c) 400 V

(d) 660 V

Answer is(c)

Practical learning Activity

1. A 3-phase, 50-Hz, 220-kV transmission line consists of conductors of 1.2 cm radius spaced 2 metres at the corners of an equilateral triangle. Calculate the corona power loss per km of the line at a temperature of 20ºC and barometric pressure of 72.2 cm. Take the surface factors of the conductor as 0.96.

Solution:

corona loss per phase is $P = 241 \frac{(f+25)}{\delta} \sqrt{(r/D)} \, . (V - V_c)^2 \times 10^{-5}$ kW/km/phase

Here, $\delta = \frac{3.92\, b}{273 + t} = \frac{3.92 \times 72.2}{273 + 20} = 0.966$

$$V_c = 48.8\, m_0\, \delta\, r \log_{10} D/r = 48.8 \times 0.96 \times 0.966 \times 1.2 \times \log_{10} \frac{200}{1.2}$$

$$= 120.66 \text{ kV/phase}$$

$$V = 220/\sqrt{3} = 127 \text{ kV/phase}$$

$\therefore$ $$P = 241 \times \frac{75}{0.966} \times \sqrt{\left(\frac{1.2}{200}\right)} \times (127 - 120.66)^2 \times 10^{-5} = 0.579 \text{ kW/km/phase}$$

Total loss for 3 phase = 3 × 0.579 = **1.737 kW/km**

2. For a string insulator with four discs, the capacitance of the disc is ten times the capacitance between the pin and earth. Calculate the voltage across each disc when used on a 66-kV line. Also, calculate the string efficiency.

Solution. Let C be the self-capacitance of each disc and kC the capacitance between each link pin and earth. We are given that $k = 10$

$$V_2 = \frac{(1+k)}{k} V_1 = \frac{11}{10} V_1$$

$$V_3 = V_1\left(1 + \frac{3}{k} + \frac{1}{k^2}\right) = \frac{131}{100} V_1$$

$$V_4 = V_1\left(1 + \frac{6}{k} + \frac{5}{k^2} + \frac{1}{k^3}\right) = \frac{1561}{100} V_1$$

$$V = V_1 + V_2 + V_3 + V_4 = V_1 + \frac{11}{10} V_1 + \frac{131}{100} V_1 + \frac{1561}{1000} V_1 = \frac{4971}{1000} V_1$$

$$V_1 = V\frac{1000}{4971} = \frac{66}{\sqrt{3}} \times \frac{1000}{4971} = \mathbf{7.66\ kV}$$

$$V_2 = \frac{11}{10} V_1 = \frac{11}{10} \times 7.66 = \mathbf{8.426\ kV}$$

$$V_3 = \frac{131}{100} V_1 = \frac{131}{100} \times 7.66 = \mathbf{10.03\ kV}$$

Points to Remember (Take home message)

The **classification of Underground cables** can be done on the basis of several criteria.

Various aspects are taken into account while classification and these include:

1. Number of conductors in the cable
2. Voltage rating of the cable
3. Construction of cable
4. Type and thickness of insulation used

Installation and Laying of the cable

Learning outcome 2.3. Specify switching and protection equipment

Duration: 5 hrs

Learning outcome 3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Size circuit breaker, fuse, protection relay and disconnector
2. Differentiate circuit breaker, fuse, protection relay and disconnector
3. Specify transformer, switching and protection equipment

Resources

Equipment	Tools	Materials
• Calculator • Laptop	Pen	• Sheet • Notebook

Advance preparation:

There are several instances when the elements of a power system (e.g. generators transmission lines, insulators etc.) are subjected to over-voltages i.e. voltage greater than the normal value. These overvoltages on the power system may be caused due to many reasons such as lightning, the opening of a circuit breaker, the grounding of a conductor etc. Most of the over-voltages are not of large magnitude but may still be important because of their effect on the performance of circuit interrupting equipment and protective devices.

Indicative Content 2.3.1: Types of switching and protection equipment.

Circuit breaker.

A circuit breaker is defined as a protective device used for protecting the electrical system or electrical equipment under normal operation and abnormal operation.

Figure 46: Circuit breaker

A circuit breaker is a piece of equipment which can:

(i) Make or break a circuit either manually or by remote control under normal conditions

(ii) Break a circuit automatically under fault conditions

(iii) Make a circuit either manually or by remote control under fault conditions

Thus a circuit breaker incorporates manual (or remote control) as well as automatic control for switching functions. The latter control employs relays and operates only under fault conditions.

Operating principle

A circuit breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. Of course, the contacts can be opened manually or by remote control whenever desired. When a fault occurs on any part of the system, the trip coils of the circuit breaker get energised and the moving contacts are pulled apart by some mechanism, thus opening the circuit. When the contacts of a circuit breaker are separated under fault conditions, an arc is struck between them. The current is thus able to continue until the discharge ceases. The production of arc not only delays the current interruption process but it also generates enormous heat which may cause damage to the system or to the circuit breaker itself. Therefore, the main problem in a circuit breaker is to extinguish the arc within the shortest possible time so that heat generated by it may not reach a dangerous value.

Classification of Circuit Breakers

There are several ways of classifying the circuit breakers. However, the most general way of classification is on the basis of medium used for arc extinction.

The medium used for arc extinction is usually oil, air, sulphur hexafluoride (SF6) or vacuum.

Accordingly, circuit breakers may be classified into:

(i) Oil circuit breakers which employ some insulating oil (e.g., transformer oil) for arc extinction.

(ii) Air-blast circuit breakers in which high pressure air-blast is used for extinguishing the arc.

(iii) Sulphur hexafluroide circuit breakers in which sulphur hexafluoride (SF6) gas is used for arc extinction.

(iv) Vacuum circuit breakers in which vacuum is used for arc extinction.

Methods of arc methods of arc extinction
There are two methods of extinguishing the arc in circuit breakers:

1. High resistance method.
2. Low resistance or current zero method

Fuse
Fuse generally means a fuse wire, placed in a fuse holder. It is a safety device, which protects electrical and electronic circuit against over loads, short circuit and earth faults.

Figure 47: Fuse

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

The commonly type fuses are:

- Rewirable or semi-enclosed fuse
- Cartridge fuses
- High rupturing capacity (HRC) fuses or high breaking capacity (HBC) fuses

Protection relays
A protective relay is a device that detects the fault and initiates the operation of the circuit breaker to ioslate the defective element from the rest of the system.

Figure 48: Relay

Operation of protection relays
The relays detect the abnormal conditions in the electrical circuits by constantly measuring the electrical quantities which are different under normal and fault conditions. The electrical quantities which may change under fault conditions are voltage, current, frequency and phase angle. Through the changes in one or more of these quantities, the faults signal their presence, type and location to the protective relays. Having detected the fault, the relay operates to close the trip circuit of the breaker. This results in the opening of the breaker and disconnection of the faulty circuit.

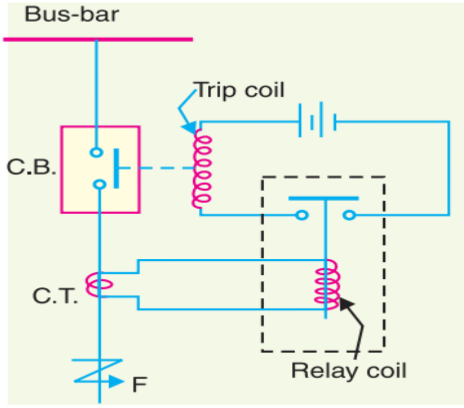


Figure 49: Relay construction

In order that protective relay system may perform this function satisfactorily, it should have the following qualities:

- **(i)** Selectivity
- **(ii)** Speed
- **(iii)** Sensitivity
- **(iv)** Reliability
- **(v)** Simplicity

Types of electrical relays

- Electromagnetic relay
- Latching relay
- Thermal relay
- Reed relay
- High voltage relay
- Time Relay
- Current and voltage relay
- Differential relay
- Distance relay
- Frequency relay
- Polarized relay
- Microprocessor-based relay
- Sequence relay
- Rotary relay
- Moving Coil Relay
- Target annunciator relay
- Flash relay
- Buchholz relay
- Safety Relays
- Ground fault relay
- Supervisory relay
- Solid state relay
- Power factor relay

Disconnector

A disconnector (disconnecting switch) is a switching device used to provide safe isolation by de-energising parts of an electrical network e.g. an overhead line, transformer, or bus bar etc. By virtue of their isolating function, disconnectors are sometimes also called isolators.

Figure 50: Isolators

Indicative Content 2.3.2: Sizing of switching and protection equipment.

In short, we must use the proper size of circuit breaker according to the device i.e. CB current should not be lower nor highest but 125% of circuit's current.

The following circuit breaker sizing calculator will show the difference in % to the load, voltage level in different countries and exact size of breaker in amperes.

Circuit Breaker Size Calculation for Single Phase Supply

To determine the appropriate size of circuit breaker for single phase supply, it depends on multiple factors like type of load, cable material and environment temperature etc.

The general rule of thumb is that circuit breaker size should be 125% of the ampacity of cable and wire or the circuit which has to be protected by the CB. Let see the following solved examples:

Example 1:

Suppose, a 12-gauge wire is used for 20 amperes lighting circuit having 120V single phase supply. What is the best size of circuit breaker for that 20 A circuit?

Solution:

Circuit Current: 12A

Circuit Breaker Size?

CB size should be 125% of the circuit current.

= 125% x 20A

= 1.25 x 20A

Circuit Breaker Size = 25A

A.2. <u>Circuit Breaker Size Calculation for Three Phase Supply</u>

To find the breaker size for three phase supply voltage, we must know the exact kind of load as there are many factors affecting the load current. In other words, same rule won't apply to the different types of loads i.e. light, motor, inductive or capacitive load as motor takes initially very high current during the starting process as well as power factor involvement. For residential use, we may follow the same formula as above for single phase with taking the √3 (1.732) due to three phase power formula.

Good to know: For the same load, the breaker size in three phase is less than the breaker size used in single phase AC circuits.

Let's find the correct size of circuit breaker for three phase circuits as follow.

Example 1: Which size circuit breaker is needed for 6.5kW, three phase 480V load?

Solution:

Power in Three Phase: P = V x I x √3
Current: P / V x √3

- I = 6.5kW / (480V x 1.732) … (√3 = 1.732)
- I = 6.5kW / 831.36
- I = 7.82A

The recommended size of circuit breaker is
1.25 x 7.82A = **9.77A**

A.3. <u>Circuit Breaker Size Calculation for Continuous & Non-contentious Load</u>

As circuit breakers (CBs) and Overcurrent Protection Devices ***(OCPD)*** are designed for 100% rated current i.e. a 30A circuit breaker can safely carry the exact 30A current but NEC suggests 80% as a safe current limit as compared to the rated current of CBs.

This is because all loads are not same i.e. some loads are simultaneous ***(continuous)*** while other are non-simultaneous ***(non-continuous)***. In case of contentious loads for three or more hours, the load current should not exceed 80% of the rated current of circuit breaker and OCPD.

The 80% of a 30A circuit breaker is 24A. This way, a 30A circuit can be safely used for 24A circuit.

In other words, a load circuit having 24A, the appropriate size of breaker would be:
24A / 0.8 = 30A.

Example 1:

CB Size for 30A Non-Contentious Load

- An exact 100% rated for 30A circuit breaker can be used for 30A non-continuous load.

