Electrical Design Course

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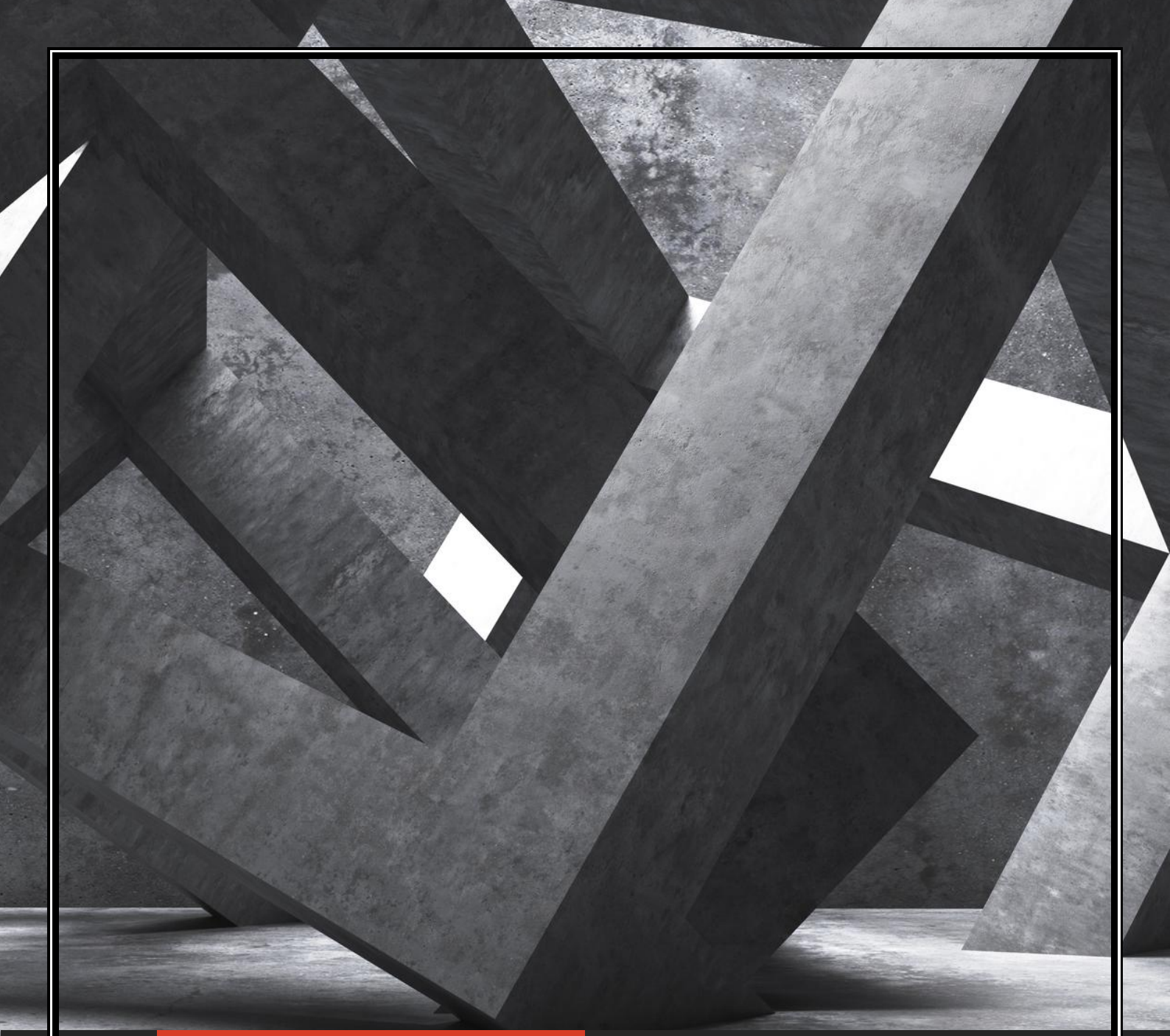


LUMINARIES SELECTION

LEACTURE SUMMARY

TYPES OF LUMINAIRES

❖ RECESSED LUMINAIRES

- Installed within the ceiling cavity (usually in gypsum or suspended ceilings).
- Provide a clean, flush appearance with no protrusions.
- Commonly used in offices, hotels, and hospitals.
- Examples: Downlights, LED Panels.

Figure 1 : RECESSED LUMINAIRES

❖ SURFACE MOUNTED LUMINAIRES

- Mounted directly onto the ceiling or wall surface.
- Suitable for solid ceilings (e.g., concrete) where recessed installation isn't possible.
- Used in hospitals, classrooms, warehouses.

Figure 2 : SURFACE MOUNTED LUMINAIRES

❖ SUSPENDED LUMINAIRES

- Hung from the ceiling using cables or rods.
- Ideal for high-ceiling spaces like factories, showrooms, and modern offices.
- Offer uniform lighting with an elegant appearance.

Figure 3: SUSPENDED LUMINAIRES

❖ WALL MOUNTED LUMINAIRES

- Fixed on walls to provide side or accent lighting.
- Common in corridors, staircases, and building façades.
- Can be Up Light, Down Light, or dual-direction types.

Figure 4 WALL MOUNTED LUMINAIRES

❖ WATERPROOF / IP-RATED LUMINAIRES

- Designed to resist water and dust, with high IP ratings (e.g., IP65, IP66).
- Suitable for bathrooms, kitchens, industrial zones, or outdoor use.
- Essential in steel factories due to harsh environments (heat, dust, moisture).

Figure 5 WATERPROOF / IP-RATED LUMINAIRES

❖ DOWNLIGHTS

- A type of recessed or surface-mounted luminaire.
- Direct light downward in a focused beam.
- Ideal for task or accent lighting in offices, showrooms, and homes.

Figure 6 DOWNLIGHT

❖ HIGH BAY LUMINAIRES

- Designed for areas with high ceilings (typically over 6 meters).
- Provide powerful and uniform lighting over large industrial spaces.
- Perfect for warehouses, factories, and production lines.

Figure 7: HIGH BAY LUMINAIRES

❖ UP LIGHTS

- Direct light upward to illuminate ceilings or upper walls.
- Used for decorative or indirect lighting effects.
- Installed on the floor or lower wall sections.

Figure 8: UP LIGHTS

❖ FLOOD LIGHTS

- Produce broad and intense beams of light.
- Used in outdoor areas, security zones, sports fields, and large yards.
- Typically high-power and weather-resistant.

Figure 9 : FLOOD LIGHTS

❖ UNDERWATER LUMINAIRES

- Specially built for installation inside pools, fountains, or ponds.
- High waterproof ratings (IP68).
- Provide decorative and functional lighting underwater.

Figure 10: UNDERWATER LUMINAIRES

❖ TRACK LIGHTING

- Luminaires mounted on a flexible track system.
- Lights can be repositioned or directed as needed.
- Ideal for galleries, shops, and exhibits requiring adaptable lighting.

Figure 11: TRACK LIGHTING

CELLING TYPES

❖ RECESSED CEILING

- A ceiling design that includes lowered or dropped sections, often used to hide lighting fixtures or HVAC ducts.
- Allows for the installation of **recessed luminaires**, spotlights, or indirect lighting.
- Common in commercial and residential projects for aesthetic and functional purposes.

Figure 12 : RECESSED CEILING

❖ SURFACE CEILING

- A basic ceiling type where fixtures are mounted directly on the visible ceiling surface.
- No cavity above; suitable for **surface-mounted lights** or fixtures that don't require concealment.
- Often found in industrial or utilitarian spaces.

Figure 13 : SURFACE CEILING

❖ GYPSUM BOARD CEILING (FALSE CEILING)

- Made from gypsum panels suspended below the structural ceiling.
- Provides smooth finishes, sound insulation, and allows integration of lighting and air-conditioning ducts.
- Compatible with both **recessed** and **surface** lighting systems.

Figure 14 :GYPSUM BOARD CEILING

❖ TRUSSES (EXPOSED OR STRUCTURAL)

- Structural frameworks typically made of steel or wood, often seen in factories or large halls.
- Lighting fixtures like **suspended luminaires** or **high bays** are hung directly from the trusses.
- Electrical conduit and cable trays may also be attached to trusses.

Figure 15: TRUSSES

❖ CEILING REPRESENTATION IN ARCHITECTURAL DRAWINGS (AUTOCAD)

Suspended Ceiling (e.g., Mineral Fiber Tiles)

- Shown as a grid of squares (usually 600x600 mm or 600x1200 mm).
- Drawn with light or dashed lines in reflected ceiling plans (RCP).
- Grid represents the tile layout.

Gypsum Board Ceiling

- Usually no hatch, just outlined or labeled with text ("Gypsum Board Ceiling").
- May include light divisions or framing lines (metal channels).

Flat Concrete Slab

- Typically not shown in floor plans.
- Shown in sections or elevations.
- Can be labeled in structural drawings as "R.C. Slab".

Sloped Roof

- Indicated in roof plans or sections.
- Shown with diagonal lines or a slope arrow (e.g., "1:10 slope").

Truss Roof

- Displayed in sections with the full truss shape.
- Not usually shown in floor plans unless exposed.

❖ HIGH LEVEL CEILING

- Ceilings at elevated heights (often above 3.5 to 4 meters).
- Require specialized lighting such as high bay luminaires or suspended fixtures.
- Found in warehouses, factories, sports halls, or industrial plants.

LUMINAIRE CONSTRUCTION

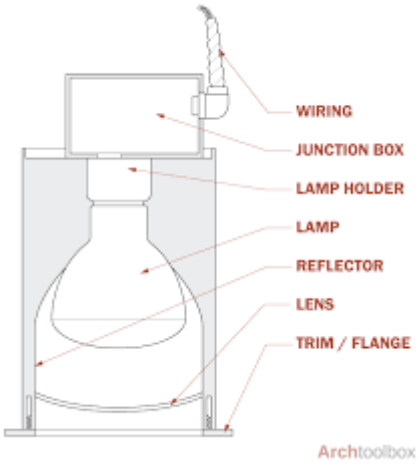


Figure 16 : LUMINAIRE CONSTRUCTION

❖ BODY MATERIAL

- The main structural part of the luminaire that provides strength and houses internal components.
- **Common materials:**
  - Aluminum: Lightweight, corrosion-resistant, excellent for heat dissipation.
  - Steel: Durable and strong, often powder-coated for protection.
  - Plastic (Polycarbonate or ABS): Used for economy fixtures or diffusers, resistant to impact and UV in some types.
  - Stainless Steel: Used in harsh environments (marine, chemical plants) due to corrosion resistance.

❖ HOUSING

- The outer shell or casing of the luminaire, designed to:
  - Protect internal components (e.g., LED boards, wiring, drivers).

- Support installation (surface, recessed, suspended, etc.).
- Provide IP rating for water/dust protection when needed.

- Housing may include:
  - Mounting brackets
  - Gasket seals
  - Heat sinks (especially in LED luminaires)

❖ REFLECTOR AND DIFFUSER

- **Reflector:**
  - Internal surface that reflects light to improve efficiency and direct it as needed.
  - Made of aluminum, silver-coated surfaces, or white powder-coated steel.
  - Shapes include parabolic, faceted, or specular depending on the beam control required.
- **Diffuser:**
  - A **cover** that spreads and softens the light output to reduce glare and improve uniformity.
  - Made of opal polycarbonate, acrylic, or frosted glass.
  - Types: prismatic, clear, frosted, or patterned.

LIGHTING CALCULATIONS

❖ LAW OF NUMBER OF LUMINAIRES

Used to determine the required number of luminaires to achieve the target illumination level.
Where:

- **N** = Number of luminaires
- **E** = Required illuminance (lux)
- **A** = Area of the room (m^2)
- **F** = Luminous flux of one luminaire (lumens)
- **UF** = Utilization Factor
- **MF** = Maintenance Factor

$$N = \frac{E \times A}{F \times UF \times MF}$$

❖ UTILIZATION FACTOR (UF)

The percentage of light emitted by the luminaire that actually reaches the working plane.
It depends on:

- Luminaire design and optics
- Room surface reflectance (walls, ceiling, floor)
- Room dimensions and layout

❖ MAINTENANCE FACTOR (MF)

Accounts for the reduction in lighting performance over time due to:

- Dirt accumulation on luminaires
- Lamp depreciation
- Environmental conditions

Typical values range between **0.7 and 0.9**, depending on maintenance frequency and environment.

❖ ROOM INDEX (K)

A geometric factor used to determine the Utilization Factor (UF).
Where:

- **L** = Room length (m)
- **W** = Room width (m)
- **Hm** = Mounting height = (height from luminaire to working plane)

$$\text{Room Index (k)} = \frac{\text{L x W}}{\text{H (L + W)}}$$

❖ LUMINAIRE PROPERTIES

Important characteristics that affect lighting design:

- Luminous Flux (lm): Total light output
- Power (W): Electrical consumption
- Luminous Efficacy (lm/W): Light output per watt
- Light Distribution: Symmetrical / Asymmetrical – narrow / wide

- Mounting Type: Recessed, surface, suspended, wall-mounted

❖ BEAM ANGLE

The angle at which 50% or more of the luminaire's light intensity is emitted.
Used to define:

- Light spread coverage
- Mounting height suitability
- Uniformity of lighting distribution

Common classifications:

- Narrow Beam (10°–30°): Spot or accent lighting
- Medium Beam (30°–60°): General area lighting
- Wide Beam (>60°): Broad area coverage

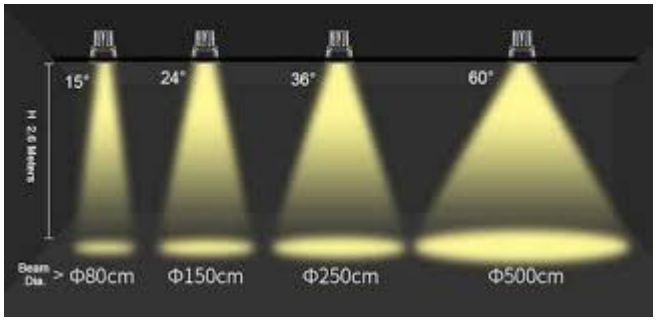


Figure 17 : BEAM ANGLE

LIGHTING TERMS

❖ LUMINOUS FLUX (LM)

- Total amount of visible light emitted by a light source in all directions.
- Measured in lumens (lm).
- Does not describe how the light is distributed on a surface.
- Example: A 10W LED bulb may produce 1000 lm → Luminous efficacy = 100 lm/W.