Example 2:

CB Size for 28A Contentious Load

- In case of continuous load, rate of %125 is applicable.
- 1.25 x 28 A = **35A**

Example 3:

CB Size for 30A Non-Contentious Load & 28A contentious Load

- = 125% Continuous Load + 100% Non-continuous load
- = (1.25 x 28A) + (30A)
- = **75A**

Fuse sizing

The function of a fuse is to break a circuit when a current threshold is exceeded. It's a single function device, and historically single-use. Calculating the rating of very basic protection equipment **<u>fuse</u>**, we use the thump rule just select a fuse rated 150% - 200% of normal operating current of the specific circuit. But actually there are numerous calculations are involved for determining an appropriate fuse rating. Frequently necessary to consider other factors like- including ambient temperature, available energy during fault, inrush current, etc. There is a simple and basic formula for working out the fuse rating, voltage or wattage for each appliance: P=VxI

Where,

- P for <u>power</u> in Watts;
- V for <u>voltage</u> in volt);
- I for <u>current</u> in Amps.

The fuse rating can be calculated by dividing the power used by the appliance by the voltage going into the appliance.

I (Amps) = P (Watts) ÷ V (Voltage).

Example:

Fuse Rating Calculation for Motor

A fuse for a machine is rated on the load that the machine carries when running. For example, a 1-HP (746W) motor operating at 115V would draw 746/115 = 6.5A at full load, so theoretically a ***10A fuse would be sufficient.***

Example

A bed side lamp is rated 60 W, 240 V. Calculate the size of fuse that should be fitted to the lamp for it to operate safely. The fuse available are 3 A, 5 A and 13 A.

<u>Fusing Factor</u>

Fusing Factor is the ratio of minimum fusing current and current rating of fuse.

Therefore, **fusing factor** = Minimum fusing current or current rating of the fuse.

The value of fusing factor is always more than 1.

Fuse Size Calculation Formula

Fuse Wire Rating: The melting point and specific resistance of different metals used for fuse wire is as below:

Metal	**Melting point**	**Specific Resistance**
Aluminium	240oF	2.86 µ Ω – cm
Copper	2000oF	1.72 µ Ω – cm
Lead	624oF	21.0 µ Ω – cm
Silver	1830oF	1.64 µ Ω – cm
Tin	463oF	11.3 µ Ω – cm
Zinc	787oF	6.1 µ Ω – cm

Many times we have to face some physical places limitation to choose the fuse or circuit breaker mounting sizes.

It is this reason that fuse and circuit breaker manufacturers have created a wide selection of components with varying physical sizes. Typically however, there are a trade-offs that the engineer must consider.

Generally speaking, the smaller the fuse, the less current and/or capabilities that the fuse or circuit breaker may have. For example, a sub-miniature fuse maybe limited to 15A whereas the larger 1/4" x 1 1/4" glass tube fuse can accommodate up to 40A.

Relay sizing

Relays often have two ratings: AC and DC. These rating indicate how much power can be switched through the relays. This does not necessarily tell you what the limits of the relay are. For instance, a 5 Amp relay rated at 125VAC can also switch 2.5 Amps at 250VAC. Similarly, a 5 Amp relay rated at 24VDC can switch 2.5 Amps at 48VDC, or even 10 Amps at 12VDC.

Volts x Amps = Watts - Never Exceed Watts!

Example Calculations	
AC Volts x AC Amps = AC Watts	**DC Volts x DC Amps = DC Watts**
Example: A 5 Amp Relay is Rated at 250 Volts AC. 5 x 250 = 1,250 AC Watts	Example: A 5 Amp Relay is Rated at 24 Volts DC. 5 x 24 = 120 DC Watts
If you are switching AC Devices, Make Sure the AC Watts of the Device you are Switching DOES NOT Exceed 1,250 when using a 5A Relay.	If you are switching DC Devices, Make Sure the DC Watts of the Device you are Switching DOES NOT Exceed 120 when using a 5A Relay.

An easy way to determine the limit of a relay is to multiply the rated Volts times the rated Amps. This will give you the total watts a relay can switch. Every relay will have two ratings: AC and DC. You should determine the AC watts and the DC watts, and never exceed these ratings.

Disconnector sizing

The National Electric Code specifies that large, permanently-wired appliances such as air conditioners or whole house attic exhaust fans have a disconnecting means within sight of the appliance. The disconnecting means must be a listed device and must be rated to disconnect the same horsepower as the appliance it is installed for. A 3-horsepower motor requires a switch rated at 3-horsepower or more. Most disconnect switches are fused so any disconnect installed must accept the correct fuse size for the appliance.

Step 1: Examine the appliance manufacturer nameplate on the appliance. Determine the horsepower rating of the appliance. If no horsepower rating is given, look for volt-amps, watts or kilowatts.

Step 2: Convert from volt-amps, watts or kilowatts to horsepower. Divide watts or volt-amps by 745.7 to obtain horsepower. Divide kilowatts by 0.7457 to convert to horsepower.

Step 3: Select a disconnect switch with the same or greater horsepower rating as the appliance. The disconnect switch must also have the correct fuse size. An appliance requiring a 30-amp double circuit breaker will need a disconnect rated to its horsepower and will accept two 30-amp fuses.

Theoretical learning Activity

Discuss on Circuit Breaker Size Calculation for Single Phase Supply

Practical learning Activity

A toaster has a power rating of 750 W, 230 V.

Calculate the size of fuse to be used.

Answer:

P = VI

P = 750 W

V = 230 V

750 W = 230 V x I

I = 3.26 A

The normal current for the toaster is 3.26 A. ***Hence a 5 A fuse would be selected***.

A 3 A fuse would “blow” when the normal operating current flowed.

A 13 A fuse would allow dangerously high current to flow and still not blow.

Points to Remember (Take home message)

To determine the appropriate size of circuit breaker for single phase supply, it depends on multiple factors like type of load, cable material and environment temperature etc

Learning outcome 2.4. Elaborate technical drawings

Duration: 3 hrs

Learning outcome 3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify of Symbols used in electrical power distribution systems and types of diagrams
2. Elaborate of bloc diagram, wiring diagram and architectural diagram
3. Respect scales and clarify legend

Resources

Equipment	**Tools**	**Materials**
• Laptop • Drawing boards. • Clutch pencils.	Pencil Mechanical pencils. Rulers. Compass. Erasers. Sharpeners.	• Sheet • Notebook

Advance preparation:

Electrical drawings, sometimes referred to as wiring diagrams, are a type of technical drawing that provide visual representation describing electrical systems or circuits. They are used to explain the design to electricians or other workers who will use them to help install or repair electrical systems.

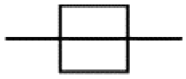
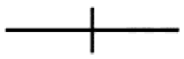
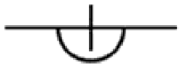
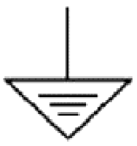
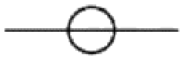
A set of electrical drawings on a project might include:

- A site plan which shows the location of the building and any external wiring.
- Floor plans which show the positions of electrical systems on each floor.
- Wiring diagrams which show the physical connections and layout of electrical circuits.

Electrical drawings tend to include the following details:

- How the electrical wires and other parts of the system are interconnected and switched.
- Where fixtures and other components connect to the system.
- Incoming power lines and their voltage, size, capacity and rating.

Indicative Content 2.4.1. Symbols used in electrical power distribution

Symbols	Description	Symbols	Description
	Electrical distribution line Cable / Wire		Line inside a conduit Line inside a tube duct...
	Line through an access chamber		Underground line
	Underwater line		Underground line
	Line block with oil or gas		Bypass Line of the gas or oil
	Line detection valved gas or oil		Online probing
	Line under plastering		Power line AC
	Protection anode		Power line DC
	End of line not connected		End of line not connected and isolated
	Overhead line		Vertical retention

Indicative Content 2.4.2. Electrical power distribution line diagram

It shows a correct power distribution path from the incoming power source to each downstream load — including the ratings and sizes of each piece of electrical equipment, their circuit conductors, and their protective devices. In many facilities, loads are continually added or removed in small increments.

Types of electrical power distribution line diagrams

1. **Single line diagram** is a simplified notation for representing a three-phase power system, Instead of representing each of three phases with a separate line or terminal, only one conductor is represented. It is a form of block diagram graphically depicting the paths for power flow between entities of the system. Simply it shows symbols to denote components.
2. **Architectural diagram**: An architecture diagram is a graphical representation of a set of concepts, which are part of architecture, including their principles, elements and components.
3. **Bloc diagram** this type of drawing illustrates the main parts and shows way the parts connect, A block diagram is a diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks. They are heavily used in engineering in hardware design, electronic design, software design, and process flow diagrams.
4. **Wiring diagram** is a simplified conventional pictorial representation of an **electrical circuit**. It shows the components of the **circuit** as simplified shapes, and the power and signal connections between the devices.

Theoretical learning Activity

- ✓ Enumerate the symbols used in electrical power distribution systems
- ✓ Discuss on the type of diagram used in electrical power distribution systems

Practical learning Activity

Draw over-head electrical power distribution line diagrams of 10 poles where the last pole is isolated.

a. Single-line diagram

b. Architectural diagram
c. Block diagram
d. Wiring diagram

Points to Remember (Take home message)

Types of electrical power distribution line diagrams are Single line diagram, Architectural diagram, Bloc diagram and Wiring diagram

Learning Unit 3: Estimate cost

Figure 51: Picture/s reflecting the Learning unit 3

STRUCTURE OF LEARNING UNIT

Learning outcomes:

3.1. Determine quantity of materials

3.2. Calculate materials cost

3.3. Calculate labor cost

3.4. Elaborate cost report

Learning outcome 3.1 Determine quantity of materials

Duration: 5 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Calculate the material cost
2. Identify different methods used for elaboration of bill of quantity
3. Elaborate content of bill of quantity

Resources

Equipment	Tools	Materials
• Laptop • Calculator	• Pen	• Sheet • Notebook

Advance preparation:

There are always two questions asked by a client considering an investment in project: "**How much**?" and **"How long?"** Estimating responds to the first question. Very few projects can go forward before the cost of the construction has-been determined.

Estimating is a distinct function in the construction management field, and unlike some other jobs in construction, the estimator's role is pretty specific. The estimator's primary focus is costs. They have the awesome responsibility of accurately determining the price of the project while maintaining a competitive edge in the market place. Projects are won or lost by the efforts of the estimator.

Whatever the estimator estimate depend on what is in the Bill of Quantity. In the Bill of Quantity, the main focus is on Description of item, unit and Quantity as measured.

All these terms are going to be explained in the next chapters.

Determine quantity of materials

For better determination of Quantity of materials, the primary task is to prepare the **takeoff** by using the drawings then the site condition may be taken into consideration.

Takeoffs, or take offs, are the estimated quantities of items that the electrical contractors need for a project. Using the plans or drawings, estimators determine the specific items and number of items that they would need to order for the job. Depending on the tools and experience of the estimator, they have many ways to calculate the takeoffs. Some estimators will do manual takeoffs from designs and drawings. Other estimators use estimating software to determine appropriate takeoffs for a given project. Takeoffs have to be as accurate as possible.

Indicative content 3.1.1: Identification of purpose of preparation of bill of quantity

Purpose of preparation of bill of quantity

BOQ or BQ) is a document prepared by a quantity surveyor or cost consultant to define the quality and quantity of works required to be carried out by the main contractor to complete a project.