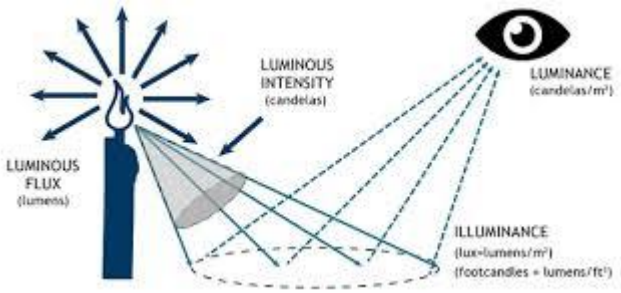
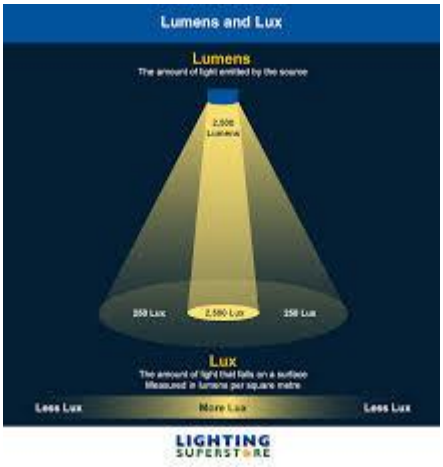


Figure 18: LUMINOUS FLUX (LM)

❖ ILLUMINANCE (LUX)

- Amount of light received on a surface per unit area.
- Measured in lux (lx) = lumens/m^2.
- Design target examples:
  - Offices: 300–500 lux
  - Workshops: 500–750 lux
  - Corridors: 100 lux
- Calculated at the work plane height



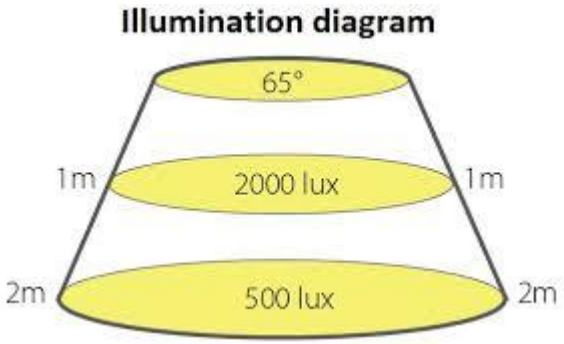


Figure 19 : ILLUMINANCE (LUX)

❖ INGRESS PROTECTION (IP RATING)

- Two-digit code that defines protection level against solids and liquids:
  - First digit (0–6): Dust protection
  - Second digit (0–8): Water protection
- Examples:
  - IP20: No water protection (indoor use)
  - IP65: Dust tight + protected from water jets (outdoor)
  - IP68: Suitable for underwater use
- Essential for outdoor or industrial luminaires.

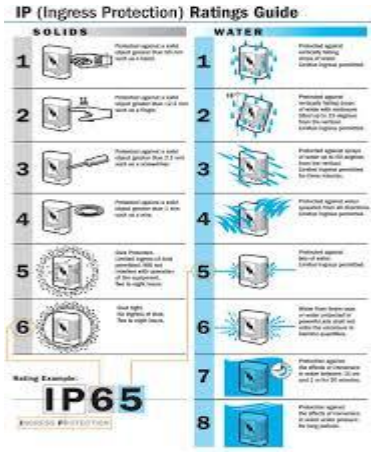


Figure 20 : INGRESS PROTECTION

❖ COLOR RENDERING INDEX (CRI)

- A scale from 0 to 100 showing how accurately a light source renders object colors compared to daylight.
- CRI > 80: Suitable for general lighting (offices, classrooms)
- CRI > 90: Used in art galleries, hospitals, high-end retail
- Higher CRI means better color visibility and visual comfort.

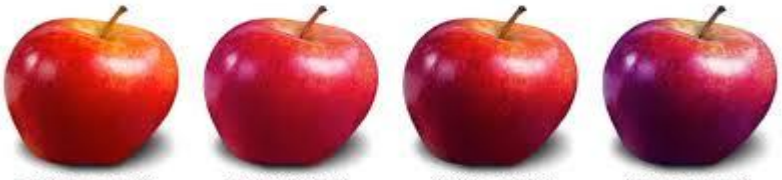


Figure 21 : COLOR RENDERING INDEX (CRI)

❖ CORRELATED COLOR TEMPERATURE (CCT)

- Indicates the color tone of white light, measured in Kelvin (K):
  - 2700–3000K: Warm white (yellowish) → residential
  - 4000–4500K: Neutral white → offices, commercial
  - 6000–6500K: Cool daylight → industrial, hospitals
- Does **not** affect brightness but influences mood and atmosphere.

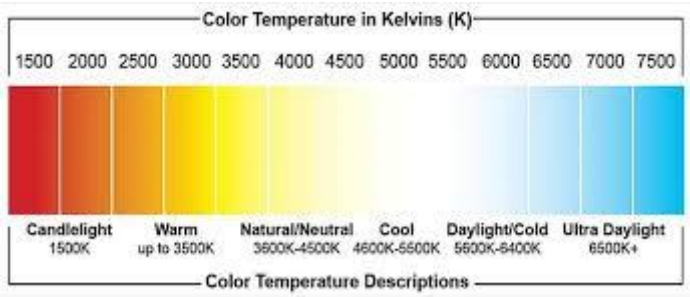


Figure 22 : CORRELATED COLOR TEMPERATURE (CCT)

❖ POLAR CURVE (LIGHT DISTRIBUTION CURVE)

- A graphical plot showing light intensity distribution from a luminaire at various angles.
- Helps designers choose the right beam spread and placement.
- Types:
  - Symmetrical → even distribution
  - Asymmetrical → focused for walls, paths
- Used in simulation software (e.g., Dialux, Relux).

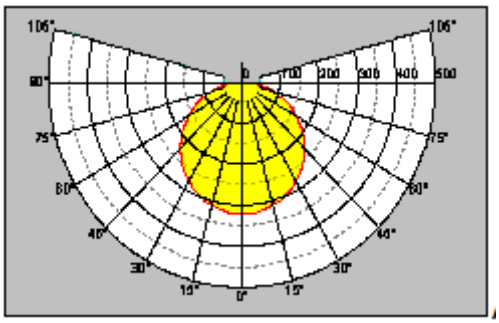


Figure 23 : POLAR CURVE

❖ WORK PLANE HEIGHT

- The height above the floor at which lighting is measured or tasks are performed.
- Examples:
  - Desks in offices: 0.8–0.85 m
  - Workbenches: 1.0 m
- Crucial for lux level compliance and visual ergonomics.

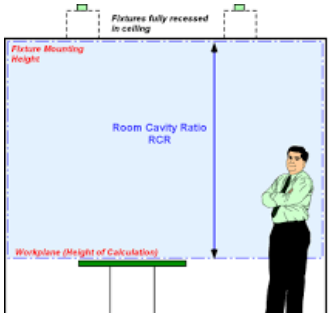


Figure 24 : WORK PLANE HEIGHT

❖ UNIFORMITY

- Describes how evenly light is spread across a space.
- Calculated as: Minimum Illuminance ÷ Average Illuminance
- Good design ensures uniformity ≥ 0.6 (reduces glare and dark zones).
- Required in areas where consistent visibility is important (e.g., classrooms, manufacturing).

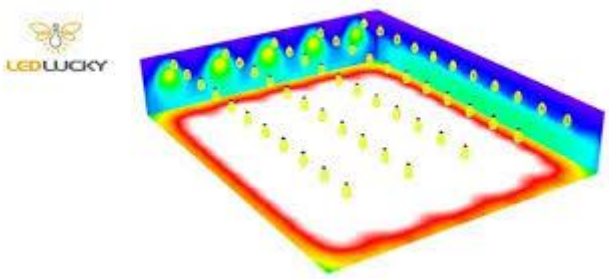


Figure 25: UNIFORMITY

❖ ROOM DIMENSIONS & ROOM INDEX

- Includes room length, width, and height (wall zone may also be considered).
- Used to calculate Room Index (K):

$$\text{Room Index (k)} = \frac{L \times W}{H\,(L + W)}$$

Helps determine the Utilization Factor (UF) for accurate lighting layout.

❖ DIRECT & INDIRECT LIGHTING

- Direct lighting: Light is projected directly onto the task area (e.g., downlights, spotlights).
  - High efficiency, may cause glare.
- Indirect lighting: Light is reflected off ceilings/walls first.
  - Soft, diffused, visually comfortable.
- Often combined in modern lighting design for both efficiency and comfort.

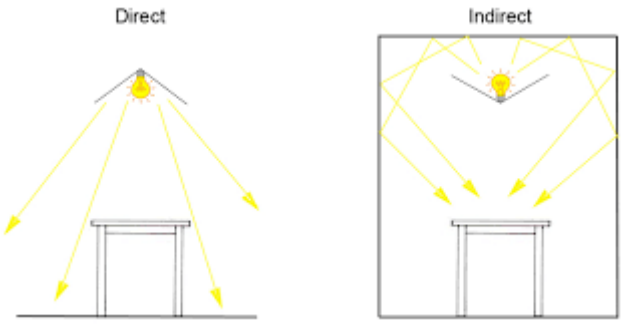


Figure 26 : DIRECT & INDIRECT LIGHTING

❖ LOAD LIGHT / FACADE FLOOD LIGHT

- High-power luminaires used for architectural lighting on building exteriors.
- Characteristics:

Figure 27 : LOAD LIGHT / FACADE FLOOD LIGHT

  - High lumen output
  - Narrow to wide beam angles
  - Weatherproof (IP66 or higher)
  - May support RGB color control or DALI/DMX dimming
- Used to highlight walls, columns, or branding elements.

STANDARDS AND GUIDELINES

- **EN 12464-1**: Indoor work places
- **IEC 60598**: Luminaires safety
- **IESNA** and **CIBSE** guides
- **NFPA / IEC 60529** for IP and emergency lighting

LIGHTING DISTRIBUTION & DESIGN CONSIDERATIONS

- **Uniformity Ratio**: (Gelany, 2023)
  The ratio between the highest and lowest illuminance levels should not exceed 1.25 to ensure uniform lighting and avoid distribution irregularity.

- **Spacing to Mounting Height Ratio (SHR)**:
  The ratio between the spacing of luminaires and their mounting height should not exceed 1.5 to prevent dark spots or poor light uniformity.

- **Perception of Space**:
  - To emphasize the width of a space, use transverse (horizontal) lighting layouts.
  - To emphasize the depth, use longitudinal (vertical) lighting layouts.
- **Lighting Arrangement**:
  - Diagonal arrangements of luminaires help reduce shadows.
  - Rectangular or grid arrangements attract visual attention and create order.

- **Lighting in Classrooms**:
  - Windows should be on the left side of students to minimize shadows caused by the writing hand.
  - Use linear fluorescent lamps parallel to the windows and spaced apart appropriately.
  - The blackboard should have dedicated indirect lighting to prevent glare for both students and teachers.

- **Shadows from Right-side Lighting**:
  Placing light sources to the right of students (right-handed) causes shadows that interfere with reading/writing.

EGYPTIAN LIGHTING CODE (ELECTERICITY, 2025)

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	التلى والتجميع	٣٠٠
	القطع	٥٠٠
	الفحص	١٠٠٠
مصانع السيارات	تجميع الهياكل	٥٠٠
	تجميع الأجزاء وتركيبها	١٠٠٠
	أعمال السباكة	١٠٠٠
	الفحص الدقيق للمسبوكات	٥٠٠٠
	التلميع والصقل والتنجيد	١٠٠٠
	التجميع النهائى والتشطيب والفحص	٣٠٠٠

Figure 28 : EGYPTIAN LIGHTING CODE

LIGHTING DESIGN

LEACTURE SUMMARY

TYPES OF LOADS

❖ NORMAL LOAD

- **Power Source:** Utility power via transformer.
- **Transfer Time:** Not backed up – will go off during outage.
- **Protection:** MCBs or MCCBs in normal distribution boards.
- **Examples:** Office lighting, general sockets, non-essential HVAC.
- **Note:** Not connected to generator or UPS.

❖ EMERGENCY LOAD

- **Power Source:** Diesel generator (via ATS – Automatic Transfer Switch).
- **Transfer Time:** Typically 10–15 seconds after utility failure.
- **Purpose:** Life safety or mission-critical systems during power failure.
- **Examples:** Emergency lighting, fire pumps, alarm systems, exit signs.
- **Design:** Usually wired through a separate emergency panel.

❖ CRITICAL LOAD

- **Power Source:** UPS (Uninterruptible Power Supply) – zero transfer time.
- **Backed Up By:** Batteries (short-term) + generator (long-term).
- **Examples:** Data centers, ICU equipment, control systems.
- **UPS Type:** Typically double-conversion online UPS.
- **Design Tip:** Keep wiring and distribution isolated to avoid overloads and ensure reliability.

CONNECTION OVERVIEW

❖ FROM THE DISTRIBUTION PANEL

- **Line (L):** Comes from a circuit breaker (MCB), and goes through the wall switch to the luminaire.
- **Neutral (N):** Goes directly from the neutral bar in the panel to the luminaire.
- **Earth (E):** Also goes directly from the earth bar in the panel to the luminaire body (for safety).

❖ AT THE WALL SWITCH

- The **Line (L)** is interrupted by the switch.
- The switch controls **when** the line reaches the luminaire (ON/OFF).
- Neutral and Earth do **not** pass through the switch.

❖ AT THE LUMINAIRE

- **L:** Connects to the live terminal (controlled by the switch).
- **N:** Connects to the neutral terminal of the lamp.
- **E:** Connects to the metal body (if applicable), for protection against electric shock.

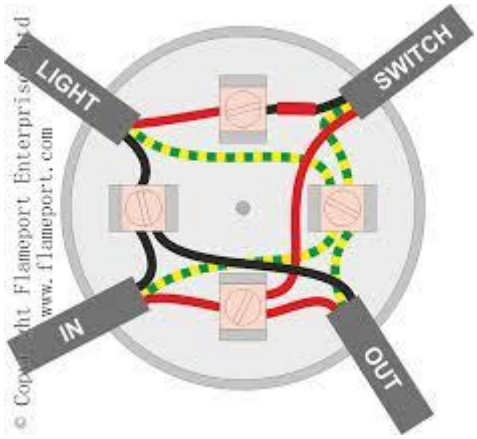

Figure 29 : CONNECTION of luminaire

TYPE OF SWITCHING

❖ MANUAL ON – MANUAL OFF

- **Operation:** The user turns the light ON and OFF using a standard wall switch.
- **Example:** Most home light switches.
- **Application:** General areas where full manual control is preferred.

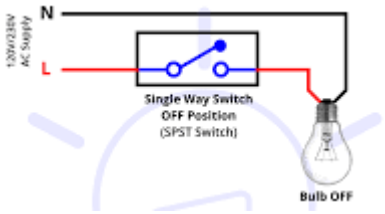

Figure 30 : MANUAL ON – MANUAL OFF

❖ MANUAL ON – AUTO OFF

- **Operation:**
  - User turns the light ON manually.
  - The light turns OFF automatically after a set time or if no motion is detected.
- **Controlled by:** Motion sensor, timer, or occupancy sensor.
- **Application:** Offices, classrooms, restrooms – to save energy.

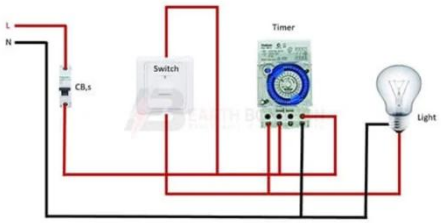

Figure 31 : MANUAL ON – AUTO OFF

❖ AUTO ON – AUTO OFF

- **Operation:**
  - Light turns ON automatically when motion or presence is detected.
  - Turns OFF automatically after delay or when the area is unoccupied.
- **Controlled by:** Occupancy sensor or motion detector.
- **Application:** Corridors, stairwells, warehouses – for safety and energy efficiency.

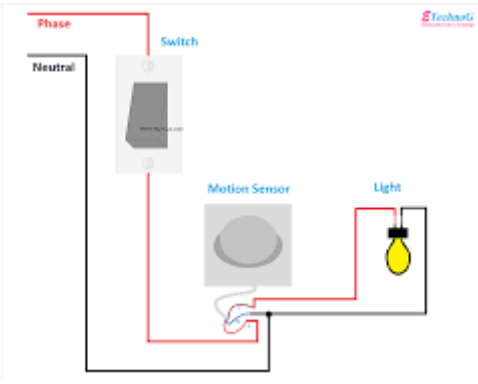

Figure 32 : AUTO ON – AUTO OFF

TYPES OF SWITCHES

❖ ONE-WAY SWITCH

- **Function:** Controls a light from one location only.
- **Wiring:** Live wire (L) goes through the switch to the luminaire.
- **Example:** Bedroom ceiling light.

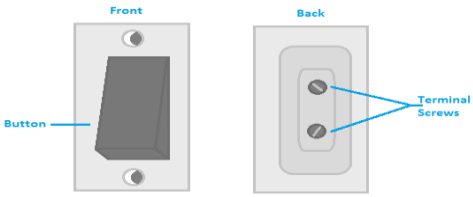

Figure 33 : ONE-WAY SWITCH

❖ TWO-WAY SWITCH

- **Function:** Controls the same light from two different locations.
- **Wiring:** Requires two switches connected with 2 travelers (L1, L2) and common terminals.
- **Example:** Staircases, long corridors.

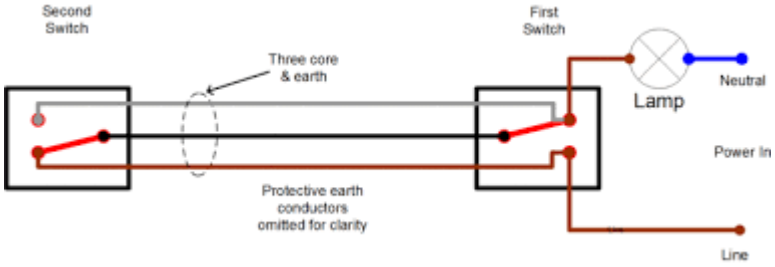

Figure 34 : TWO-WAY SWITCH

❖ INTERMEDIATE SWITCH

- **Function:** Used between two two-way switches to control the same light from three or more locations.
- **Wiring:** Crosses or swaps the two travelers coming from two-way switches.
- **Example:** Hallways with 3+ entrances.

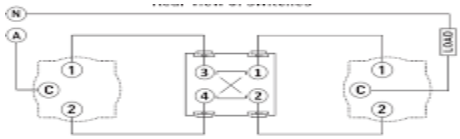

Figure 35 : INTERMEDIATE SWITCH

❖ DIMMER SWITCH

- **Function:** Manually adjusts brightness (dimming) of the light.
- **Wiring:** Replaces a normal switch; connected in series with the live wire.
- **Types:** Rotary, slider, touch, or digital.

Figure 36 : DIMMER SWITCH

- **GANG**
  - Refers to the **number of switches in one faceplate**:
    - **1-gang:** One switch
    - **2-gang:** Two switches in the same box
    - **3-gang:** Three switches, etc.
  - Each gang can control a different circuit or luminaire.

Figure 37 : number of switches in one faceplate

WIRING BETWEEN SWITCHES AND LUMINAIRES

❖ ONE-WAY SWITCH WIRING:

- **Live (L)** from DB → **Switch**
- **Switch → Live terminal** of luminaire
- **Neutral (N)** from DB → luminaire
- **Earth (E)** → luminaire body (if metallic)

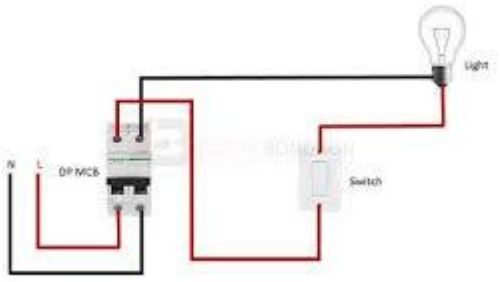

Figure 38 : ONE-WAY SWITCH WIRING

❖ TWO-WAY SWITCH WIRING:

- **Live (L)** from DB → common terminal of **first switch**
- Two traveler wires (L1, L2) connect **first switch** to **second switch**
- Common of **second switch** → **luminaire live**
- **Neutral (N)** from DB → luminaire
- **Earth (E)** to all metal parts

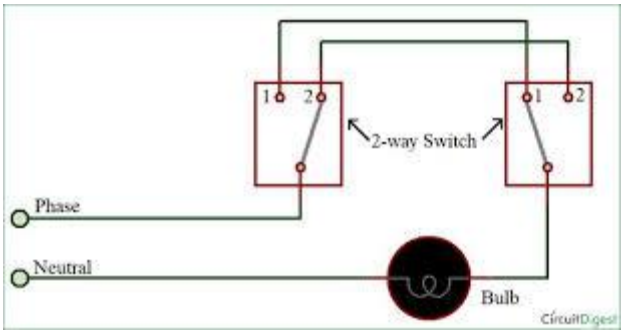

Figure 39 : TWO-WAY SWITCH WIRING:

❖ INTERMEDIATE WIRING (3-POINT SWITCHING):

- Intermediate switch inserted between the two two-way switches
- Traveler wires from switch 1 → intermediate → switch 2
- Same connections to luminaire as in two-way

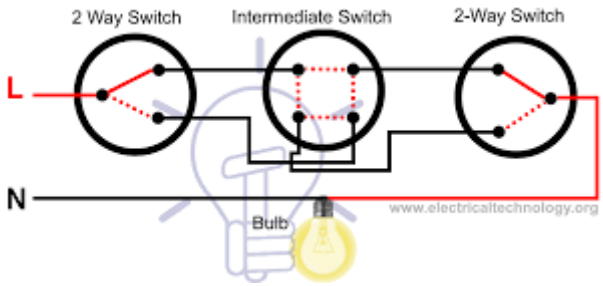

Figure 40 : INTERMEDIATE WIRING

LIGHTING IN PRIVATE VS GENERAL PLACES

❖ PRIVATE AREAS

- Controlled locally.
- Examples: Rooms, offices, private stores.
- Use basic wall switches or dimmers.
- Simple wiring (one-way or two-way switch).

❖ GENERAL/COMMON AREAS

- Centralized control from a **Lighting Control Panel (LCP)**.
- Examples: Corridors, lobbies, staircases, parking, outdoor areas.
- Often controlled using push buttons and silent contactors for better durability and noise reduction.

LIGHTING CONTROL PANEL (LCP)

❖ MAIN BREAKER

- Disconnects the whole lighting panel.
- Protects upstream cable.

❖ MCBS (BREAKERS)

- Protect individual lighting circuits.

❖ SILENT CONTACTOR

- Used for switching the lighting load silently (no loud clicks).
- Rated based on load current (AC1/AC3 duty).

❖ PUSH BUTTON (LOCAL OR REMOTE)

- Controls the contactor (ON/OFF).
- Used in the control circuit, not the power circuit.

❖ TYPE OF CIRCUITS

- **Control Circuit**
  - Low-power circuit to operate the contactor coil.
  - Includes: push button, coil, sometimes a timer or photocell.
- **Power Circuit**
  - Carries actual load current to luminaires.
  - Includes: MCB → Contactor → Lights.

Figure 41 : LIGHTING CONTROL PANEL

LIGHTING PANEL (LP) – THREE CONFIGURATIONS

❖ LCP INSIDE LP

- Lighting Control panel (MCBs + switching) fully integrated in the LP.
- Shortest cable runs and cheapest design.
- Best when loads are nearby.

❖ LCP NEAR LOAD, CONTACTOR IN LP

- Lighting Control panel is near the load (e.g., corridor), but switching (contactor) remains in LP.
- Saves load cable length.
- Requires control cables between LCP and LP.

❖ LCP AND CONTACTOR BOTH NEAR LOAD

- Lighting Control panel and contactor are both installed near the load.
- Reduces both load and control cable lengths to luminaires.
- Requires more distributed panels = more cost and space.

❖ COST COMPARISON

- **First type is cheapest**, with centralized components.
- **Second type** reduces load cable length but adds control wiring.
- **Third type** gives most localized control but increases panel and wiring cost.

TYPES OF CRITICAL LIGHTING

❖ CRITICAL LIGHTING WITH BUILT-IN BATTERY

Description:

- The luminaire itself contains an internal battery + charger.
- Normally powered from the emergency circuit (from generator).
- In case of power failure, the battery automatically powers the lamp (usually LED) for a fixed duration (e.g., 1–3 hours).

Wiring:

- Line and Neutral from emergency distribution panel → luminaire.
- No external UPS needed.
- Earth connected to the body (if metal).

Advantages:

- Simple installation.
- No need for extra control wiring or central battery.
- Each unit works independently.

Figure 42 : CRITICAL LIGHTING WITH BUILT-IN BATTERY

❖ CRITICAL LIGHTING SUPPLIED SEPARATELY (UPS + GENERATOR)

Description:

- Used for loads that require zero interruption, like ICU lights or data center emergency lighting.
- Powered through UPS (for immediate supply) + Generator (for backup after delay).

Wiring:

- Two supply sources:
  - UPS output → Critical DB → Luminaire
  - Generator → UPS input (or via ATS)
- Requires dedicated critical DB.
- Neutral and earth must be properly segregated and bonded.

Features:

- UPS handles instant switching with no blackout time.
- Generator recharges UPS or supports it during long outages.
- Can be combined with monitoring systems for battery health, alarms, etc.

❖ COMBINED EMERGENCY + CRITICAL SUPPLY SCENARIOS

Sometimes, critical luminaires (e.g., exit signs) are:

- Connected to emergency circuit (generator-fed),
- And also have built-in battery (as backup to the backup).

This gives double assurance, especially in life safety systems (NFPA/IEC compliant designs).

LIGHTING LOADS CLASSIFICATION

❖ NORMAL LIGHTING LOADS

- 15 luminaires installed
- Total load: **2000 VA**
- Supplied from utility power via transformer
- Controlled manually or automatically depending on the design

❖ EMERGENCY LIGHTING LOADS

- Represent 25% of the normal load ≈ 500 VA
- Supplied by the generator through the emergency panel
- Used for escape routes and basic visibility during power outage

❖ CRITICAL LIGHTING LOADS

- Operate using built-in batteries
- Backup duration: at least 3 hours
- System selection depends on:
  - Cost
  - Required reliability
  - Building function
  - Owner's request

EXIT SIGN

Recommended locations :

1. **Above Exit Doors**
   - All final exit doors leading to the outside or safe area.
2. **At Staircase Entrances**
   - Top and bottom of all staircases (including fire escapes).

3. **In Corridors Leading to Exits**
    - At intersections or where direction to the exit may not be obvious.
4. **At Every Change of Direction**
    - Where the path to exit turns (e.g., L- or T-shaped corridors).
5. **Near Elevators (with caution)**
    - Marked clearly: **"Exit Stair" or "Do Not Use Elevator in Fire"**.
6. **In Large Halls or Open Spaces**
    - Multiple signs may be needed to indicate the nearest exit.
7. **Above Emergency Exit Routes in Public Areas**
    - Malls, cinemas, hospitals, schools, etc.
8. **Inside Basement and Underground Areas**
    - Where natural light or orientation is limited.