BOQ is the core element for any project whether its Civil, Electrical, Mechanical or any other filed. If all the quantities worked out properly no further variation comes during the execution phase.

In simple language you can consider BOQ as a list of items with their description and quantities provided to contractors and asked to bid their rates against each item and respective amount.

The main purposes of a BOQ are:

- To provide the same information to all tendering Contractors or Principal Contractors, that enables them all to prepare their tenders efficiently and accurately based on the same information
- Provide a basis for the valuation of completed work for the purpose of making interim payments to the Contractor or Principal Contractor
- Provide a basis for the valuation of variation work
- It provides a very strong basis for budgetary control and accurate cost reporting of the contract (i.e. post contract cost control)
- The first few words in a written description should indicate clearly the nature of work required to be completed
- BOQ helps to monitor and control the project as well as it will help to identify new items in the project
- Through BOQ, progress billing is done based on the work done for each portion as a percentage completed with the rates agreed to get the figure.

Importance of Bill of Quantities

The main importance of preparing the bill of quantities can be listed as follows:

1. It is necessary to determine the total estimated contract price.
2. It gives a rough idea about the entire project.
3. It provides the quantities to the contractors concerning which the contractors can bid.
4. It determines the extent of the work to be performed.
5. It provides the schedule of rates and is important for preparing the variation orders and assists in the valuation.
6. It serves as the basis for the valuation of the interim payments.
7. It is also important for the preparation of the final bill amount.

The major Parts of BOQ

The parts of the bill of quantities may vary from place to place depending upon the size of the project, prevailing practices, etc.

In general, the bill of quantities consists of three major parts namely the preliminaries, the measured works, and the provisional sum which has been further described below:

a. Preliminaries

In the construction industry, the preliminaries refer to the indirect costs that are incurred during the execution of the project and are inevitable for the completion of the project.

These indirect costs are grouped in a separate category as it is difficult to distribute them among the measured works.

Some of the examples of the preliminaries can be duly listed as follows:

a. Cost for maintenance of the site.

b. Charges for the performance bond and advance payment guarantee.

c. Compensation charges such as workmen compensations.
d. Costs for ensuring site safety.
e. Charges of the project management professionals.
f. Costs for the drawings.

b. Measured Works

Measured works enlist the items of work that are inevitable for the completion of the project. These works can be measured in different units such as meter, square meter, cubic meter, number, etc.
The value of such measured work is obtained by multiplying the quantity and the prevailing rate of each item of the work.

c. Provisional Sums

Provisional sum refers to the price that is included for the various items of work that need to be carried out during the execution of the project but the price of those works cannot be quoted or fixed at the tendering phase.
It is usually adjusted during the execution phase of the project.

Indicative content 3.1.2: Identification of different methods used for elaboration of bill of quantity

Methods of Bill of Quantity | BOQ Meaning
The bill of quantities (BOQ) is a form of tender document which sets out the quantities and descriptions of the items of labor, material, and plant required to erect and complete a building or other works in a systematic manner.

TRADITIONAL ABSTRACT AND BILLING
This is the main method of producing bills of quantities and for this type of billing the work is taken off then squared and checked. The taking off is then transferred/ written onto abstract sheets/ dimension paper than checked again.
CUT AND SHUFFLE
The cut and shuffle method is a semi-mechanical method of producing bills of quantities that help to save time with abstracting and billing. For this method, the paperwork is taken off using cut and shuffled into the correct order (trade or element), which can then be used to collate a draft bill that can be checked again until the final bill is produced.
The `cut and shuffle' system of bill preparation operates as follows:

(a) The taking-off is carried out to the same procedures as described above. but the dimensions are entered on special `cut and shuffle' paper. Each sheet comprises a white original and a yellow carbon copy and is ruled in such a manner that it forms three separate small dimension sheets, which are commonly referred to as `slips'.

Each `slip' should be numbered, and have the job number stamped on the top. Taking-off then proceeds in the usual manner, except that a separate `slip' must be used for each individual item.

(b) When the taking-off is completed, or in the case of a large job, substantial sections are completed, the dimensions on each `slip' are squared and checked.

(c) The person who carries out the taking off retains the yellow carbon copy as a record, but the white original sheets are cut into three separate `slips', each containing one item or part of an item.

(d) The `slips' are shuffled, or sorted, into sections, such as Earthworks, Drainage, Concrete, etc., similar items are collected and stapled together, and the whole of the slips placed, as near as possible, in bill order.

(e) The slips are then edited to form the preliminary draft bill, with further slips inserted as necessary to provide headings. The correct unit is entered in the box provided on each slip, or on the top slip where a number of similar items are stapled together.

(f) The total quantity for each item is calculated and inserted in the box provided on the slip. This process must be independently checked and ticked in red ink or ball pen.

(g) Once completed, these slips are attached together in bill order by a treasury tag from the draft bill, and can be passed directly for typing onto billing paper.

(h) The typed bill must be closely checked with the draft to ensure that all descriptions, quantities and units have been transferred correctly.

(i) As a final check, the cut slips should be counted and compared to the yellow carbon copy sheet to ensure that all slips are accounted for. Although this system takes a long time during the taking-off stage owing to the need to write descriptions out in full, the time saved in the bill preparation process means a considerable reduction in overall time spent on pre-contract measurement.
This method of bill preparation can be used for all projects, but is best suited to large complex jobs where there are a large number of similar items. Used correctly, it can result in great savings in time in the bill preparation process, as it omits both the abstracting and billing stages.

DIRECT BILLING

This method of bill production is produced directly from the take-off, without the need to abstract and bill or cut and shuffle. The work is taken off as usual then squared and checked but the dimensions and their quantities are reduced and only checked on the taking of sheets. The draft bill is then written directly from the reduced dimension sheets.

COMPUTER SYSTEM

This process can be used either for a full or particular process for producing bills of quantities.

Standards for preparing of Bill of Quantities

Since the bill of quantities serves as a communication medium between the parties involved in a construction project, a standard that is widely accepted must be used for its preparation.

When the bills of quantities are prepared by standards, misunderstandings or ambiguities and disputes among the parties may be avoided.

Some of the common standards that are used for the preparation of the bill of quantities can be listed as follows:

1. Standard Method of Measurement, UK (Previously used).

2. New Rules of Measurement, UK (Replaced Standard Method of Measurement on 1st July 2013).

3. Civil Engineering Method of Measurement (the standard method for work measurement).

4. Common Arrangement of Work Sections (the standard method for work categorization).

Preparation of bill of Quantities

When preparing the bills of quantities, a series of steps must be carried out in proper order to make the bill of quantities managed and easy to understand.

In the preparation of the bill of quantities, the first step includes taking off the quantities from the working drawings.

The taken-off measurements from the working order must be in a particular order which can easily be recognized.

Such measurement recording sheet is known as TDS (Technical Data Sheet).

Bill of Quantities sample

Item No	Description	Unit	Quantity	Rate	Amount

Figure 52: Framework of the BOQ Sheet

As shown in the figure above, then the units and the quantities of the measured work are filled.

Then, the standard rates for the particular item of work are filled.

Finally, the amount is determined by multiplying the quantity and the rate for each item of work.

Indicative content 3.1.3: Content of bill of quantity

A bill of quantities (BOQ or BQ) is usually used on larger construction projects and consists of a list of materials and services required to perform a project. The list includes materials, labor, and quantities of each, and is often prepared by the engineer or architect after project design is complete, while preparing a BOQ, you should include at least the following 5 components:

1. Item Description
2. Unit
3. Quantity
4. Rate per unit
5. Total Amount

Indicative content 3.1.4: Determination the way of laying out the table of bill of quantity

Steps for Creating a Bills of Quantities.

Creating bills of quantities takes a few easy steps and appoint a cost consultant is very important for making the process flawless. The complete process of the Bill of quantities is performed digitally. Here below there are five Steps for Creating a Bills of Quantities

1. Formulate the list of Bill of quantities

It is the preliminary step for formulating a Bill of quantities and maintains the proper format to create the list. Considering the digital method of creating such a document, you need to set up a spreadsheet and introduce a few columns and rows according to your requirement. These columns and rows are present to help the cost consultants to maintain a format to focus each element of the project and their respective costs separately.

2. Draft a list of the required items

The most important step is drafting the required items for your construction project. The architect's design must need the proper materials to become a reality. Analyzing the design and setting up the required items and their quantities is a crucial task to encounter. A cost consultant or a quantity surveyor mostly assists the owners by offering the Bill of quantities for the project.

3. Introduce sub-sections of your construction project

Sometimes working on a whole project entirely becomes difficult to maintain the quantity of the items at the right place. So, you can divide the entire project into a few sub-groups to effectively improve the workers' and the sub-contractors working activities.

4. Predict the working hours of the laborers

Determine the total working hours of each labor to complete each sub-group and make some quick calculations to evaluate the total time required for completing the entire project. For such cases, you can take the contractors' advice to set up the hour limit for each worker to finish your project on time.

5. Estimation of the budget

Estimation of the total budget for the materials, labor, and other activities is crucial to running your project smoothly. But, before sending the Bill of quantities to the tenderer, make sure you have a rough calculation on the probable budget to proceed with your project further.

Sample of bill of quantity (BOQ) for electrical works

Generally, BOQ is in tabular form which contains Item number, description, unit, quantity, rate and amount in different columns as showed below:

PROPOSED COMPANY

Item No	Description	Qty	Unit	Rates	Amount
1.	**Electrical Works** Brief description of each unit of work to be done with specification of material to be used (Ex: Cabling, Lights, sockets, Power supply, Lightening protection, etc)	Quantity of described work as measured in takeoff	Pcs/ Set/ Lm/ Cm/ Sm/	Unit cost (Material price+ labour+ Overhead +Profit+ Tool& equipment)	Here the Rate is multiplied with the Quantity

Where: **Pcs** is Pieces, **LM** is linear meter, **CM** is cubic meter, and **SM** is square meter.

For making the total,

- You can make a total at the end of each page and carry it to the next page
- You can make a total of related work and sum it up at the end
- You can make the total at the end of each page and make the grand total at the last page.

With the above format, let's take an example of Bill of Quantity for better understanding.

PROPOSED COMPANY

Item No	Brief Description	Qty	Unit	Rate	Amount
	ELECTRICAL WORKS **1.0: LIGHTING AND SOCKETS INSTALLATION** Supply, install, test, commission and handover in working condition the following:				
001	Lighting points only excluding switches wired in 1.5mm2 pvc/sc copper cables drawn in 20mm dia. heavy gauge pvc conduits as shown on the layout drawings	20	No		
	The following switches mounted at minimum 1450mm from finished floor level and as described in the Schedule of symbols (ALL LEGRAND):				
002	5A 1 Gang, 1 Way	13	No		
003	5A 1 Gang, 2 Way	3	No		
	The following luminaries complete with rated gear and lamps (screw type).				