Figure 43 : EXIT SIGN

❖ **Notes:**

- Signs should be clearly visible, mounted at proper height (typically ≥2 meters).
- Must have emergency battery backup (min. 1–3 hours).
- Directional arrows should be included where needed.

EXIT SIGN TYPES BY OPERATING MODE

❖ MAINTAINED EXIT SIGN

- Always illuminated — whether power is available or not.
- Powered by mains supply in normal conditions and battery during outage.
- Most commonly used type for public and commercial buildings.
- Ensures visibility at all times.

❖ NON-MAINTAINED EXIT SIGN

- Off during normal operation, and only lights up when power fails.
- Powered only by the internal battery during an emergency.
- Used in areas where exit signs are not required to be visible under normal lighting.
- Less common due to safety standards.

❖ SWITCHED MAINTAINED (OR SWITCHED NON-MAINTAINED)

- Can be switched ON/OFF manually during normal operation.
- Automatically turns ON in case of power failure, even if it was OFF before.
- Used where dual function is needed (e.g., works as general light + emergency light).

EMERGENCY LOADS REQUIREMENTS

- An alternative power source (generator, UPS, or central battery) must be provided, with automatic transfer within ≤ 10 seconds.
- Emergency loads should be at least 25% of general lighting loads and must include only critical systems such as evacuation, alarms, and safety.
- Loads must operate for a minimum of 90 minutes in public buildings and 180 minutes in hospitals or high-risk facilities.
- Emergency loads must be fed from independent panels, fully isolated from normal loads, and use an ATS if a generator is used.
- Normal loads must not be connected to emergency circuits; wiring must be color-coded (e.g., red) and protected with separate thermal and electrical protection.
- Emergency systems include exit and escape lighting, fire pumps, fire alarm systems, emergency elevators, and vital medical or industrial equipment.
- Operation must be fully automatic with no manual intervention; regular testing (monthly or quarterly) is required to ensure reliability.
- Emergency circuits should be routed in fire-resistant conduits or cable trays when needed.

MECHANICAL LOADS

LEACTURE SUMMARY

MECHANICAL LOADS

❖ HVAC SYSTEMS

- Ventilation Fans
- Air Conditioning Units (Chillers, Split Units, Package Units)

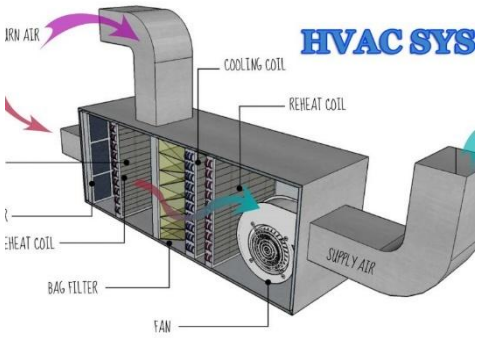

Figure 44 : HVAC SYSTEMS

❖ FIRE FIGHTING SYSTEMS

- Fire Pumps (Main, Jockey, and Diesel Pumps)

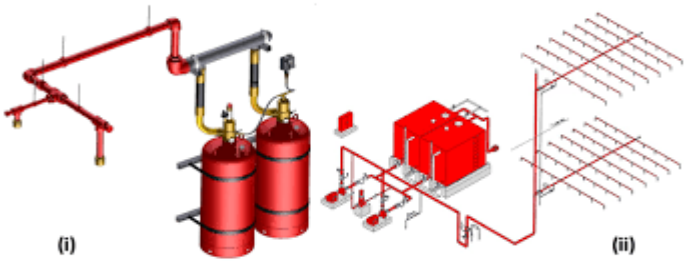

Figure 45 : FIRE FIGHTING SYSTEMS

❖ PLUMBING SYSTEMS

- Water Supply Pumps
- Drainage Pumps (Sump Pumps, Sewage Pumps)

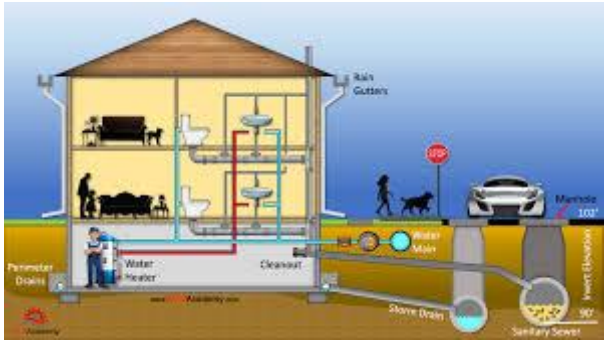

Figure 46 : PLUMBING SYSTEMS

❖ VERTICAL TRANSPORTATION

- Elevators (Lifts)

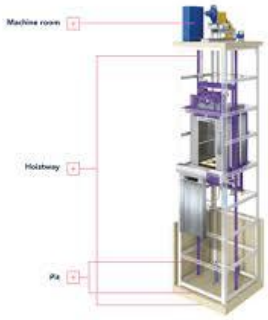

Figure 47 : Elevators (Lifts)

- Escalators

Figure 48 : Escalators

HVAC SYSTEM

❖ OUTDOOR UNITS

- Air-Cooled Condensing Units
- Chillers (Air-cooled or Water-cooled)
- Packaged Units
- Heat Pumps

Figure 52 : Air-Cooled Condensing Units

Figure 51 : Chillers

Figure 50 : Packaged Units

Figure 49 : Heat Pumps

❖ INDOOR UNITS

- Fan Coil Units (FCU)
- Air Handling Units (AHU)
- Ducted Split Units
- VRF/VRV Indoor Units (Wall-mounted, Cassette, Ducted)

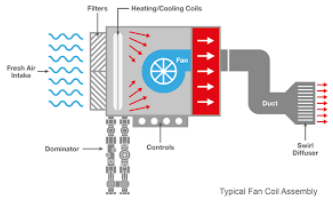

Figure 54 : Fan Coil Units (FCU)

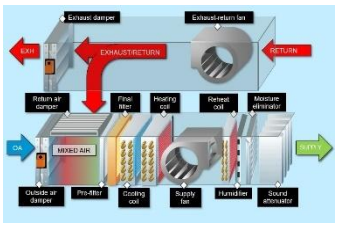

Figure 53 : Air Handling Units

Figure 56 : Ducted Split Units

Figure 55 : VRF/VRV Indoor Units

TYPES OF FANS IN MECHANICAL SYSTEMS

❖ FRESH AIR FAN (FAF)

- **Function:** Supplies fresh outdoor air to improve indoor air quality (IAQ).
- **Installation:** Mounted on the roof or in mechanical rooms, connected to AHUs or duct systems.
- **Control:** Often combined with CO_2 sensors, dampers, and filters.
- **Note:** Required to meet ASHRAE and ventilation code standards.

Figure 57 : FRESH AIR FAN (FAF)

❖ EXHAUST FAN

- **Function:** Extracts stale air, odors, or moisture from bathrooms, kitchens, and service areas.
- **Installation:** Wall- or ceiling-mounted, with short or direct ducting to outside.
- **Control:** Operated by a switch, timer, or motion/humidity sensor.
- **Note:** Commonly used in toilets, garbage rooms, and technical spaces.

Figure 58 : EXHAUST FAN

❖ JET FAN (FOR CAR PARKS)

- **Function:** Moves air horizontally inside large spaces like underground parking garages. Supports ventilation and smake extraction.
- **Installation:** Suspended from ceiling, no ductwork required.
- **Control:**
  - **Two-Speed Operation:** Normal mode and emergency (fire) mode.
  - **VFD/VSD Controlled:** For energy efficiency and airflow adjustment based on CO/NOx levels.
- **Note:** Part of a complete car park ventilation system with exhaust/supply fan

Figure 59 : JET FAN

❖ SMOKE EXTRACTION FAN (DUCTED TYPE)

- **Function:** Extracts smoke during fire incidents to clear escape routes and reduce heat.
- **Installation:** Connected to dedicated fire-rated ductwork, usually located on rooftops or special rooms.
- **Specifications:**
  - Fire-rated (e.g., 300°C for 2 hours – per EN 12101).
  - Powered via fire-rated cables and connected to the fire alarm system.
- **Note:** Must operate automatically upon fire alarm activation.

Figure 60 : SMOKE EXTRACTION FAN

❖ TOILET VENTILATION FAN

- **Function:** Removes odors and moisture from restrooms to maintain hygiene and comfort.
- **Installation:** Ceiling- or wall-mounted, often connected to a short duct.
- **Control:** Operated by switch, timer, humidity sensor, or motion detector.
- **Note:** Should be low-noise and energy-efficient for continuous or frequent use.

Figure 61 : TOILET VENTILATION FAN

OUTDOOR UNITS IN HVAC SYSTEMS

❖ CHILLER

A central unit that produces chilled water, which is used to cool air in Air Handling Units (AHUs) or Fan Coil Units (FCUs). Commonly used in large buildings like malls, hospitals, and office towers.

Figure 62 : CHILLER

❖ AIR-COOLED CHILLER

A type of chiller that rejects heat directly to the outside air using condenser fans, without the need for a cooling tower.

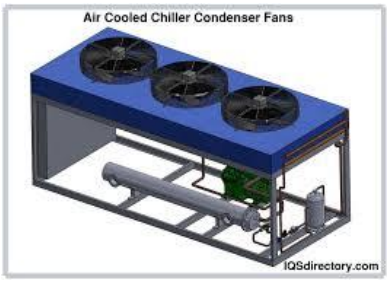

Figure 63 : AIR-COOLED CHILLER

❖ WATER PUMP

Pumps used to circulate chilled water from the chiller to the indoor cooling units and back. The system may include primary and secondary pumps depending on the design.

Figure 64 : WATER PUMP

❖ LARGE ACU (AIR CONDITIONING UNIT)

A packaged unit that includes a compressor, fans, filters, and cooling coil in one enclosure. Used to serve large zones or open spaces.

Figure 65 : LARGE ACU

❖ COOLING TOWER

Used with water-cooled chillers to reject heat from the system by evaporating water. Usually located on rooftops or in open mechanical yards .

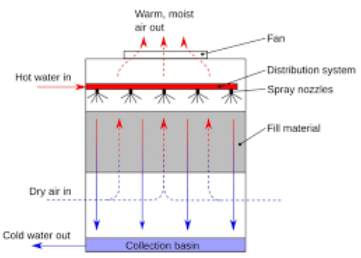

Figure 66 : COOLING TOWER

❖ SMALL ACU

Small outdoor units, such as split-type or VRF systems, used to cool individual rooms or smaller areas.

Figure 67 : SMALL ACU

CYCLE OF OPERATION FOR HVAC SYSTEMS

❖ HEAT ABSORPTION (INDOOR SIDE)

- Warm indoor air passes over a cooling coil (evaporator) containing chilled water or refrigerant, which absorbs the heat and cools the air.

❖ COOLING MEDIUM CIRCULATION

- In chilled water systems: water pumps circulate the chilled water between the chiller and indoor units.
- In DX (Direct Expansion) systems: refrigerant is circulated between indoor and outdoor units by the compressor.

❖ HEAT REJECTION (OUTDOOR SIDE)

- In air-cooled systems: the outdoor unit uses fans to release heat to the ambient air.
- In water-cooled systems: heat is transferred to water, then expelled through a cooling tower by evaporating a portion of the water.

❖ CONTINUOUS OPERATION

- The cycle repeats automatically based on temperature settings controlled by a thermostat to maintain the desired indoor climate.

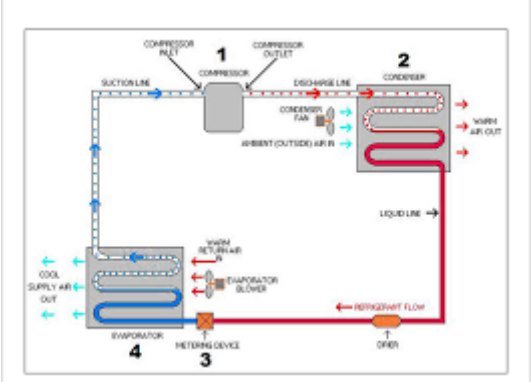

Figure 68 : CYCLE OF OPERATION FOR HVAC SYSTEMS

TYPES OF AIR CONDITIONING UNITS

❖ MINI SPLIT UNIT

- A compact system consisting of an indoor wall-mounted unit and an outdoor condenser.
- Ideal for single rooms or small zones.
- Quiet, energy-efficient, and doesn't require ductwork.

Figure 69 : MINI SPLIT UNIT

❖ CASSETTE AC UNIT

- Indoor unit is mounted in the ceiling (usually in false ceilings) with 4-way air distribution.
- Commonly used in offices, meeting rooms, and retail spaces.
- Connected to an outdoor unit like a split system.

Figure 70 : CASSETTE AC UNIT

❖ CENTRAL SPLIT SYSTEM

- Consists of a large outdoor condensing unit and an indoor air handling unit connected via ductwork.
- Distributes cooled air to multiple rooms through air ducts.
- Suitable for large apartments, villas, and small commercial buildings.

Figure 71 : CENTRAL SPLIT SYSTEM

❖ SPLIT UNIT (WALL-MOUNTED)

- The most common residential type.
- Includes one indoor unit fixed on the wall and a separate outdoor unit.
- Cost-effective and easy to install for single zones.

Figure 72 : SPLIT UNIT (WALL-MOUNTED)

ADDITIONAL HVAC SYSTEM TYPES

❖ FCU – FAN COIL UNIT

- A terminal unit used to cool or heat a single room or zone.
- Contains a fan and a coil (connected to chilled/hot water).
- No ductwork required (except for optional fresh air).
- Controlled individually via a room thermostat.
- Applications: Offices, hotel rooms, apar tments.