004	Recessed down lighter fitting with floating glass ring with 2x28W with P-LG24D2 LED bulb : 180mm diameter.	20	No		
005	600x600x4 by 18w fluorescent fitting with louvres complete with LED two feet tube: " Nation wide"	20	No		
	Sockets and switches				
006	Twin socket outlets points only for NORMAL and UPS mains excluding the outlet wired using 2.5mm2pvc/sc copper cables and 2.5mm2pvc/sce.c.c drawn in 25mm diameter pvc heavy gauge conduits or trunking.	48	No		
007	40A Double pole switch point only completely wired using 2.5mm2 pvc/sc copper cables plus 2.5mm2 earth continuity conductor for the Air Conditioning Units	6	No		
008	Supply and install only of 12-Way TPNMCB Distribution Board,PVC or sheet metal made complete with Integral Isolators, Bus bars and door for raw or UPS power distribution like LEGRAND or any other approved equivalent. 2 No Supply and install of the following MCBs:Legrand	2	No		
009	80A TPNMCB main incomer	2	No		
010	40A TPNMCB Shunt for surge arrestor	1	No		
011	16A DP MCB for UPS power sockets	10	No		
012	TPN Surge Protector 15KA	1	No		
013	105 x 50mm,double Compartment, PVC trunking, AS LEGRAND set into double lane: complete with accessories: covers, end caps, bends etc	50	Pcs		
	TOTAL CARRIED TO SUMMARY				

Theoretical learning Activity

- ✓ Identify the types of documents found in a bill of quantities
- ✓ Assess the steps towards preparing a bill of quantities

Points to Remember (Take home message)

Steps for Creating a Bills of Quantities.

1. Formulate the list of Bill of quantities
2. Draft a list of the required items
3. Introduce sub-sections of your construction project
4. Predict the working hours of the laborers
5. Estimation of the budget

https://dreamcivil.com/bill-of-quantities/
https://quantitysurveyor4u.blogspot.com/2018/02/bills-of-quantities-boq.html

Learning outcome 3.2 Calculate materials cost

Duration: 5 hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify number of manpower needed to accomplish the task
2. Determine appropriate labour rate per man-hour and the anticipated labour required to complete the task
3. Clarify Job average labour rate and labour Burden

Resources

Equipment	Tools	Materials
• Laptop • Calculator	• Pen	• Sheet • Notebook

Advance preparation:

Material is the most important element of cost. In most manufacturing organizations, 50% to 70% of the total cost of a product is represented by the cost of the material.

Material cost was defined by the Institute of Cost and Management Accountants as follows: "the cost of commodities supplied to an undertaking."

Examples of material cos: Cost of wood, other raw materials, and factory supplies for a furniture manufacturer

Indicative content 3.2.1: Different methods of collecting information on the cost of materials

1. How to calculate materials cost

Developing an accurate cost estimate is the first step in a successful electrical job. A contractor who estimates poorly will ultimately fail, no matter how well his technical skills.

If he underestimates his costs, he will find himself either using his own funds to complete a job, returning to his client to ask for more money or leaving the job incomplete or completed poorly. Overestimating will put him at a competitive disadvantage and cause him to lose work to better estimators.

Material costs: Usually include the prices of materials or parts incorporated into a project. The price of materials is based on its purchase price with allowances for delivery, off- loading, storage and placing in position. In addition, an allowance must be made to cover wastage which may arise as follows:-

a) **Handling/breakages**: brittle materials such as bricks, clay tiles and precast concrete paving slabs, etc have high breakage rate even for the advances in mechanized handling of material which is wrapped and delivered to site on pallets.

b) **Site losses**: an allowance has to be made for loose material such as sand and aggregate which, when delivered and tipped on site will, to some extent, be trampled into the ground, washed away by rain, etc.

c) **Cutting losses**: sheet materials are manufactured in standard sizes, therefore plaster-board, plywood, glass, carpet; etc must be cut of it. Where the material is patterned has to be cut to a difficult shape, losses can be considerable.

Materials can be in any one of the categories below:

(a) Permanent materials included in the final constructed product or structure.

(b) Expendable materials and supplies those are necessary for the work to be accomplished, but will not be incorporated into the final structure, or will otherwise be used up during the work, such as lubricants and concrete forms.

2. Methods of collecting information on the cost of materials:

- Referring to the sellers
- Referring to the technicians
- Referring to the internet

Indicative content 3.2.2: Compiling collected information on drafted bill of quantity

The question of whether BQ is still needed, useful or relevant in our construction industry should be considered holistically from various angles. It is an issue very much associated with project cost management which is an important part of Project Management Processes. Project cost management processes include cost estimating, cost planning, cost monitoring, cost control and cost information system. Since construction project development involves the client or the owner, the designers, the managers and contractors, it is fair to consider the issue of the use and relevance of BQ from the perspectives of **these different groups**.

i. From Contractor's Perspective

For contractors, any construction project will involve the process of tendering or bidding, resources planning (money, materials, labour, plant), work planning and execution, procuring of subcontractors, supervision, monitoring and controlling.

ii. From Client's Perspective

For the building owners, their main concern is to see that their projects are completed on time, within the estimated cost and within specified quality. But in today's environment more owners want to be better informed of their projects and be provided with accurate and reliable information pertaining to the progress and financial aspects of the projects.

iii. From Consultant's Perspective

As the representative of the owner, the consultants are expected to manage the project properly and effectively to ensure that the owner get value for money for their projects. They must ensure that the project is of high quality, completed on time and more importantly within the estimated cost or budget. The owner also should be provided with accurate and reliable cost information at the early stage of the project and always kept informed of the project's financial situation in term of monthly expenditure, any deviation from the estimated budget and how their fund are being used in the project.

Indicative content 3.2.3: Identification of number of manpower needed to accomplish the task

By quantifying manpower productivity, business owners and managers see how employees' efforts translate to income and profits. Evaluating the factors that affect productivity can help business organizations make any necessary changes to boost the bottom line.

Manpower Calculation by Industry

Productivity can be defined as the amount of output that is generated with a given amount of input. Depending on the industry, the output may be goods, services or sales; the manpower productivity formula is essentially the same. To calculate manpower or labor productivity, you divide the value of goods and services produced by the total hours worked by employees over a specified period. You can also calculate labor productivity by dividing the total sales by the total amount of hours worked. Here are the step-by-step instructions for running a manpower calculation:

a. Figure Hours Worked

Determine the total hours that employees worked. For employees who work a specified number of hours each day, subtract the hours or fractions of hours allocated to lunch and break times. You may need to ask employees to keep a log of tasks and times over a given period.

Time management software calculates work hours automatically for employees who punch a time clock. In some small companies with few employees, employees maintain time cards with manual entries. Calculate hours worked by subtracting the start time from the end time. Make manual calculations easier by using a 24-hour clock. For example, noon is designated 12:00. One o'clock is 13:00, two o'clock is 14:00, etc.

b. Quantify the Work Product

Determine the unit of measurement for your employees' work product. For example, if you employ salespeople, use either the number of sales or the dollar value of sales. If you employ factory workers, look at the number of units of an item produced. Evaluate customer service employees on the number of phone calls answered or the number of people served. Employees who work one-on-one with clients can be evaluated according to their billable hours.

c. Total the Units of Work Product

For a given period, add the work units produced by each employee. Add the individual numbers to arrive at the total number of work products produced by all members of the organization.

d. Determine Work Units per Hour

For the same period, total the total number of hours worked by all employees. If time management software calculates the hours, you may want to round the number to the nearest hour.

Divide the number of hours by the number of units produced to get the number of work units produced by the organization in one hour.

e. Determine Work Units per Employee

Divide the number of work units produced in an hour by the total number of employees. The resulting figure tells you how many employees it takes to produce the number of work units in an hour.

Indicative content 3.2.4: Determination of an appropriate labor rate per man- hour

Estimating for labor rates involves the analysis of both the **basic wage and the labor burden.** It is common knowledge that the labor rates do not involve the wages only as the labor burden can form a big proportion of the labor costs. The labor burden includes items such as taxes, insurance, etc. which employers are required by law to pay. Basic wage is determined based on labor **productivity.** Productivity can be measured by using the value added on site. Value added is the difference between the price of construction contract and the cost of materials, prefabricated components and other inputs except labor. **Value added** is equal to **net output** (gross output - Inputs)

Productivity of Net Output per head = Net Output

Labor units

Output per head, per week = Net Output

Labor units X Time period

[P = NO/LXT]

Where: **P**= Productivity, **L**= Labour units, **T**= Time periods, **NO** = Net output

In construction, from the available statistics, it is possible to estimate the value of construction output per man-hour, man-day, man-week or man-month over the industry as a whole. However, comparison of productivity on different projects and between operatives is much more difficult.

Variations in output are experienced because the day-to-day performance of operatives is influenced by:

- Motivation, skills and health of the operatives
- Difficulty and complexity of work. Difficult and more complex works slows down output rate of the operatives
- Location of work (indoor, outdoor, higher up or below ground0
- Familiarity with the work: there is always a learning curve associated with unfamiliar tasks
- Degree of effectiveness of plant. This depends on the quality of the plant selected for production.
- Degree of quality of the finished work
- Weather conditions

Calculation for 'all-in' hourly labour rate of Skilled-worker earning Rwf 5,000 per day And un-skilled worker earning Rwf 3,000 per day.				**September-2012**	
Description	**Entry Column**		**Calculation Column**		
PERIOD	Number of weeks	52			
	Weekly hours	45			
	Total hours		**2,340**		
	Days annual holidays(Leave)	21	(168)		
	Days public holidays	18	(144)		
	Total hours for holidays		(312)		
	Sickness	8	(64)		
	TOTAL HOURS FOR PAYMENT		**1,96 4**		
	2% Allowance for weather bad		(39)		
	TOTAL PRODUCTIVE HOURS		**1,92 5**		
		Skilled	**Un-skilled**	**Skilled**	**Un-skilled**
ANNUAL EARNINGS	Basic wage	30,000	24,000		
	Attraction bonus 9%	2,700	2,160		
	Total weekly rate	**32,700**	**26,160**		
	Hourly rate of pay (45hrs)	**727**	**581**		
	Annual earnings (Total productive			1,427,828	1,141,084
	Public Holidays with Pay		144hours	104,688	83,664
ADDITIONALCOSTS	**NON PRODUCTIVE OVERTI ME**				
	Hours per week		4.5		
	Hours per year(4.5hrs x 49 weeks)		220.5 hours		
	Cost of non-productive overtime			240,455	192,166
	SICKPAY(64hrs x Hourly rate)		64 hours	46,528	37,184
	ANNUAL LEAVE WITH PAY		168 hours	122,136	97,608
			Sub-total	**1,941,635**	**1,551,706**
OVER HEADS	**1.SOCIAL SECURITY FUND**		10.0%	194,164	155,171
	2.WORKMANS COMPENSAT ION		4%	77,665	62,068
	3. TRAINING LEVY		1%	19,416	15,517
			Sub-total	**2,232,880**	**1,784,462**
SEVERANCE PAY&SU NDRIES			1.5%	33,493	26,767
ANNUAL COST OF OP ERATIVE				**2,266,373**	**1,811,229**
Divide by Total Productive Hours			1,925		
	TOTAL HOURLY RATE			**1,180**	**940**

In order to calculate the all-in hourly rate, that is the hourly rate charged by a contractor for a construction operative, the estimator must first decide on the following:

- The number of hours worked per week.
- Overtime rate – assumed to be time and a half.
- Annual holidays.
- Public holidays.
- Sick pay
- Social security

Indicative content 3.2.5: Determination of execution delay

Construction delays are considered as time lag in completion of activities from its specified time as per contract or can be defined as late completion or late start of activities to the baseline schedule, directly affecting specified cost. As a result, there will be extensions of time required which will further result in fine, increased cost due to inflation, termination of contract, court cases etc. or combinations of above stated factors, resulting in delay damages.

Delay in construction project has a negative effect on clients, contractors, and consultants in terms of growth in adversarial relationships, mistrust, litigation, arbitration, and cash-flow problems.

In determining whether there is an execution delay, however, it is important to understand the types or categories which a delay falls into before analyzing construction delays.

The delays are classified or categorized into four basic ways:

A) Critical or non-critical Delays:

A delay that is responsible for extending project duration is a **critical delay**. The delay is going to extend your project's completion date and will require you to update your project plan. Critical delays need to be resolved immediately. Few results are mentioned below:

- Extended Field Overhead
- Unabsorbed home office Overhead
- Liquidated Damage
- Idle Labor & equipment cost
- Labor & Material Cost Escalation and many more.

A delay that is not the cause of extended project duration is a **non-critical delay**; however, it will have an effect in terms of activities getting completed late than scheduled completion. These activities will also affect project cost estimates as reiterated below;

a) Idle labor & equipment cost

b) Labor & Material Cost Escalation and many more.

B) Excusable & non-excusable Delay

A delay where the contractor is entitled for extension of time or compensation or both, under the terms & conditions of contract is **excusable delay**. In this case, contractor does not have any control on the activity getting delayed.

The causes may be:

1. Force Measure Clause

2. Natural Calamities

3. Political / Social Unrest

4. Terrorist Attacks

5. Delay from Client (Approvals, Decisions), etc.

A delay where the contractor is fully responsible for the activities getting delayed and resulted in extending project duration (responsible for critical delays) are **non-excusable delays**. In this case, the contractor has to bear the risk of cost consequences including the liability to pay damages for itself but possibly for the other parties as well.

The causes may be:

- Delayed mobilization
- Delayed Procurement
- Delayed submission of important documents
- Planning &Scheduling
- Critical events that were not highlighted to client on right time, etc.

C) Concurrent Delays in Construction Projects

A situation where more than one delay event occurs at the same time affecting multiple activities simultaneously/independently affecting the completion is **concurrent delay**. However, not all those events enable the contractor to be entitled for extension of time & cost claim.

D) Compensable or non-compensable Delays in in Construction Projects

Scenario where contractor is liable for Time Extension & Cost compensation is **compensable delays**. However, non-compensable may fall under critical, noncritical, excusable or non-excusable; depending upon the situation it has created and conditions of contract.

Indicative content 3.2.6: Clarification of Job average labor rate

The job average method is one way of determining the labor rate for a job. This method requires you to anticipate the job crew, their skills, and their wage for the duration of the job. To determine this rate, calculate the number of persons on the job and their average rate. Naturally, this requires you to know the difficulty level of the job and how you expect to man the job.

Indicative content 3.2.7: Clarification of labor Burden

In calculating the labor cost, you also must not forget to include in the estimate other related labor costs such as payroll taxes, insurance, vacation pay, holiday pay, sick pay, and pension. Typically, labor burden represents 38% of your total labor cost.

The labor burden includes items such as taxes, insurance, etc. which employers are required by law to pay as well as fringe benefits negotiated between employers and employees either individually or collectively through a trade union.

So what are some of the possible components of “fringes” or “burden” labor cost.

i. **Social Security:** A statutory program designed to bring eventual retirement, medical, survivor, and other benefits to employees or their beneficiaries. It is funded equally and jointly on a per pay period basis by employees and employers. The estimator is concerned only with that part of social security cost borne by the employer since that portion paid by the employee is deducted from base salary.

ii. **Unemployment Insurance:** It is a program designed to provide protection to workers during times of unemployment. It is employer paid.

iii. **Worker’s Compensation Insurance:**

Designed to provide protection to employees who are killed, injured, or suffer health problems due to job related accidents or conditions.

The percentage is determined by the medical reports and the degree of incapacity. The premiums payable are normally negotiable and range from 1½%- 3%.

iv. **Vacations**: For salaried employees, the cost is included in the annual salary amount. For hourly wage employees, it is considered to be an added cost since it is assumed that they will be physically on the job at all times.

v. **Medical Insurance:** The cost is borne either in whole or in part by the employer.

vi. **Other Insurance:** May include either group life or accident insurance. These are handled in a manner similar to medical insurance.

Other benefits: May include pension plans, on-duty training, or off-duty education assistance.

vii. **Other benefits:** May include pension plans, on-duty training, or off-duty education assistance.

Indicative content 3.2.8: Preparation of final document on bill of quantity include materials cost and labor cost.

To ensure you are properly preparing a final document on BOQ, **take these steps and tips into consideration:**

(A).**Estimating Overhead Costs**: First, knowing your overhead costs is key to establishing a base figure for an estimate. What it costs to run your business, like rent and utilities for your shop, administrative personnel, insurance, and taxes, is essential information to know, so you can ensure those costs are considered when compiling an estimate.

(B). **Estimation Labor Costs**: An important factor in your estimate is your labor costs. Calculate your labor costs and take into consideration any costs for contractors you may use. Make sure you get accurate estimates for work from contractors if you use them. Also, consider the need for overtime pay if the job is one that requires the extra labor.

(C). **Estimating Construction Materials**: Materials are also a primary consideration in any estimate. Have an accurate estimate on the items you will need to complete the job. Here you will want to take into consideration the need for any special tools or equipment that may be needed to complete the job.

(D). **Summing Up Electrical Estimating Costs**: Once you have your labor, materials, and overhead figured out, determine an amount that pays you for your time and expertise. Total all of these costs, and add a ten percent cushion to the total to get your estimate.

Indicative content 3.2.9: Format of cost report

Cost reporting is a process used to inform a client (or other party) about the magnitude of a construction projects predicted, or actual Cost. This can be expressed either in absolute terms or as a variance compared to the project budget. The first step when cost reporting is to ascertain what the production/series cost to date is.

A. **Cost to date can be defined as follows**:

Cost to date = costs invoiced/paid to date + costs incurred but not yet invoiced/paid to date (accruals)

B. **Costs invoiced/paid to date**

The costs invoiced or paid to date are a statement of fact and can be determined by referring to the expenditure codes on the trial balance at the cost report date. For completeness, all received invoices and petty cash should be on the system and both bank and petty cash reconciliations performed up to the cost report date.

C. **Costs incurred but not yet paid/invoiced (accruals)**

These are the costs for goods and services that have been used or consumed at the cost report date but no invoice has been received or cash paid out yet.

Learning outcome 3.3 Calculate labour cost

Duration: 5 hrs

Learning outcome 3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Prepare cost report format and final document
2. Determine appropriate labour rate per man-hour and the anticipated labour required to complete the task.

Resources

Equipment	Tools	Materials
• Laptop • Calculator	• Pen	• Sheet • Notebook

Advance preparation:

The labor cost per unit is obtained by multiplying the direct labor hourly rate by the time required to complete one unit of a product.

Indicative content 3.3.1: Calculate labor cost

1. How to calculate labor cost

Estimating the labor cost for a job is just as important, and it can be the difference between making money and losing it. To determine the estimated labor cost for a job, **multiply the total adjusted labor man-hours by the labor rate per man-hour.**

First, you must determine the anticipated labor required to complete the project (total adjusted labor man-hours). Use the time-tested labor units based on the material needs of the project, adjusting those labor units to accommodate the expected working conditions of the job, and then add any additional labor not included in the original take-off.

Second, determine an appropriate labor rate per man-hour. Again, this is not as easy as you might think. The labor cost per man-hour is significantly different in different areas of the country. For example, in Karongi, a qualified licensed electrician might have a base pay rate of less than 1400Rwf per hour. In Kigali, the base pay rate might be over 1700 Rwf per hour. To determine the labor rate per man hour, you have to know the location of your project.

Indicative content 3.3.2: Techniques of controlling labour cost

Techniques of controlling labour cost can be effectively used by **coordinating the activities of various departments concerned with the labour, namely:**

(A) Personnel Department

The Board of Directors lays down the policies relating to the recruitment, training, placement, transfer and promotion of employees. The main function of this department is recruiting workers, training them and their placement in suitable jobs.

Employee Placement Requisition

This is a document initiated by a department which is in need of employees. On receipt of the requisition, the personnel department initiates action to appoint workers by receipt of applications, scrutiny of applications, interviewing of applicants and finally selection of suitable candidates the proforma of employee placement requisition is given below:

XYZ Co.

Employee Placement Requisition

Department .... Date ....

No. ....

Please provide workers as per the following details, with effect from ....

S. No.	*Categories*	*No. of Employees required*	*Job Specification*	*Description*
Prepared by			*Authorised by*	

All the workers are appointed as per labour budget. The budget specifies number of workers to be appointed and skills required. It is the task of the personnel department to adhere to the budget and appoint additional workers only if sanctioned by competent authority.

Employee History Card:

The personnel department maintains full details of workers employed. The particulars of each employee are maintained on employee's history card.

The card contains all the relevant information like:

a) Name and address
b) Number
c) Department
d) Date of employment
e) Category
f) Educational qualifications

g) Experience
h) Name of former employer and reason for leaving him
i) Scale of pay
j) Skills
k) Promotions
l) Reason for leaving.

These details will help the management to assess the employees and particularly the last column will help the management to prevent labour turn over.

Specimen form of employee history card is as follows:

XYZ Co.

Employee's History Card

Name ____________ Category ____________

Number ____________ Grade ____________

Department ________ Scale of Pay ______

Address

Date of Birth ___________

Material Status ________

Date of Appointment _________

Educational Qualification ________

Previous Employer ____________

Reason for leaving previous employer _______

Reason for leaving:

Particulars of service regarding changes in pay

Date	*Grade*	*Pay*	*Reason for change – Promotion, Increment, etc.*	*Remarks*

Leave Record

Date	*Details of Eligible Leave*	*Leave applied*	*Reasons for leave*	*Balance of Leave*

In order to have optimum number of suitable workers, control over recruitment of workers is essential.

The following measures will help to control labour recruitment:

1. Recruitment is to be routed through the personnel department.
2. Recruitment is made as per labour budget.
3. Recruitment is to be made only on receipt of employment placement requisition.

4. Additional labour over and above the budgeted labour has to be recruited only if the sanction is made by appropriate authority.

5. Recruitment of casual workers is to be properly sanctioned.

6. Mechanization is to be introduced wherever possible.

7. Labour utilization reports are to be insisted from all departments concerned to enable the management to take decisions regarding the surplus workers, employment of casual labour, utilization of surplus labour, reduction of labour, reduction of labour turnover, etc.

(B) Engineering and Work Study Department

This department is concerned with improving working conditions by undertaking the following activities:

1. Conducting work studies such as methods study, motion study and time study for each operation.
2. Maintaining required safety standards.
3. Conducting job analysis and job evaluation.
4. Preparing specifications and time schedules for each job.
5. Devising suitable wage system, and
6. Conducting research and experimental work.

The engineering department is basically concerned with work content, standard time, work performance, etc.

They are achieved by conducting detailed work study which includes method study, motion study and time study.

Work study

Work study is study of technical aspects of production. It involves a detailed study of processes, operations, evaluation and analysis of jobs and work measurement. Therefore, work study involves methods study, motion study and time study.

(i) Methods Study: It is a procedure to analyze the work to remove unnecessary operations or practices, systematic arrangement of remaining work and standardization of work methods. It is only after deciding the best method of doing the work those motion study follows.

(ii) Motion Study:

This is a vital part of work study which divides the work into several important elements. Each of these elements is analyzed in detail separately and in relation to each other.

Main purpose of motion study is to standardize the method of working by economizing efforts, reducing fatigue and improving efficiency.