Figure 73 : FCU

❖ VAV – VARIABLE AIR VOLUME SYSTEM

- An air distribution system that varies the airflow (not temperature) to each zone based on demand.
- Works with a central AHU that supplies conditioned air.
- VAV boxes in each zone adjust the airflow using dampers.
- Efficient and widely used in commercial buildings with multiple zones.
- Allows better comfort control and energy savings.

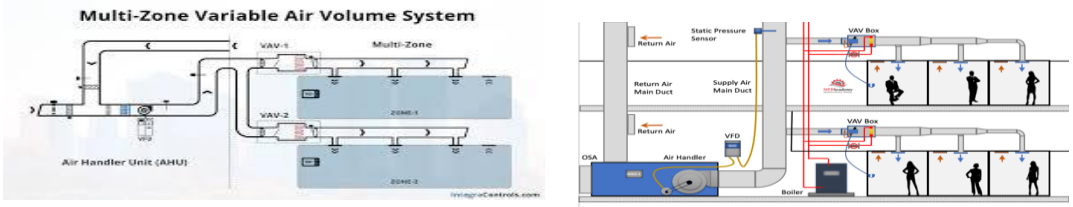

Figure 74 : VAV

❖ VRF – VARIABLE REFRIGERANT FLOW

- A refrigerant-based system where a single outdoor unit connects to multiple indoor units.
- Controls the amount of refrigerant flowing to each indoor unit depending on the load.
- Types:
  - VRV (Variable Refrigerant Volume): same as VRF (term used by Daikin).
  - Heat Pump Type: all zones either cool or heat.
  - Heat Recovery Type: allows simultaneous cooling and heating in different zones.
- Highly efficient, flexible, and suitable for buildings with many rooms and varying loads (hotels, clinics, offices).

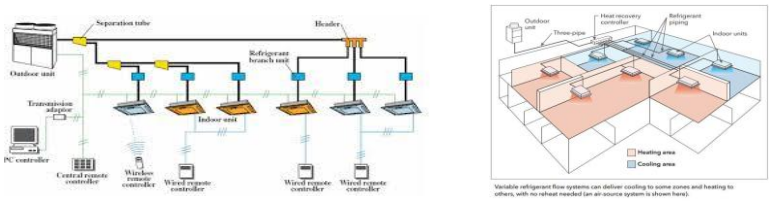

Figure 75 : VRF

POWER DESIGN

LEACTURE SUMMARY

SMALL POWER SOCKETS

❖ SIMPLEX

- 2-pin, no earth, 10A, 1 module.
- Used for light loads like chargers.

Figure 76 : SIMPLEX

❖ SCHUKO

- 2-pin + side earth (3 contacts), 16A, 2 modules.
- Common for general appliances.

Figure 77 : SCHUKO

❖ MK (UK TYPE)

- 3-pin (L, N, E), 16A, 2 modules.
- Safer option, used in hospitals, kitchens, etc.

Figure 78 : MK

INDUSTRIAL SOCKET

- Rated up to **125 A**.
- Available in **2, 3, 4, or 5 poles** depending on the application (single-phase or three-phase with/without neutral and earth).
- Used in factories, heavy-duty equipment, and outdoor panels.

Figure 79 : INDUSTRIAL SOCKET

DISCONNECT SWITCH

- Rated up to **2500 A** (or up to 1250 A in some catalogs).
- Also available in **2, 3, 4, or 5 poles**.
- Used to isolate circuits for maintenance or safety shutdown.

Figure 80 : DISCONNECT SWITCH

AVAILABLE CURRENT RATINGS

- 10 – 16 – 20 – 25 – 32 – 40 – 50 – 63 – 80 – 100 – 125 – 160 – 200 – 250 – 320 – 400 – 500 – 630 – 800 – 1000 – 1250 – 1600 – 2000 – 3200 – 4000 – 5000 – 6300 – 8000 A

❖ APPLICATIONS BY DEVICE TYPE

- **Industrial Sockets:** Up to **125 A**
- **Disconnect Switches:** Up to **1250 A** (some types up to 2500 A)
- **Circuit Breakers:** Up to **8000 A**

POWER RATING FOR SOCKETS

❖ NORMAL SINGLE SOCKET

- **Power rating: 180 – 250 VA**
- This refers to a single outlet socket.
- Commonly used for small devices like chargers, fans, lamps, etc.

❖ DUPLEX SOCKET (DOUBLE SOCKET)

- **Power rating: 360 – 500 VA**
- This is a double outlet socket (two plugs in one unit).
- Can supply power to two devices simultaneously, so the estimated load is higher.

Figure 82: NORMAL SINGLE SOCKET

Figure 81 : DUPLEX SOCKET (DOUBLE SOCKET)

TYPES OF SOCKETS

❖ BED HEAD UNIT SOCKET

- Used in hospital rooms, integrated into the bed head unit.
- Often includes sockets for medical devices, nurse call systems, gas outlets, etc.
- Must comply with medical-grade standards (e.g., IEC 6 0601).

Figure 83 : BED HEAD UNIT SOCKET

❖ EXPLOSION-PROOF SOCKET

- Designed for hazardous areas where there is a risk of explosion due to flammable gases, vapors, or dust.
- Enclosed in a sealed and rugged casing.
- Used in industries like oil & gas, chemical plants, or fuel stations.

Figure 84 : EXPLOSION-PROOF SOCKET

❖ ANTI-BACTERIAL SOCKET

- Made of germ-resistant materials (e.g., silver ion coatings).
- Used in hospitals, clinics, laboratories, or food processing facilities.
- Helps prevent the spread of bacteria and infections.

Figure 85 : ANTI-BACTERIAL SOCKET

❖ TAMPER-RESISTANT SOCKET

- Has internal shutters that block access unless a proper plug is inserted.
- Used in schools, kindergartens, and homes to protect children from electric shocks.
- Often required by electrical codes in certain regions (like NEC in the US).

Figure 86 : TAMPER-RESISTANT SOCKET

❖ SOCKET WITH USB

- Combines a standard power outlet with USB charging ports (e.g., USB-A or USB-C).
- Convenient for charging phones, tablets, and small devices without a charger adapter.
- Common in hotels, offices, modern homes.

Figure 87 : SOCKET WITH USB

❖ UNIVERSAL SOCKET

- Accepts multiple plug types (e.g., US, UK, EU, etc.).
- Useful in international hotels, airports, or travel-related environments.
- Not always allowed in some countries due to safety concerns.

Figure 88 : UNIVERSAL SOCKET

❖ FLOOR SOCKET (FLOOR BOX)

- Installed in the floor (concrete, raised floor, wood, etc.).
- Comes with a cover for protection when not in use.
- Common in offices, conference rooms, showrooms, etc.

Figure 89 : FLOOR BOX

❖ TABLE SOCKET

- Mounted on or inside meeting tables, workstations, or desks.
- Usually includes power + data + USB.
- Popular in office spaces , co-working environments, and educational facilities.

Figure 90 : TABLE SOCKET

SOCKET OUTLETS ARE DISTRIBUTED BASED ON

1. **Room Function**
   - Depends on usage: kitchen, office, bedroom, hospital, etc.
2. **Load Requirements**
   - To avoid overloading, socket circuits are designed based on expected loads.
3. **Standards & Codes**
   - Placement follows standards like IEC, NEC, or local codes (e.g., Egyptian Code).
4. **User Accessibility**
   - Sockets should be easy to reach and installed at proper heights.
5. **Furniture Layout**
   - Coordinated with furniture to avoid blocked outlets.
6. **Special Needs**
   - USB sockets (modern use)
   - Tamper-resistant (child safety)
   - Explosion-proof (hazardous areas)
   - Anti-bacterial (hospitals)
7. **Diversity Factor**
   - Not all sockets are used at the same time — diversity is considered in design.
8. **Aesthetics & Cable Management**
   - Floor and table sockets help reduce visible wiring and maintain clean layouts.

MCC PANELS (MOTOR CONTROL CENTERS)

❖ DEFINITION

- An MCC panel is a centralized panel or cabinet that houses equipment to control multiple electric motors in an industrial or commercial facility.

❖ MAIN COMPONENTS:

1. **Circuit Breakers / Fuses** – Protection for each motor.
2. **Contactors** – To start/stop motors remotely.
3. **Overload Relays** – To protect motors from overcurrent.
4. **Starters** – DOL, Star-Delta, Soft Starters, or VFDs (Variable Frequency Drives).
5. **Control Devices** – Push buttons, selector switches, indicators.
6. **Power Busbars** – For distributing power to all motor feeders.

❖ WHERE MCC PANELS ARE USED:

- Factories & Industrial Plants
- Water treatment stations
- HVAC systems
- Pumping stations
- Oil & gas facilities

❖ PURPOSE / FUNCTIONS:

- Centralized control and protection of motors.
- Ease of maintenance: All motor controls are in one location.
- Safety: Clear isolation and emergency stop.
- Can integrate with SCADA or PLC systems for automation.

Figure 91 : MCC PANELS

EGYPTIAN CODE FOR SOCKETS (SHABAN, 2025)

- Sockets in residential and office areas should be installed at heights between 30 cm and 50 cm above the finished floor level.
- In kitchens and bathrooms, the mounting height should be between 1.2 m and 1.35 m.
- Each socket must have a proper grounding connection with the metal back box.
- The socket faceplate must be made from a solid, non-flammable insulating material that:
    - Does not soften up to 85°C
    - Does not deform during normal use

- All sockets must be 2-pole with an earth terminal, whether single or double.
- The rated voltage and current must be clearly marked on the socket body in raised characters.
- Floor-mounted sockets must be of a waterproof type to avoid insulation damage from cleaning.
- Outdoor sockets must be:
    - Weatherproof
    - Equipped with a tight-sealing cover
    - Suitable for surface or flush mounting
- When sockets are installed on opposite sides of a wall, they must be separated by a minimum horizontal distance of 100 mm to prevent sound transfer.
- In wet areas (e.g., kitchens, bathrooms), sockets must be located where they are not reachable by a wet person.
- The correct IP protection rating must be used for sockets in wet or dusty environments.
- Sockets are not allowed inside bathtubs or shower enclosures.
- The maximum horizontal distance:
    - Between a socket and a corner wall: 1.8 m
    - Between two adjacent sockets: 3.65 m

PANEL BOARDS AND ZONING

LEACTURE SUMMARY

TYPES OF PANELS

❖ MAIN DISTRIBUTION BOARD (MDB)

- **Function**: Receives power from the main source (transformer/generator) and distributes it to sub-panels.
- **Voltage**: Typically 400/230V (Low Voltage systems).
- **Current Rating**: High capacity depending on total load.
- **Components**: Main circuit breaker, busbars, outgoing feeders.

Figure 92 : MAIN DISTRIBUTION BOARD

❖ SUB DISTRIBUTION BOARD (SDB)

- **Function**: Receives power from the MDB and distributes it to specific areas (e.g., floors or zones).
- **Used** in multi-story buildings or large facilities.
- **Current Rating**: Medium, based on connected loads.

Figure 93 : SUB DISTRIBUTION BOARD

❖ LIGHTING PANEL (LP)

- **Function**: Controls and distributes power to lighting circuits only.
- **Components**: MCBs, timers, motion sensors (if needed).
- **Load**: Low current.

Figure 94 : LIGHTING PANEL

❖ POWER PANEL (PP)

- **Function**: Distributes power to sockets, outlets, and power loads.
- **Load**: Medium to high loads, such as equipment and appliances.

Figure 95 : POWER PANEL

❖ MOTOR CONTROL CENTER (MCC)

- **Function**: Controls and feeds motors (e.g., pumps, fans, compressors).
- **Components**:
  - Motor starters (DOL, Star-Delta, Soft Starter, VFD),
  - Protection devices (Overload, Short Circuit, Phase failure).
- **Common in** industrial facilities.

Figure 96 : MOTOR CONTROL CENTER

❖ ATS PANEL (AUTOMATIC TRANSFER SWITCH)

- **Function**: Automatically switches between two power sources (e.g., utility and generator).
- **Components**: ATS controller, mechanical/electronic switching devices.

Figure 97 : ATS PANEL

❖ UPS PANEL

- **Function**: Provides backup power to sensitive equipment during outages.
- **Components**: UPS module, batteries, protection circuits.

Figure 98 : UPS PANEL

❖ CAPACITOR BANK PANEL

- **Function**: Power Factor Correction.
- **Used in** facilities with many inductive loads (motors, compressors).

Figure 99 : CAPACITOR BANK PANEL

❖ MEDIUM VOLTAGE SWITCHGEAR PANEL

- **Function**: Handles medium voltage (e.g., 11kV) distribution if applicable.
- **Components**: MV circuit breakers, disconnect switches, protection relays.

Figure 100 : MEDIUM VOLTAGE SWITCHGEAR PANEL

MOUNTING METHODS OF ELECTRICAL PANELS

❖ EMBEDDED (FLUSH MOUNTED) PANEL

- **Definition**: Installed inside the wall so that the front cover is flush with the wall surface.
- **Usage**: Common in residential and commercial projects for aesthetic purposes.
- **Requirement**: Requires a **thick enough wall** to accommodate the panel box.

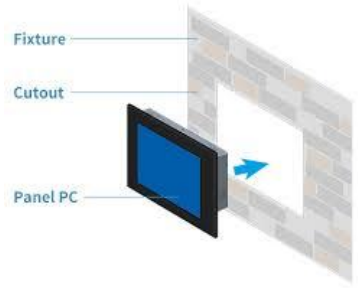

Figure 101 : EMBEDDED (FLUSH MOUNTED) PANEL

❖ EXPOSED (SURFACE MOUNTED) PANEL

- **Definition**: Installed on the surface of the wall with the entire box visible.
- **Usage**: Common in industrial and utility rooms or when the wall is too thin for embedding.
- **Easy** to install and maintain.

Figure 102 : EXPOSED (SURFACE MOUNTED) PANEL

CLASSIFICATION BY CONTENT

❖ EMPTY PANEL (UNWIRED)

- Supplied without any internal components (circuit breakers, busbars, etc.).
- Usually used when the contractor will install and wire the components on-site.

Figure 103 : EMPTY PANEL (UNWIRED)

❖ WIRED PANEL (PRE-ASSEMBLED / READY-TO-USE)

- Comes fully equipped with circuit breakers and internal wiring.
- Factory-tested and ready for installation.

Figure 104 : WIRED PANEL

CLASSIFICATION BY DELIVERY TYPE

❖ STOCK PANEL

- Standard sizes and specifications available off-the-shelf.
- Faster delivery, cheaper cost.

❖ SPECIAL ORDER PANEL

- Custom-made for specific requirements (size, components, brand, etc.).
- Requires more time for manufacturing and higher cost.

FACTORS AFFECTING INSTALLATION METHOD

1. Wall Thickness
   - Thick walls allow embedded panels.
   - Thin or partition walls require surface-mounted panels.
2. Location Type (residential, commercial, industrial).
3. Aesthetic Requirements (e.g., in villas or offices, embedded may be preferred).
4. Ease of Access and future maintenance.

MAIN COMPONENTS OF AN ELECTRICAL PANEL (LCP)

Used to control and monitor local equipment (like motors, pumps, fans).

Typical components inside an LCP:

- Push buttons (Start / Stop)
- Selector switches (Auto / Manual / Off)
- Indicator lamps (status lights: ON / OFF / Trip)
- Control relays
- Overload relays
- Contactor (Silent or Standard)

Figure 105 : LCP

❖ INDICATOR LAMPS (PILOT LIGHTS)

- **Function**: Visual status indication for:
  - Power ON (Incoming supply)
  - Motor Running
  - Fault / Trip
- **Colors** (typically according to IEC):
  - Red – Fault / Stop
  - Green – Running / ON
  - Yellow / Amber – Warning / Standby
  - Blue / White – Auxiliary or special functions

❖ CONTACTOR

- **Standard Contactor**: With audible operation (clicking noise).
- **Silent Contactor**: Designed for noise-sensitive areas (e.g., hospitals, offices). Operates quietly using solid-state or soft coil mechanisms.

CIRCUIT BREAKERS ARRANGEMENT

1. Used Breakers (In-Use)

- Already installed and connected to specific loads.

2. Spare

- Breakers installed in the panel but not connected to any load yet — for future expansion.

3. Space

- Empty physical space reserved for future installation of breakers.

NEUTRAL AND EARTH BARS

❖ NEUTRAL BAR (N-BAR)

- **Isolated** from the panel body (using insulated supports).
- Prevents unintended grounding.
- All neutral wires of outgoing circuits are connected here.

❖ EARTH BAR (PE – PROTECTIVE EARTH)

- **Directly bonded** to the panel enclosure (no insulation).
- Connected to all grounding wires.

CONNECTION OF CIRCUIT BREAKERS

1. Using Terminals

- Each breaker is connected to a screw or spring terminal.
- Suitable for small panels and low-current applications.

2. Using Busbars

- A copper or aluminum busbar connects a group of breakers.
- More reliable and tidy for higher current and better distribution.
- Comes in single-pole, 3-phase, or modular comb busbar types.

MINI CENTER

❖ GENERAL DESCRIPTION:

- A Mini Center is a compact distribution panel used mainly in residential and commercial buildings.
- Typically flush mounted (embedded) into the wall.
- Designed for distributing power in small-scale circuits like lighting and socket outlets.

❖ FISHBONE BUSBAR SYSTEM

Definition:

- A Fishbone busbar is a pre-fabricated copper busbar with a comb-like shape, enabling quick and neat connection of circuit breakers.
- Installed inside the panel for safe and efficient power distribution.

❖ TECHNICAL FEATURES

- **Incoming**: 3-phase (L1, L2, L3).
- **Outgoing**: Can be single-phase or 3-phase depending on the circuit.
- **Rated up to**: **160 A**.

❖ PANEL CONFIGURATION AND TERMINOLOGY

Block = 2 Ways

- Each **block** in the panel consists of **2 ways**.
  1 Way = 3 Single Pole Slots
- Each way accommodates 3 single-pole circuit breakers, or a 3-pole breaker.

❖ UNUSED BREAKER SLOTS

- Unused circuit breaker positions must be covered with insulating covers or blanking plates.
- This ensures safety and prevents accidental contact.

❖ ALIGNMENT ISSUES WITH FISHBONE BUSBAR

- Sometimes the fishbone busbar terminals may not perfectly align with the breaker terminals.
- In such cases, a "Modification Kit" or "Adaptation Set" is used.

Adaptation Kit

- Designed specifically for the type/brand of the miniature breaker.
- Connects the busbar to the breaker securely.
- Ensures mechanical fit and electrical continuity.

❖ BREAKER TYPES USED

- Miniature Circuit Breakers (MCB) are commonly used.
- Ratings vary depending on the load (e.g., 6A to 63A).

INSTALLATION GUIDELINES

- Support height should be at least 20 cm, and can be higher based on site conditions.
- The top point of the panel equals the panel height plus the support height.
- Support depth should be 2 cm less than the panel depth to maintain proper alignment.
- All panels within the same room should be installed at the same elevation for consistent appearance.
- Panel height must allow easy and safe access for maintenance.
- Adequate clearance should be provided in front of the panel to allow full door opening and technician movement.
- Panels are typically flush-mounted (embedded) into the wall unless surface mounting is required.
- The electrical room door should have a ventilation grill to support air circulation and reduce heat buildup.

PANEL COMPONENTS AND INTERNAL CONFIGURATION

- Panels are available with capacities of 6, 12, 18, 24, 30, 36, 42, 48, 54, and 60 single lines.
- Miniature circuit breakers (MCBs) are interconnected using fishbone busbars or terminals.
- Fishbone busbars are usually fed by a 3-phase input and can feed either single-phase or 3-phase circuits.
- Typical busbar rating is up to 160 A.
- One block includes 2 ways, and each way can hold 3 single-pole breakers.
- Unused MCB slots must be closed with blanking covers or insulators for safety.
- In case of misalignment between busbar and breaker terminals, an adaptation kit matching the breaker type should be used.
- The main breaker should be of the same type as the outgoing breakers, but must have a lower tripping threshold to provide upstream protection.
- A single-phase panel can be used as a 3-phase panel by reducing the number of input lines and using a merging busbar connected to an MCCB.

INSPECTION, LABELING, AND DOCUMENTATION

- During handover, verify that the panel dimensions match the approved drawings.
- Perform functional testing on all breakers and internal wiring.
- Confirm that all labels are properly installed on breakers, terminals, and the panel nameplate.
- Each panel should have a unique name and number identifying its function, type, and location.
- The design and internal arrangement of the panel must follow the approved panel schedule.

PANEL SCHEDULE , CABLES AND C.B CALCULATIONS

LEACTURE SUMMARY

ELECTRICAL MEASURING AND MONITORING DEVICES

❖ VOLTMETER

- Measures the voltage (potential difference) between two points in a circuit.
- Connected in parallel with the load.
- Commonly used in distribution panels and control boards to monitor supply or phase voltage.

Figure 106 : VOLTMETER

❖ AMMETER

- Measures the electric current (in amperes) flowing through a circuit.
- Connected in series with the circuit.
- For high currents, it works with a Current Transformer (CT).
- Used for load monitoring and overload detection.

Figure 107 : AMMETER

❖ POWER METER

- Measures electrical power:
  - Active Power (kW)
  - Reactive Power (kVAR)
  - Apparent Power (kVA)
- Helps monitor system performance and load efficiency.

Figure 108 : POWER METER

❖ ENERGY METER

- Measures the total energy consumption over time, typically in kWh.
- Used in residential, commercial, and industrial metering for billing or monitoring.

Figure 109 : ENERGY METER

❖ POWER FACTOR METER

- Displays the power factor (PF), i.e., the ratio of real power to apparent power.
- Indicates how efficiently the electrical power is being used.
- Helps identify the need for Power Factor Correction (PFC).

Figure 110 : POWER FACTOR METER

❖ FREQUENCY METER

- Measures the frequency (Hz) of the AC voltage.
- Typical values: 50Hz or 60Hz depending on the country.
- Important in monitoring power quality and generation stability.

Figure 111 : FREQUENCY METER

INSTRUMENT TRANSFORMERS

❖ CT (CURRENT TRANSFORMER)

- Steps down high current to a smaller, measurable value (e.g., from 1000A to 5A).
- Used with meters and relays to enable safe monitoring and protection.
- Essential in medium/high v oltage switchboards.

Figure 112 : CT (CURRENT TRANSFORMER)

❖ VT OR PT (VOLTAGE TRANSFORMER / POTENTIAL TRANSFORMER)

- Steps down high voltage to a safer, measurable level (e.g., 11kV to 110V).
- Used in metering and protection of hi gh-voltage systems.

Figure 113 : VT OR PT (VOLTAGE TRANSFORMER / POTENTIAL TRANSFORMER)

PHASE MONITORING DEVICES

❖ PHASE SEQUENCE INDICATOR

- Detects the order of phases (R-Y-B).
- Ensures correct motor rotation and prevents reverse running.
- Common in motor and generator installations.

Figure 114 : PHASE SEQUENCE INDICATOR

PROTECTIVE RELAYS

❖ OVER/UNDER VOLTAGE RELAY

- Monitors voltage levels.
- Trips the circuit if voltage exceeds or drops below set thresholds.
- Protects equipment from damage due to voltage instability.

Figure 115 : OVER/UNDER VOLTAGE RELAY

❖ EARTH LEAKAGE RELAY (ELR)

- Detects leakage currents to the ground caused by insulation faults or contact with live parts.
- Trips the circuit to protect people and equipment.
- Common in systems with RCDs and sensitive loads.

Figure 116 : EARTH LEAKAGE RELAY (ELR)

REMOTE MONITORING

❖ REMOTE MONITORING UNIT (RMU)

- Collects and transmits data from meters, relays, and sensors to a central monitoring system (e.g., SCADA, BMS).
- Allows remote control, real-time monitoring, and fault diagnostics.
- Often includes alarms and event logging.

Figure 117 : REMOTE MONITORING UNIT (RMU)

PANEL AND CELL DEPTH GUIDELINES

- The panel depth is usually 30 cm or less
- The switchgear cell (MV cell) depth can be 40 cm, 60 cm, or 80 cm
- If the circuit breaker is 630 A, then we should use a cell with 80 cm depth
  - It provides enough space for the breaker, cable connections, and protection devices.

Figure 119 : PANEL

Figure 118 : switchgear cell

CONTENTS OF A PANEL SCHEDULE

❖ Panel Location

- Specifies the exact physical location of the panel (e.g., Ground Floor Electrical Room)

❖ Panel Feed From

- Indicates the upstream source panel or MDB supplying this panel

❖ Panel Mounting

- Describes how the panel is installed: wall-mounted, floor-standing, or flush-mounted

❖ Main Cable Entry

- Direction of incoming cable entry: from top or bottom

❖ Rated Voltage (Type and Value)

- The operating voltage level and type (e.g., 400/230V, 3-phase, 4-wire)

❖ Rated Frequency

- Usually 50 Hz or 60 Hz depending on the country

❖ Main Circuit Breaker and Its Rating

- Type and capacity of the main protection device (e.g., MCCB 250A, 3P)

❖ Cable Size and Type

- Incoming cable specification, e.g., 4C x 50 mm^2 Cu XLPE/SWA/PVC

❖ Panel Enclosure

- Panel body material and IP rating (e.g., Steel, IP54, indoor type)

❖ Number of Panel Ways / Circuits / Lines

- Total number of outgoing ways or breakers (e.g., 24 circuits)

❖ Notes

- Additional remarks like spare circuits, future provisions, o r special conditions

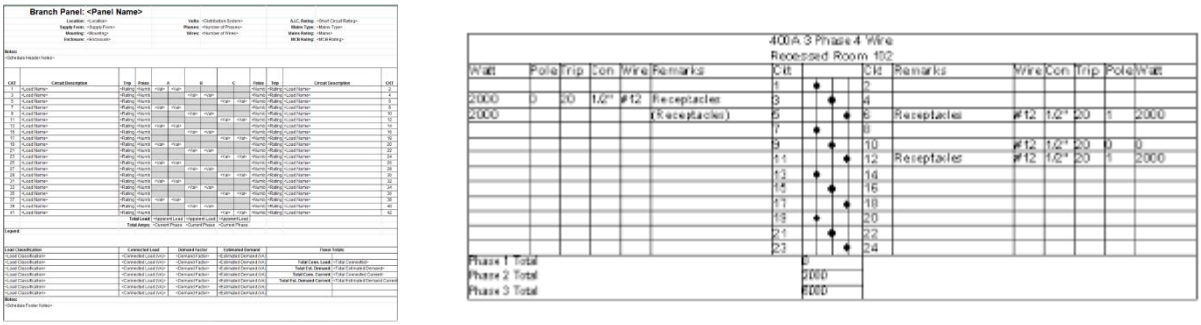

Figure 120 : PANEL SCHEDULE

ELECTRICAL FACTORS

❖ PHASE BALANCE

- Equal distribution of electrical load across the three phases
- Reduces neutral current and improves system per formance