(iii) Time Study:

Fixing of standard time for each operation is called 'Time Study'. It is also called **work measurement**. A standard hour is fixed for each operation which is a hypothetical hour which measures the amount of work to be done in one hour.

Job analysis

Job analysis is a process of determining the list of qualifications to be possessed by workers to perform the work effectively.

Thus Job analysis is the study of the job and identifying the duties and responsibilities involved in the performance of the job, conditions for performance, nature of the job, qualifications to be possessed, opportunities and privileges.

Elements of Job Analysis:

Information relating to a job can be analyzed under two sub-heads:

1. Analysis of Information Relating to the Job:

Under this analysis the requirements of the Job are analyzed. The requirements are known as Job descriptions.

2. Analysis Relating to the Jobholder:

Under this analysis qualities to be possessed by the employee are analyzed. The qualities to be possessed by the job holder are called job specifications.

Advantages of Job Analysis

1. **Fixation of Suitable Rates of Pay**: Since rates are fixed according to the nature of work of each job, the rates fixed will be suitable and equitable.

2. **Elimination of Personal Prejudices:** Since the rates are fixed on the basis of job content rather than individual workers worth, disputes relating to pay disparities are avoided.

3. **Effective Recruitment:** Job analysis ensures the policy of right man for the right job or "no square pegs in round holes" as the job description and job specifications are the main elements of job analysis.

4. **Effective Training:** Job analysis procedure leads to identifying the qualifications and skills required for each job. Thus workers can be given training in the skills needed for a specific job.

Job evaluation

(1) Meaning and Purpose:

Job evaluation is the process of studying and assessing the relative values of jobs within an industry, to ascertain their comparative worth.

In addition to indicating relative wage value, job evaluation serves the following varied purposes:

a) It helps to know whether workers are placed in jobs best suited to them and to the advantage of employers.
b) It assists the personnel department in recruitment of workers by indicating the responsibilities, requirements and conditions of work and qualities required for each job.
c) Job evaluation forms the basis for training schemes.

Advantages of Job evaluation

(I) To the Employer

(a) As the qualities required for a job are specified, the recruited employees will be suitable for jobs.

Therefore there are ‘no square pegs in round holes’.

(b) As the labour worth is ascertained by job evaluation, the wage fund is fairly distributed.

(c) Jobs evaluation helps in minimizing the labour turnover.

(II) To the Employee

(a) The jobs are best suited to the employees as they are appointed to jobs based on the requisite qualities, skills and experience.

(b) Job evaluation reveals comparative worth of a job and any prospects it has for the employee.

(c) It makes workers happier as the total wages are distributed among the workforce fairly.

(3) Job Evaluation Procedure

(a) Detailed study of the jobs
(b) Description of Jobs
(c) Job analysis
(d) Arrangement of Jobs in Progression
(e) Determining the wage value of Job

(4) Methods of Job Evaluation:

There are four methods of job evaluation as explained below:

(a) Ranking Method:

Under this method the jobs are graded from the highest to lowest according to their relative responsibilities and complexities and not in terms of wage rates. This method is simple and suitable in case of small factories. It is limited in effectiveness as accurate measurement of work is not done.

(b) Grading or Classification Method:

Under this method, the basis of evaluation is defined and the jobs are classified into different grades. For example, grades may be classified as Skilled, Unskilled, Supervisory, Executive and Administrative.

(c) Factor Point Scoring

Job evaluation under this method is done by comparing and analyzing jobs into common factors. Points are allotted to each factor according to its relative importance.

Following are the common factors generally recognized:

a) Education
b) Experience and Skill
c) Complexities of duties
d) Responsibilities
e) Effort, and
f) Working conditions

The main advantages:

- It is simple to operate and the results are accurate.

The main disadvantages

- The points are not clearly defined.
- The points to each factor are not scientifically allocated.
- Jobs requiring unusual expectations cannot be analyzed by fixed factors.

(d) Factor Comparison Method

a) Mental requirements
b) Skill requirements
c) Physical requirements
d) Responsibility
e) Working conditions.

The factors are valued by apportioning existing rate of pay among each of them. The jobs are compared factor by factor with the scales of 'Key Jobs'. The total of values of all the factors is the cash rate for each job.

(e) Merit Rating: Merit rating aims at evaluating the performance of workers. Main objective of merit rating is to reward the employee on the basis of efficiency and merit. Merit rating brings out the comparative worth of workers.

The traits generally considered for determining merit and worth of workers are as under:

(1) Educational Qualification and knowledge
(2) Skill and experience
(3) Attitude to the work
(4) Quality of work done
(5) Efficiency
(6) Regularity
(7) Integrity
(8) Reliability
(9) Qualities like leadership, initiative, self-confidence and sense of judgement
(10) Discipline, and
(11) Cooperation.

The above traits are allotted with points and total points scored on all traits determine the worth of workers. The employees may be rated individually as per the points they score and they may be put in groups based on their common scores of points.

Importance of Merit Rating: Merit rating is a valuable tool considered to be important for human resource measurement.

Merit rating has the following advantages:

(1) It helps to know the individual worker's worth and traits; this helps the supervisor to assign the tasks in which the worker is proficient.
(2) It points out traits in which the workers are not proficient. The workers will have an opportunity to improve by suitable training.
(3) It helps in increasing wages and promotion opportunities.

(4) It helps to stimulate the self-confidence of workers as it recognizes the merit and worth of workers.

Limitations of Merit Rating:

(1) The worker may be rated high based on a single trait. The rater may ignore the other traits in which the worker may not be good.
(2) The difference of opinion between the members of merit rating committee may lead to unsatisfactory evaluation.
(3) The men doing the rating may be influenced by their personal ill feelings towards particular workers which may lead to unsatisfactory ratings.

(C) Time-Keeping Department

This department is concerned with maintenance of attendance time and job time of workers. Attendance time is recorded for wage calculation and job time or time booking is considered for computing time spent for each Department, Job, Operation and Process for calculating labour cost department wise, job wise and of each process and operation.

Objectives of Time-Keeping:

(1) Ensures regularity of employees
(2) Enforces discipline among work force;
(3) Satisfies safety requirements
(4) Useful for preparation of payroll, and
(5) Keeps track of normal! Time, late attendance and early leaving of workers.
(6) Used for Overheads absorption on the basis of labour hours.

Depending on the size of the organization, a separate time office may be maintained at the gate of the factory. If the firm is small personnel of the gate office may take care of time recording. Since payments of wages are on the basis of time spent by the-workers, accurate time recording is essential.

Essentials of a Good Time-Keeping System

(1) Good time keeping system prevents 'proxy' for one another among workers.
(2) Time-keeping has to be done for even piece workers to maintain uniformity, regularity and continuous flow of production.
(3) Both the arrival and exit of workers is to be recorded so that total time spent by workers is available for wage calculations.
(4) Mechanized methods of time keeping are to be used to avoid disputes.
(5) Late arrival time and early departure time are to be recorded to maintain discipline.
(6) The time recording should be simple, quick and smooth.
(7) Time recording is to be supervised by a responsible officer to eliminate irregularities.

Methods of Time Keeping

There are two methods of time keeping:

1. Manual methods.
2. Mechanical methods.

1. Manual methods

1.1. Attendance Register Method:

This is one of the traditional methods of time keeping. An attendance register is kept at the time office adjacent to the factory gate or in each department for the workers of that department. The register contains details regarding name of the worker, worker's number, department in which he is employed, arrival time, departure time, normal time, over time, etc. The arrival and departure times may be recorded by the time keeper.

1.2. Metal Disc Method:

Under this method the workers are allotted a disc or token with a hole bearing the identification number of the workers. The discs or tokens are hung in board with pegs. Board may be maintained separately for each department. The workers remove their tokens as they enter the factory and put them in a specified box.

Once the scheduled time lapses the box is removed. The workers who come late have to remove their token and handover to time keeper who will record exact time of arrival. If any tokens remain they indicate the absentee workers. Later on the time keeper records the attendance in a register known as '**Daily Muster roll'** which is used by the payroll department to prepare wage bill and wage slips.

This method is simple and easy to follow. It can be followed even if there are illiterate employees. They can easily identify their tokens. It is usable by companies which are large in size with more number of workers.

But it has certain disadvantages-

(a) An employee may remove his companion's token to have the attendance marked even when his companion is absent.

(b) Disputes may arise regarding the arrival time of the workers as the time keeper may commit mistakes.

(c) There is possibility of time keeper including dummy or ghost workers in the muster roll.

(D) Pay Roll Department

This department prepares the pay bill of the entire organization.

The objectives of the pay roll department are mentioned below:

(1) Maintaining a record of Job, department and wage rate of each worker and to arrive at each worker's total earnings, deductions and net earnings.

(2) Ascertaining wages of different cost centres.

(3) Summarizing the total deductions to post them to the accounts concerned.

(4) Ascertaining the total hours of each cost centre to calculate labour cost and rate per hour for control purpose.

(5) Ascertaining overtime and idle time wages.

(6) Providing internal check system in payment of wages.

Preparation of Pay Roll:

On the basis of time cards the departmental payroll or wage sheets are prepared. A full-fledged pay roll shows the gross wages, various deductions and net wages payable. The pay roll is the basis for ascertaining wages and posting entries to various control accounts. The details of pay roll depend on requirements of the organization.

The following is the specimen of pay roll:

ABC Co. Ltd.
Pay roll

Dept/Cost Centre — Week ending ......

Name	No. of worker	Rate	Total hours	OT hours	Wages	D.A	Other Allowances	Gross wages	Deductions					
									ESI	P.T	IT	Others	Total deductions	Net wages
Total														

Prepared by .... — Checked by ....

Preparation of pay roll has two aspects; one is to arrive at gross wages payable in the form of wages including over time premium and allowances. The second aspect of pay roll is to compute deductions in the form of ESI, PF, Income Tax, recovery relating to loans and advances, etc. Most of the firms prepare this nowadays through computers.

(E) Cost Accounting Department

The department is responsible for ascertaining correct cost of production.

Cost ascertainment involves classification, collection and computation of labour cost of output. In most of the organizations a representative of cost department is posted in the production department to accumulate and classify the cost. The cost accountant supervises the work of the representatives and uses the information contained in time cards and pay roll to find the labour cost of production by production departments, operations, production orders, etc.

The cost accounting department also analyses the labour cost in the form of idle time and overtime. Labour cost reports are also submitted to the management to intimate the effectiveness of labour utilization

Theoretical learning Activity

- ✓ **Discuss on the Methods of Time Keeping**

Points to Remember (Take home message)

measures that will help you to control labour recruitment:

- Recruitment is to be routed through the personnel department.
- Recruitment is made as per labour budget.
- Recruitment is to be made only on receipt of employment placement requisition.
- Additional labour over and above the budgeted labour has to be recruited only if the sanction is made by appropriate authority.
- Recruitment of casual workers is to be properly sanctioned.
- Mechanization is to be introduced wherever possible.

Learning outcome 3.4. Elaborate cost report

Duration: 5 hrs
Learning outcome 4 objectives: By the end of the learning outcome, the trainees will be able to: 1. Prepare final document 2. Elaborate cost report
Resources

Equipment	Tools	Materials
• Laptop • Calculator	• Pen	• Sheet • Notebook

Advance preparation: This guidance note sets out the principles of cost reporting from the perspective of the quantity surveyor to the client during construction. This guidance note explains the purpose of cost reporting, the factors affecting outturn cost and explores the different formats and types of cost report.