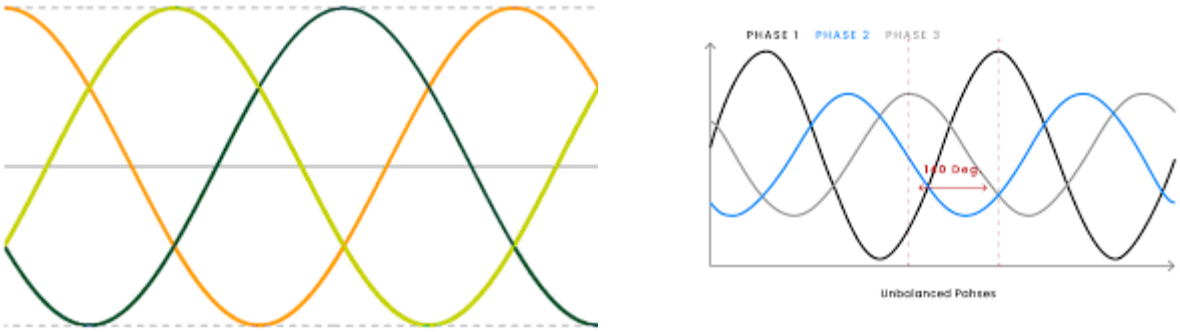

Figure 121 : PHASE BALANCE

❖ CONNECTED LOAD

- Total rated power of all connected equipment
- Includes all loads, whether running or not

❖ DEMAND LOAD

- Actual power drawn at a specific moment
- Always less than or equal to the connected load

Figure 122 : CONNECTED LOAD & DEMAND LOAD

❖ DEMAND FACTOR

- Indicates how much of the connected load is actually used
- Formula: Maximum Demand ÷ Connected Load
- Value is less than or equal to 1

❖ LOAD FACTOR

- Measures load efficiency over time
- Formula: Average Load ÷ Peak Load
- Higher value means better system utilization

❖ DIVERSITY FACTOR

- Reflects that not all loads operate at the same time
- Formula: Sum of Individual Maximum Demands ÷ System Maximum Demand
- Value is greater than 1
- Helps in designing smaller, more efficient systems

CIRCUIT BREAKER OVERVIEW

❖ FUNCTION OF CIRCUIT BREAKER

- Automatically interrupts the electrical circuit during overload or short-circuit conditions
- Protects equipment and cables from damage caused by fault currents
- Allows safe manual or automatic switching of circuits for maintenance or isolation

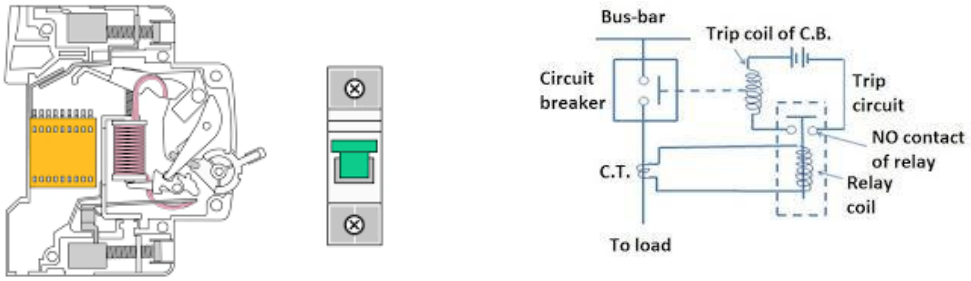

Figure 123 : FUNCTION OF CIRCUIT BREAKER

❖ CONSTRUCTION OF CIRCUIT BREAKER

- Contacts: Fixed and moving parts that open or close the circuit
- Arc Chute: Extinguishes the arc generated during contact separation
- Operating Mechanism: Spring or motor-operated system that controls the contacts
- Trip Unit: Detects abnormal conditions (thermal, magnetic, or electronic) and triggers the breaker
- Housing/Enclosure: Provides insulation and protect ion from external factors

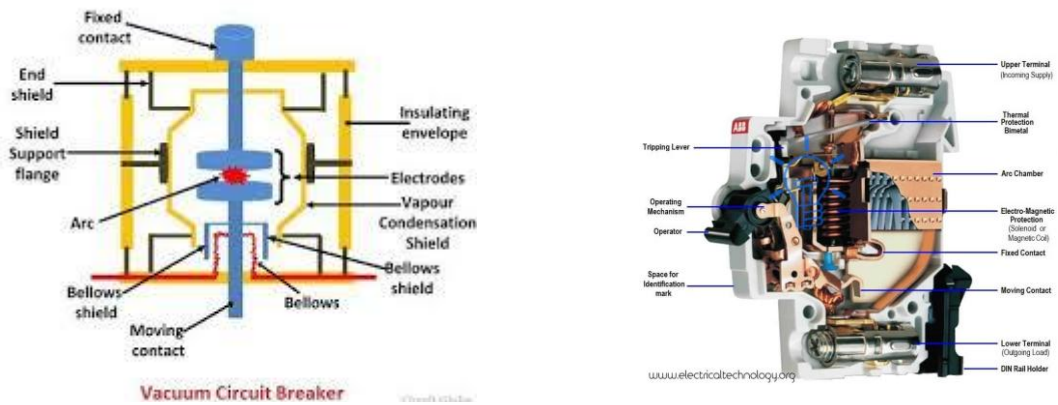

Figure 124 : CONSTRUCTION OF CIRCUIT BREAKER

❖ CLASSIFICATION OF CIRCUIT BREAKER (ACCORDING TO OPERATING VOLTAGE)

- **Low Voltage Circuit Breakers (LV)**
  - Used for voltages up to 1000 V
  - Examples: MCB, MCCB, RCCB
- **Medium Voltage Circuit Breakers (MV)**
  - Used for voltages from 1 kV to 33 kV
  - Examples: Vacuum CB, SF6 CB
- **High Voltage Circuit Breakers (HV)**
  - Used for voltages above 33 kV
  - Examples: Oil CB, SF6 CB, Air Blast CB

❖ AMPERE FRAME & AMPERE TRIP

Ampere Frame (AF)

- Represents the maximum current capacity the circuit breaker's body can handle structurally.
- It defines the physical size and maximum **rating** of the breaker.
- Example: A breaker with 400AF can be fitted with trip units of 100A, 250A, or 400A.

Ampere Trip (AT)

- Represents the actual current rating at which the breaker will trip.
- It's the adjustable or fixed setting for protection against overloads.
- Example: A breaker with 400AF and 250AT means it will trip at 250A.

❖ TYPES OF CIRCUIT BREAKERS

MCB (Miniature Circuit Breaker)

- Used for low current ratings (up to 125A)
- Common in residential and small commercial applications
- Provides protection against overload and short circuit
- Non-adjustable, compact in size

Figure 125 : MCB (Miniature Circuit Breaker)

MCCB (Molded Case Circuit Breaker)

- Used for **medium current ratings** (up to 1600A or more)
- Suitable for industrial and large commercial use
- Offers adjustable trip settings for overload protection
- Can protect against short circuits, overloads, and ground faults

Figure 126 : MCCB (Molded Case Circuit Breaker)

ACB (Air Circuit Breaker)

- Used for high current ratings (up to 6300A)
- Mainly used in main distribution panels and substations
- Operates in air as the arc extinguishing medium
- Supports advanced protection settings, communication, and remote operation

Figure 127 : ACB (Air Circuit Breaker)

❖ SPECIFICATION OF CIRCUIT BREAKER

Short Circuit Current (Icu / Ics)

- The maximum fault current the breaker can safely interrupt.
- Icu: Ultimate breaking capacity (withstand once).
- Ics: Service breaking capacity (withstand multiple times, usually a % of Icu).
- Measured in kiloamperes (kA).

Rated Current (In)

- The continuous current the breaker can carry without tripping.
- Examples: 16A, 100A, 250A, etc.
- Can be fixed (in MCBs) or adjustable (in MCCBs and ACBs).

Categories (AC/DC)

- Specifies whether the breaker is used in AC systems, DC systems, or both.
- Affects arc extinguishing design and application.

Classes (for MCBs – B, C, D)

- Defines the **tripping curve** or response time of the breaker:
  - **Class B:** Trips at 3–5 times rated current (for lighting/residential use)
  - **Class C:** Trips at 5–10 times rated current (for general loads/motors)
  - **Class D:** Trips at 10–20 times rated current (for heavy inductive loads)

Poles

- Indicates the number of conductors the breaker can disconnect:
  - **1P**: Single-phase (1 live wire)
  - **2P**: Single-phase + Neutral
  - **3P**: Three-phase
  - **4P**: Three-phase + Neutral

❖ SIZING OF CIRCUIT BREAKER

- Depends on:
  - Load current
  - Type of load (resistive, inductive)
  - Short circuit capacity of the system
  - Cable size and thermal capacity
- Always choose a breaker rated above the full load current and compatible with system fault levels.

CABLES AND WIRING SYSTEMS

❖ ARMORING OF CABLE

- **STA (Steel Tape Armored)**: Suitable for indoor or duct installations, offers basic mechanical protection.
- **SWA (Steel Wire Armored)**: Suitable for outdoor and underground installations, provides high mechanical protection.

Figure 128 : ARMORING OF CABLE

❖ WAY OF CABLE INSTALLATION

- Cables can be installed underground, on trays, ladders, in conduits, or directly on walls.
- The method depends on load type, environment, mechanical risks, and code requirements.

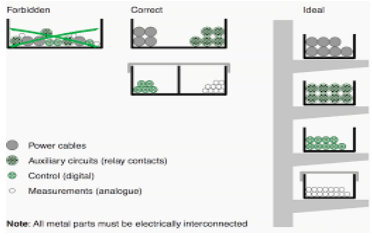

Figure 129 : WAY OF CABLE INSTALLATION

❖ DISCONNECT SWITCH

- Used for maintenance isolation only.
- Does not operate under load and should be switched when current is off.

Figure 130 : DISCONNECT SWITCH

❖ DEVICES AND WIRING DEVICES

- **Devices:** Functional components like relays, sensors, contactors.
- **Wiring Devices:** End-user elements like switches, sockets, plugs.

Figure 131 : Wiring Devices

Figure 132 : Devices

❖ WIRE VS. CABLE

- **Wire:** Single conductor, may be solid or stranded.
- **Cable:** Combination of two or more insulated conductors in a single sheath.

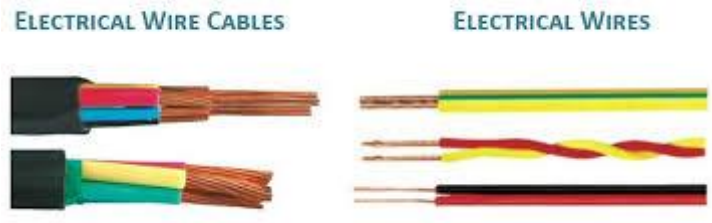

Figure 133 : WIRE VS. CABLE

❖ INSULATION TYPES OF CABLES

- **PVC:** Common, low cost, for general use.
- **XLPE:** Withstands higher temperatures, used in MV systems.
- **Mica:** Fire-resistant, used in emergency circuits.
- **LSOH:** Emits low smoke and zero halogen in fire, id eal for public buildings.

Figure 134 : INSULATION TYPES OF CABLES

❖ CABLE NAMING

- Based on number of cores, insulation, armoring, and material.
  - Example: 3C × 70 mm^2 Cu XLPE/SWA/PVC.

❖ AREA OF WIRE FOR TIME-BASED LOADING

- Cable sizing depends on the current it carries and time duration (e.g., 38 min).
- Selected according to standards (IEC, NEC) and inst allation conditions.

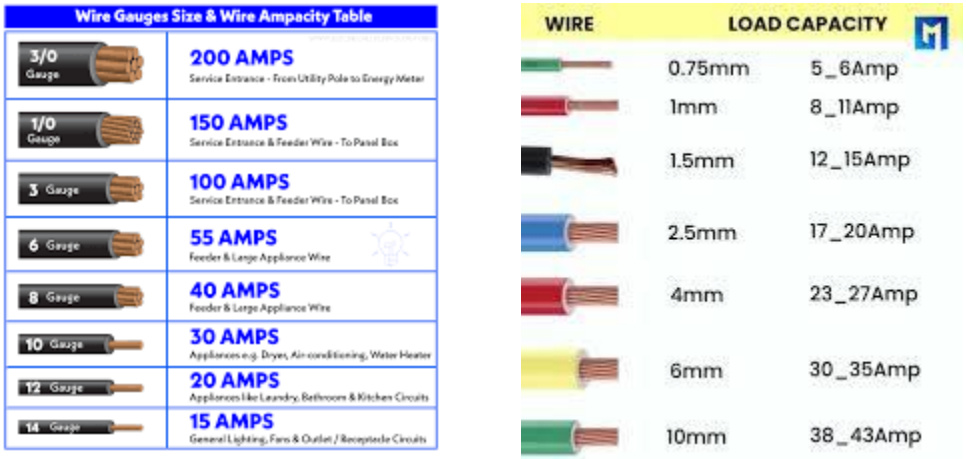

Figure 135 : AREA OF WIRE FOR TIME-BASED LOADING

- ✓ Aluminum Conductors Above 16 mm^2
  - Aluminum is used instead of copper in large sizes to reduce cost and weight.

- ✓ Medium Voltage Cables Are 3-Core Only
  - MV systems use delta connection, so neutral not needed.
  - Standard MV cables are 3-core (for 3-phase only).

- ✓ Neutral Size Based on Cable Size
  - For cables **≤ 35 mm^2** → Use **full-size neutral**
  - For cables **> 35 mm^2** → Use **reduced-size neutral** (e.g., half the phase size)

BULK EQUIPMENT AND SLD

LEACTURE SUMMARY

TRANSFORMER TYPE: POWER OR DISTRIBUTION

❖ POWER TRANSFORMER

- Used in transmission systems.
- Operates at high voltage levels (e.g., 220kV, 400kV).
- Designed for continuous full-load operation.
- Installed in transmission substations.
- Focused on maximum efficiency.
- Typically large in size and cost.

Figure 136 : POWER TRANSFORMER

❖ DISTRIBUTION TRANSFORMER

- Used in distribution networks to supply power to end users.
- Operates at medium or low voltage levels (e.g., 11kV, 400V).
- Handles variable loads depending on consumption.
- Installed near residential or commercial areas.
- Emphasizes cost-effectiveness and compact size.