Indicative content 3.4.1: Purpose of cost reporting

The purpose of cost reporting is to inform the client in a construction project of the likely outturn cost of the construction project. The forecast of outturn costs may be expressed as a variance against a budget amount, or expressed in absolute terms.

1. A cost report will record:

- All costs incurred at the date of the report, where they are known and can be accurately valued in accordance with the particular contract conditions
- All costs incurred at the date of the report, where they are known and can be estimated in accordance with the particular contract conditions
- The forecast of costs to be incurred as can reasonably be foreseen at the date of the report and estimated in accordance with the particular contract conditions; and
- The risk allowances necessary as can reasonably be foreseen at the date of the report.

2. Cost reporting models

Costs can be reported at three basic levels in a construction project: A construction cost report captures historic and forecast costs incurred under a construction contract.

Indicative content 3.4.2: Contract arrangement

Examples of typical cost report headings for common contract arrangements include:

1. Lump sum contracts

- Contract sum
- Adjustment of variable costs
- Adjustment of variations
- Adjustment of fluctuations
- Claims for loss and/or expense; and
- Adjustment of risk allowances.

2. Remeasurable contracts

- Contract sum
- Adjustment of remeasurable work
- Adjustment of variable costs
- Adjustment of variations
- Adjustment of fluctuations
- Claims for loss and/or expense; and
- Adjustment of risk allowances.

3. Reimbursable contracts

- Contract sum/target cost
- Adjustment of reimbursable costs incurred
- Forecast of reimbursable costs to be incurred
- Adjustment of risk allowances.

4. Management contracts

- Contract sum/target cost
- Adjustment of management fee
- Adjustment of reimbursable costs incurred
- Forecast of reimbursable costs to be incurred
- Adjustment of risk allowance.

5. Construction management contracts

- Construction management fee
- Adjustments to the construction management fee
- Adjustments to the trade contracts
- Adjustment to project risk allowances.

Indicative content 3.4.3: Cost report

A project cost report captures historic and forecast costs across a construction project.

Typical cost report headings are given below:

- Construction costs
- Professional fees
- Statutory fees and charges
- Third-party costs
- Direct works costs
- Land costs
- Agency costs
- Finance cost; and
- Legal fees.

The quantity surveyor may be asked to produce a project cost report and draw specific cost advice from other individual budget holders or advisers. The quantity surveyor should include a note in the cost report to draw attention to the costs provided by others and exclude liability for the accuracy of these costs.

A programme cost report captures historic and forecast costs across a programme of construction works. Typical cost report headings are given below:

- Programme management office costs
- Project costs.

Detailed cost reports can be prepared to give a greater level of detail within a construction project.

Some examples are given below:

- **Elemental cost reports:** report costs at an elemental level. This type of cost reporting can assist in value management and value engineering when budgets have been established for each project element.
- **Building cost reports:** cost reports for individual buildings across a project comprising several buildings.
- **Budget holder reports**: cost reports prepared for the elements of the construction works under the control of individual budget holders. A budget holder may be a specific designer of the project i.e. architect, building services engineer, structural engineer.
- **Stakeholder reports:** cost reports prepared for individual stakeholders in projects with multiple stakeholders.

3. Report formats

There is no single type of cost report format recommended. Most professional practices have a preferred or standard format which is used in the absence of specific client requirements.

Example of report

A simple cost report should include the following headings:

Authorized expenditure

Contract sum	10,000,000
Additional authorized expenditure	400,000
Total authorized expenditure	10,400,000

Adjustment of provisional sums		20,000
Adjustment of prime cost sums		(120,000)
Adjustment of provisional quantities		20,000
Contract instructions		250,000
Anticipated instructions		100,000
Fluctuations		10,000
Loss and/or expense		120,000
Risk allowance for remainder of contract		150,000
Direct works		0
Total forecast cost		**10,250,000**
Remaining authorized expenditure		150,000
Forecast cost		
Contract sum	10,000,000	
Less risk allowances	(300,000)	
	9,700,000	
		10, 400,000

The format of the cost report should be discussed and agreed with the client at the outset.

Indicative content 3.4.4: Preparation of final document on bill of quantity include materials cost and labour cost

PREPARE BILLS OF QUANTITY

Planning an electrical project? You might need a bill of quantities (BOQ). A BOQ itemizes the specific materials and labor needed for the project so you can get accurate bids from contractors. In the field, BOQs are typically prepared by quantity surveyors or civil engineers who specialize in them. But even if you don't regularly prepare BOQs, it's worth knowing how they're made so you can evaluate the quality of the ones you see. Read on to learn everything you need to know about how to prepare an organized and reliable BOQ, as well as how to put this document to work for you during the planning and construction process.

The point to note while you are making BOQ

- Use a BOQ to specify all of the materials you'll need for a project.
- Make a simple spreadsheet to easily organize your BOQ.
- Choose the best contractors for your project based on their BOQ cost estimates.
- Continue using your BOQ throughout your project for scheduling and cost planning.

1. **Create a spreadsheet to organize your BOQ.**

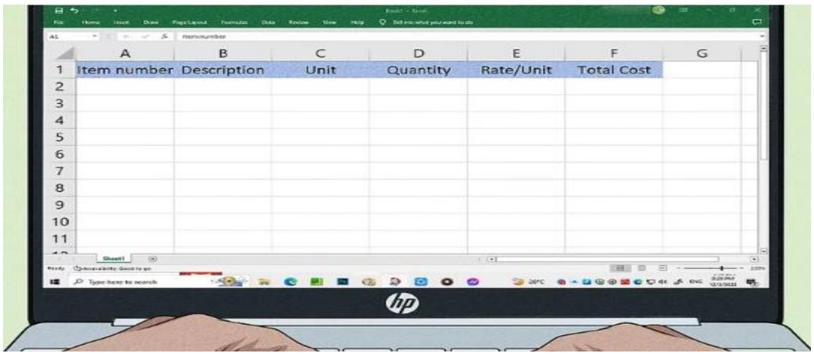


Figure 53: Create a spreadsheet to organize your BOQ

Use the spreadsheet to list materials you'll need to complete your project. Set up your spreadsheet so that each row is a material you'll need to complete your project. Use the columns to organize the following information about each material:

- ✓ Item number (could be a serial number or part number)
- ✓ Description
- ✓ Unit of measurement
- ✓ Quantity
- ✓ Rate per unit (to be filled in by contractors bidding on the project)
- ✓ Total cost of material (to be filled in by contractors bidding on the project)

2. **Compile a list of materials needed for your project.**

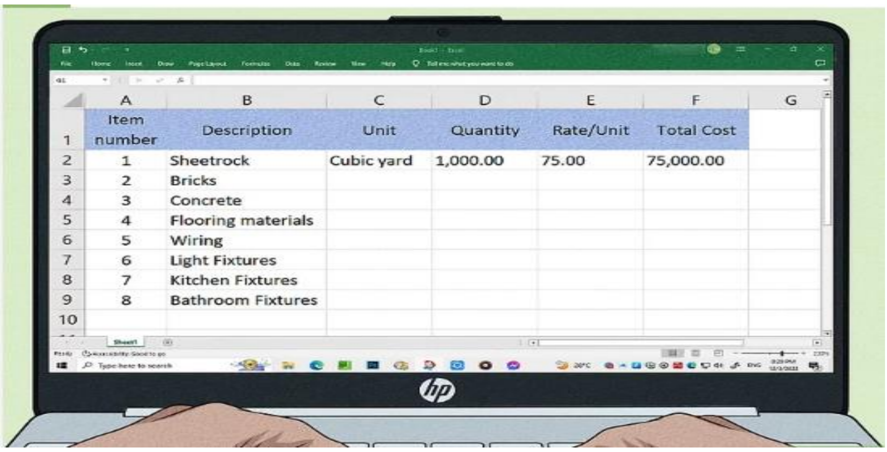


Figure 54:1.Compile a list of materials needed for your project

Pull materials from the architect's plans. The architect's plans include specifications for various building materials used to complete the design. Write down dimensions as well—these will come in handy when you're estimating the amount of a material you'll need.[2]

The name and specifications for each material go into the "description" column of your BOQ spreadsheet. For example, if you're building a house, you might need framing materials, sheetrock, bricks, concrete, flooring materials, wiring, lighting fixtures, and kitchen and bathroom fixtures.

Be as specific as possible with your description. Include the dimensions of the surface or area, the thickness of the material you need, and any other details that might impact the quality of the material.

3. **Break down your project into categories.**

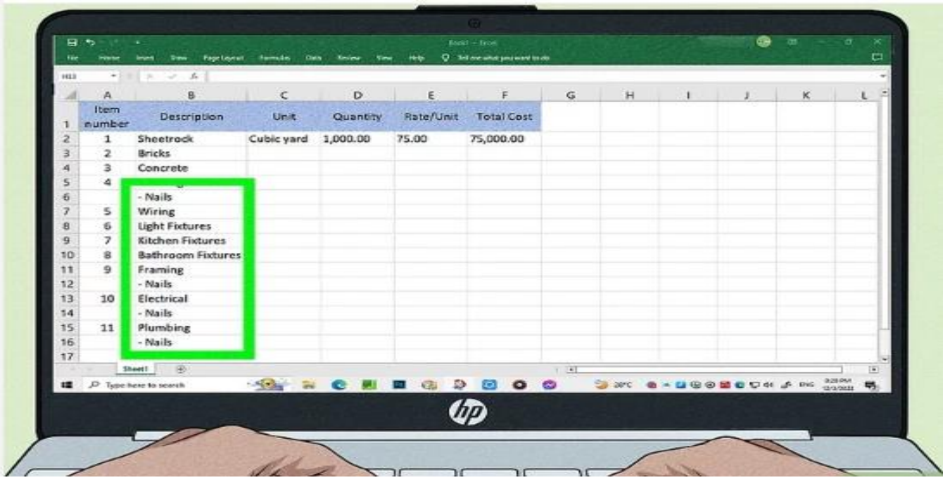


Figure 55: Break down your project into categories

List specific materials needed in each category, even if they repeat. Different parts of your project will likely be handled by different contractors. Your BOQ tells each contractor what they will need for the project so they can prepare their bid. This doesn't mean you need a new spreadsheet for each category—just divide one spreadsheet into sections.[3]

For example, if you're building a house, you might have separate categories for framing, electrical, plumbing, and flooring. Since both framing and flooring require nails, each of these categories would have a row for "nails" under each category.

Traditionally, each row is numbered consecutively from "1," with the numbers starting over for each category or section.

4. **Provide the quantity you need of each material.**

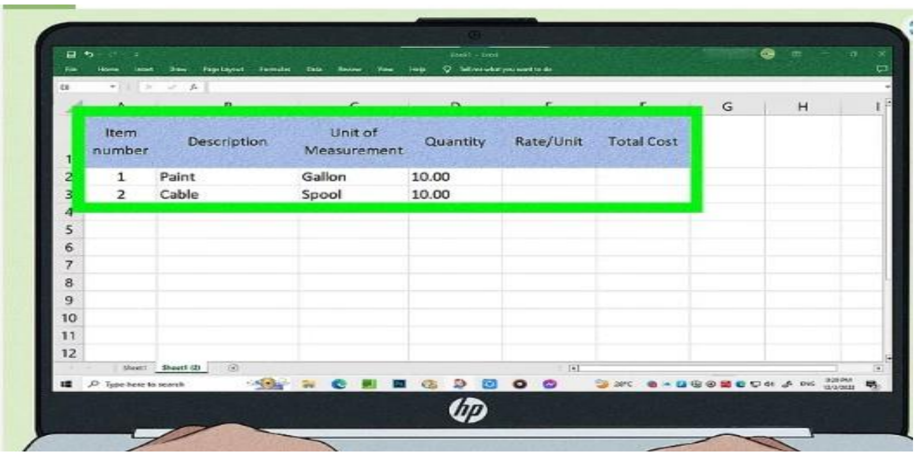


Figure 56:Provide the quantity you need of each material.

Enter the unit of measurement for each material, then the amount you need. In the column you created for "unit of measurement," enter the unit used for each material. These are usually standard units, such as feet (meters) or gallons (liters). Then, in the "quantity" cell, enter the amount of that unit that you need for that material.[4]

For example, if part of your project includes painting a room, you might list "gallon" as the unit of measurement for the paint, then "10" as the number of gallons of paint you need.

Add 15-20% to each material calculation to account for waste.

Sometimes your unit of measurement will reflect how that particular material is sold. For example, if cable is one of your materials, and that cable is sold in spools of a standard size, you could use "spool" as your unit of measurement.

5. **Estimate the labor needed in each category.**

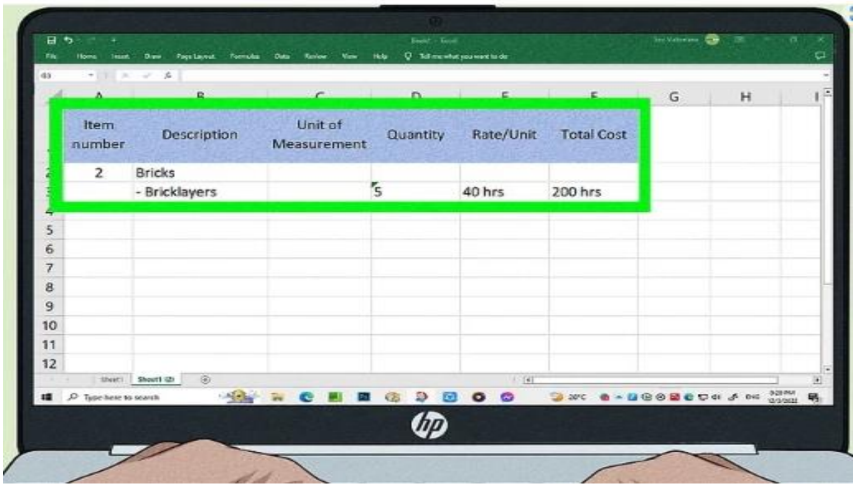


Figure 57:Estimate the labor needed in each category

Quantify labor in terms of the man-hours needed to complete a task. A man-hour is, roughly, the amount of work that can be done by a single person skilled at that work in one hour. How you specifically define this depends on the size and scope of your project and the type of labor you need.

For example, if a brick wall is part of your project, you would need to know how many bricks the average bricklayer can lay in one hour—that would be your man-hour, roughly, although it would also need to account for other aspects of bricklaying, such as mixing mortar.

Different contractors may work with different crew sizes. Your total number of man-hours helps contractors figure out what size crew they need for the job. Based on the number of bricks you need for your brick wall, it might take 200 man-hours for the build. But for a team of 5 bricklayers could get it done in 40 hours—so maybe a week to 10 days.

On top of your basic man-hours include time for rest breaks and meals. This is still a very conservative estimate because you can't account for things that might happen once work starts.

Talk to contractors to get an idea of how long it would take to complete a given task. A quantity surveyor would usually be able to estimate this off the top of their head, based on their experience with similar projects.

6. **Make an initial cost estimate for the project.**

Figure 58: Make an initial cost estimate for the project

Evaluate bids from contractors based on the cost estimate you draw up. Figure out the average prices for materials and labor in your area by calling suppliers and talking to contractors. BOQs from similar projects that were recently completed can also help you come up with a cost estimate.
Your initial cost estimate gives you a benchmark that helps you rate the feasibility of the bids you get in. Don't include these numbers in the BOQs you give to contractors—just keep it for your own reference.
It might not be strictly necessary to make an initial cost estimate for every project, but they can actually save you a lot of time on larger projects where you have a lot of bids to sort through.

7. **Draft a project schedule based on your labor estimates**

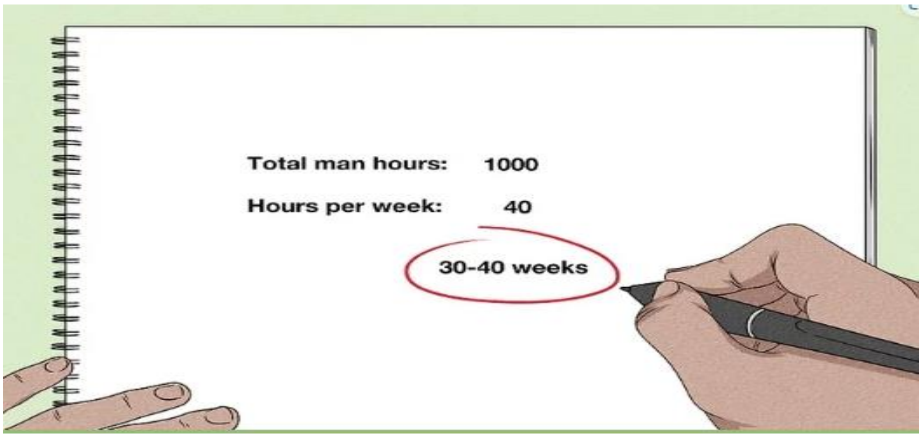


Figure 59:Draft a project schedule based on your labor estimates

Set a timeline for completing each construction task. The man-hours you've calculated will give you a rough idea of when each task needs to be done. It's a loose schedule since you can't account for a lot of things, such as weather, that could cause delays. But even a loose schedule helps potential contractors figure out if they can work on the project.
For example, if you've estimated it will take a total of 1,000 man-hours to build your house, it would take 25 hours for contractors to complete the build (assuming they all work 40 hours a week with no delays). You might set a schedule for 30-40 weeks.

8. **Solicit bids from contractors with your BOQ**

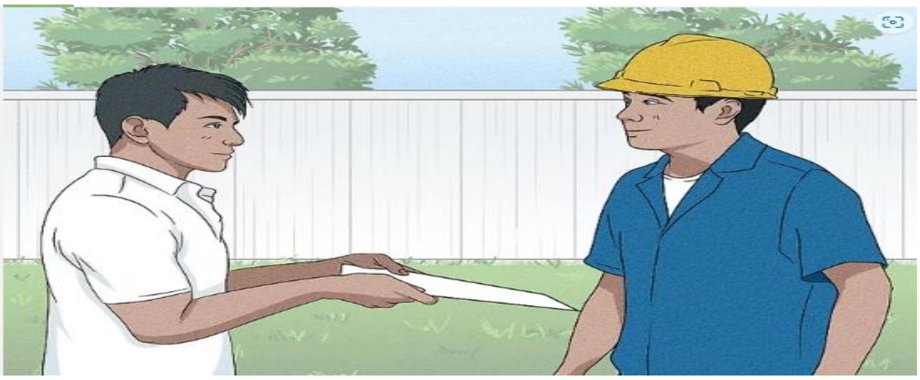


Figure 60:Solicit bids from contractors with your BOQ

Call contractors and provide them with a basic run-down of the project. If the contractor says they're interested and have the time to commit to your project, go ahead and forward them your BOQ. They'll go through it and enter their estimates in the columns for "rate per unit" and "total cost.
If you have experience managing a building project, you can save some money by overseeing the project yourself. Otherwise, you'll likely want to hire a main contractor to manage and supervise the project.
Always verify the contractors' licenses and check their references before you solicit bids from them.
Ask your architect or quantity surveyor for contractor recommendations. They tend to know people in the industry and can tell you who you should talk to (and who you should stay away from).

9. **Evaluate contractor bids for specific jobs.**

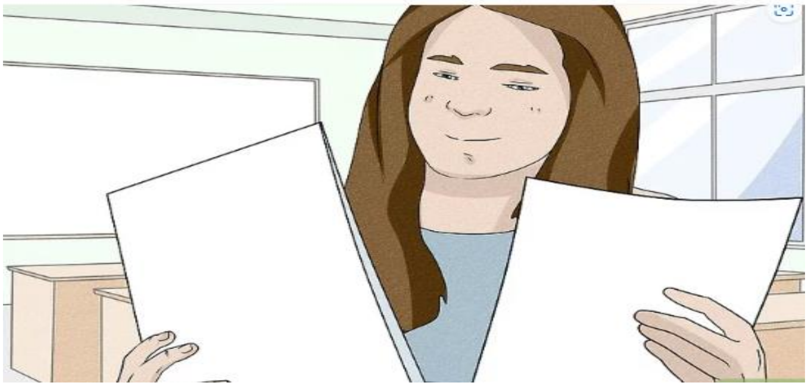


Figure 61:Evaluate contractor bids for specific jobs

Use your BOQ to compare contractor bids so you can choose the best fit. With a BOQ, each contractor who bids on a project is using the exact same materials and labor estimates as the basis of their bid. You can easily compare the numbers they've provided without needing to break them down at all.

This is where your initial cost estimate comes in handy. If a contractor submits a bid significantly lower than your initial cost estimate, you know to be skeptical.

10. Refer to your BOQ throughout the project.

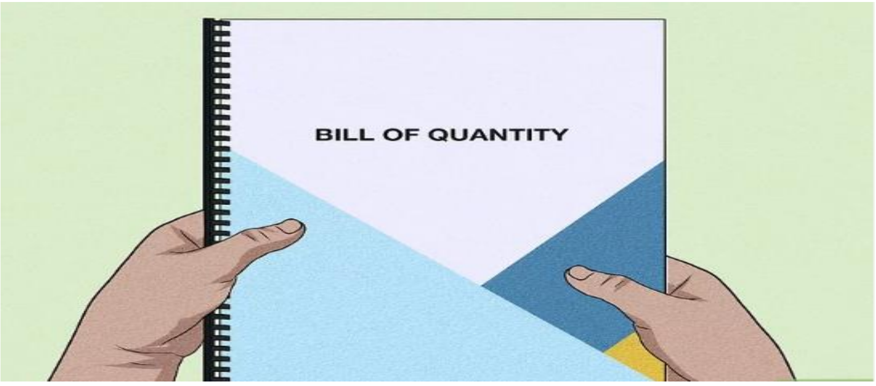


Figure 62:Refer to your BOQ throughout the project.

Use your BOQ for material scheduling, cost analysis, and other project planning. As your project progresses, your BOQ gives you a good idea of what's coming up next so you can plan ahead. Knowing what needs to happen and when keeps you flexible so you can adjust your plans as needed to account for any unforeseen delays.

For example, what if there's a shortage of a particular material you need to complete the flooring? Looking at your BOQ, you could push ahead with another part of the project that isn't dependent on flooring so your project stays on schedule.

Theoretical learning Activity

- ✓ Discuss on the preparation of BOQ

Points to Remember (Take home message)

The point to note while you are making BOQ

- Use a BOQ to specify all of the materials you'll need for a project.
- Make a simple spreadsheet to easily organize your BOQ.
- Choose the best contractors for your project based on their BOQ cost estimates.
- Continue using your BOQ throughout your project for scheduling and cost planning.