Figure 137 : DISTRIBUTION TRANSFORMER

COOLING OF TRANSFORMER: OIL VS. DRY-TYPE

❖ OIL-IMMERSED TRANSFORMER

- Uses mineral or synthetic oil for cooling and insulation.
- Offers efficient heat dissipation, suitable for outdoor use.
- Not recommended for indoor installations due to fire/explosion risk.
- In indoor setups, usually limited to 80% of rated load for safety.
- Requires regular maintenance (oil testing, leak checks).
- Can cause environmental hazards if oil leaks.

Figure 138 : OIL-IMMERSED TRANSFORMER

❖ DRY-TYPE TRANSFORMER

- Uses air as the cooling medium; windings are resin-coated.
- Safe for indoor use – no oil, no risk of explosion.
- Can operate at 100% of rated capacity.
- Requires minimal maintenance.
- Ideal for commercial buildings, hospitals, schools, etc.
- More environmentally friendly and compact.

Figure 139 : DRY-TYPE TRANSFORMER

NAMEPLATE OF DISTRIBUTION TRANSFORMER

The nameplate of a distribution transformer typically includes the following key information:

- Rated power (kVA)
- Primary voltage (e.g., 11 kV or 22 kV)
- Secondary voltage (e.g., 400 V / 230 V)
- Frequency (50/60 Hz)
- Cooling type (Oil-immersed or Dry-type)
- Vector group
- Impedance (%)
- Insulation class
- Rated current (HV and LV sides)
- Weight and dimensions
- Serial number and manufacturer

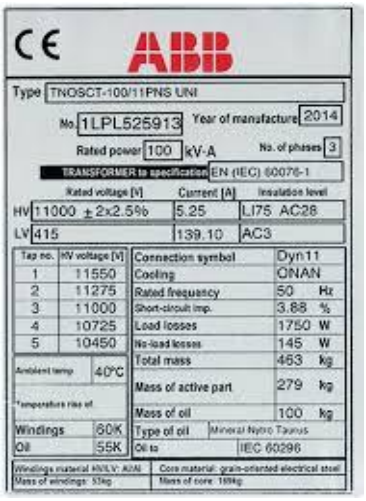

Figure 140 : NAMEPLATE OF DISTRIBUTION TRANSFORMER

TRANSFORMER SIZING

❖ DETERMINE THE INPUT VOLTAGE (PRIMARY VOLTAGE)

- Depends on the electrical network feeding the transformer.
- Example:
  - **Old city** network: 11 kV
  - **New city** network: 22 kV

❖ SELECT THE TYPE OF TRANSFORMER:

- Choose between:
  - **Oil-immersed** transformer: suitable for outdoor use or high loads.
  - **Dry-type** transformer: safer and better suited for indoor installations.

❖ CALCULATE THE REQUIRED TRANSFORMER CAPACITY:

- Based on the Main Distribution Panel (MDP) total connected load.
- Include diversity factor and future expansion if needed.
- Example:
  - Total connected load: 800 kVA
  - Demand factor: 0.8
  - Required capacity = 800 × 0.8 = 640 kVA

❖ ADJUST FOR OIL-TYPE TRANSFORMER LOAD FACTOR (IF APPLICABLE):

- If an oil-immersed transformer is used indoors, it may operate safely at only 80% of its rated capacity.
- So, required rated capacity = Required Load / 0.8
  Example: 64*/0.80 = 800 kVA

❖ SELECT THE NEAREST STANDARD TRANSFORMER SIZE:

- Transformer sizes follow standard steps (e.g., 630 kVA, 800 kVA, 1000 kVA...).
- Choose the next standard size equal to or greater than the calculated capacity.
- From example above, the selected transformer would be: 800 kVA

DETERMINING THE CIRCUIT BREAKER AND FUSE

❖ SELECT BASED ON TRANSFORMER RATING (NOT MDP LOAD)

- The protection device for a transformer (circuit breaker or fuse) should be sized according to the **transformer's rated capacity**, **not the total load on the MDP**.
- This ensures proper protection of the transformer itself during overloads or short-circuits.

❖ TYPE OF CIRCUIT BREAKER

- The main breaker for transformer protection can be one of the following:
  - **ACB** (Air Circuit Breaker) – typically used for **higher ratings**.
  - **MCCB** (Molded Case Circuit Breaker) – suitable for **medium and low ratings**.

❖ BASE CURRENT CALCULATION

- To calculate the base current (I_base) of the transformer:
  $I_{base} = \text{Transformer kVA} \times 1000 / (3 \times 220)$ *(Assuming LV side = 220V)*

❖ NOMINAL BREAKER CURRENT (IN)

- Select the breaker current rating as: $I_n = 1.25 \times I_{base}$
- This 125% margin allows for temporary overloads and inrush currents without nuisance tripping.

TRANSFORMER AND RMU INSTALLATION

❖ TRANSFORMER INSTALLATION (OIL OR DRY TYPE):

- **Foundation:**
  - Concrete base with vibration isolation.
  - Oil pit or bund wall for oil-immersed transformers to contain leakage.
- **Ventilation:**
  - Natural or forced ventilation for dry-type units.
  - Ensure proper airflow around transformer for cooling.
- **Earthing:**
  - Separate earthing for neutral, body, and surge arrestors.
- **Cabling:**
  - Use cable trench or cable risers with proper bending radius.
  - Ensure clear separation between HV and LV cables.
- **Clearances:**
  - Maintain safe distance from walls and other equipment per IEC standards.

❖ RMU (RING MAIN UNIT) INSTALLATION:

- **Location:**
  - Usually installed next to the transformer.
  - Mounted on concrete floor or foundation.
- **Cable Termination:**
  - Proper cable glands and sealing.
  - Use heat-shrink or cold-shrink terminations.
- **Earthing:**
  - All metal parts grounded; include earthing bar connection to building system.
- **Testing:**
  - Perform insulation resistance, functionality test, and continuity test before energizing.

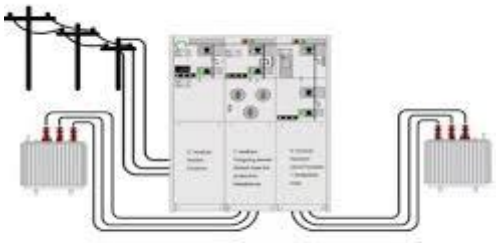

Figure 141 : TRANSFORMER AND RMU INSTALLATION

SPECIFICATIONS OF TRANSFORMER ROOM

❖ GENERAL REQUIREMENTS

- **Access:**
  - Dedicated access door (preferably double-leaf metal door).
  - Fire-rated door with panic bar (minimum 1.5 hours rating).
- **Ventilation:**
  - Cross ventilation or exhaust fans.
  - Maintain temperature within permissible limits (below 40°C for oil-type).
- **Lighting:**
  - LED industrial lights with emergency backup.

- **Flooring:**
  - Oil-resistant non-slip flooring.
  - Sloped to oil pit or containment area.
- **Fire Protection:**
  - Fire extinguisher (CO_2 or dry powder).
  - Fire/smoke detection system.
  - No flammable storage allowed.

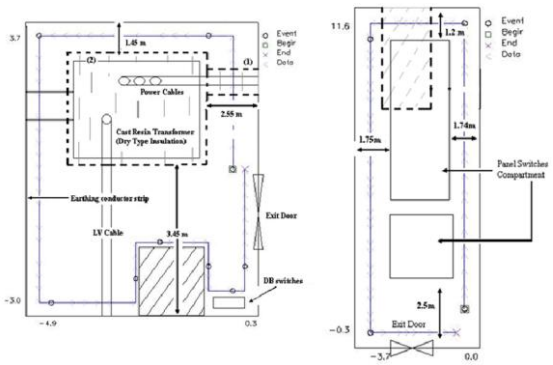

Figure 142 : TRANSFORMER ROOM

❖ ELECTRICAL AND SAFETY

- **Minimum Height:**
  - At least 3 meters clear height.
- **Clearances:**
  - 1 meter clearance on all sides of the transformer.
- **Cable Trench:**
  - Covered trench for LV and HV cables.
- **Earthing:**
  - Copper earth busbar fixed on the wall.
- **Signage:**
  - Warning signs, operating instructions, and equipment labels.

SPECIFICATIONS OF GENERATOR ROOM

❖ LOCATION AND ACCESS

- Should be at ground level or open area.
- Separate from other building areas.
- Large access doors for maintenance/removal.

❖ VENTILATION AND EXHAUST

- **Air Inlet:** Sized to meet engine air intake and cooling needs.
- **Exhaust System:**
  - Steel exhaust duct to the outside.
  - Flexible connection with silencer and weatherproof termination.

❖ SOUNDPROOFING

- Use acoustic insulation panels or install in a soundproof canopy.
- Comply with local noise regulations (usually < 75 dB at 1m distance).

❖ FUEL SYSTEM

- **Fuel Tank:** Day tank inside the room; bulk tank outside.
- **Leak Detection:** Sensors or bund wall for spill protection.
- **Ventilation:** Ensure proper ventilation to avoid gas buildup.

❖ ELECTRICAL & SAFETY

- **Automatic Transfer Switch (ATS)** installed outside or in nearby panel.
- **Fire Suppression System:** CO_2 system recommended.
- **Emergency Lighting:** Mandatory for safe exit during failure.
- **Earthing:** Dedicated earthing for generator neutral and body.

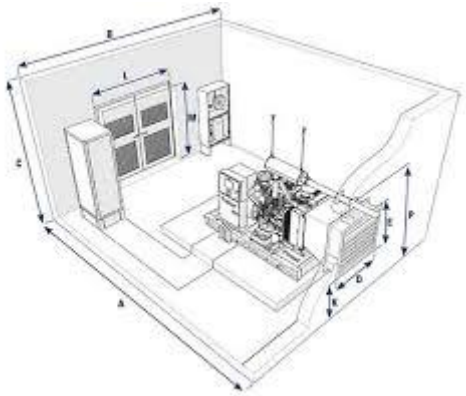

Figure 143 : GENERATOR ROOM

TYPES OF GENERATOR ACCORDING TO POWER RATINGS

❖ CONTINUOUS OPERATING POWER (COP):

- Provides non-stop power at a constant load without time limit.
- Used in locations with no utility grid.
- Generator runs 24/7 at steady load.

❖ PRIME POWER – UNLIMITED TIME:

- Operates for unlimited hours, but load can vary over time.
- Suitable for areas where main utility supply is not available.
- Allows 10% overload for 1 hour every 12 hours.

❖ PRIME POWER – LIMITED TIME:

- Similar to prime, but with a fixed number of running hours per year (e.g., 500 hrs/year).
- For temporary installations or scheduled power outages.

❖ EMERGENCY STANDBY POWER (ESP):

- Used only during utility power failure.
- Rated to run for max 200 hours/year, not continuously.
- No overload capability.

GENERATOR SIZING – MANUAL METHOD

- **Step 1:** Get load from EMDB in kW.
- **Step 2:** Convert to kVA → kW/0.8\text{kW} / 0.8kW/0.8.
- **Step 3:** Derate for 80% generator loading → kVA/0.8\text{kVA} / 0.8kVA/0.8.
- **Step 4:** Choose generator type: Standby / Prime / Continuous.
- **Step 5:** Select installation type:
  - **Open type:** For outdoor or isolated room.
  - **Enclosed type:** For indoor use (soundproof/weatherproof).
- **Step 6:** Select nearest standard rating (e.g., 150, 200 kVA).
- **Step 7:** Estimate fuel tank size based on consumption × runtime.

GENERATOR SIZING – SOFTWARE METHOD

- **Considers:** Starting current, voltage & frequency dip, load type.
- **Tools:** Caterpillar SpecSizer, Cummins Power Suite, FG Wilson Selector.
- Ensures accurate sizing & protection from under/overloading.

UPS – CIRCUITS & TYPES

❖ UPS CIRCUITS

- Installed between main supply and critical loads.
- Provides uninterrupted power during voltage failure or instability.
- Includes bypass, rectifier, battery, and inverter sections.

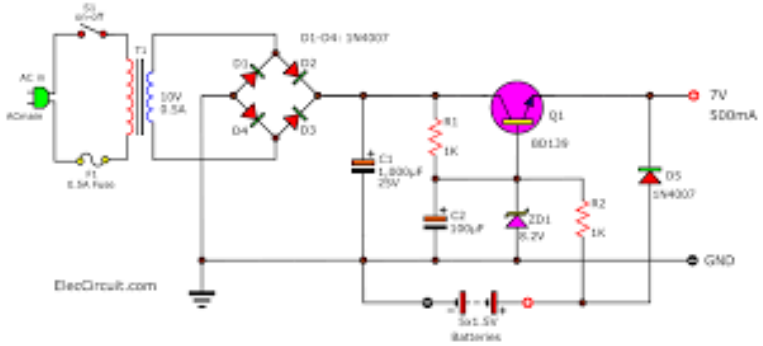

Figure 144 : UPS CIRCUITS

❖ UPS TYPES

- **Offline UPS:**
  - Normal mode: load powered directly from utility.
  - UPS activates only during power failure (few ms delay).

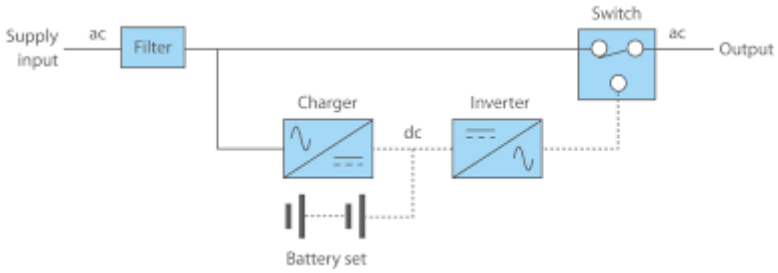

Figure 145 : Offline UPS

- **Online UPS:**
  - Load always fed from inverter.
  - Provides true isolation and zero transfer time.

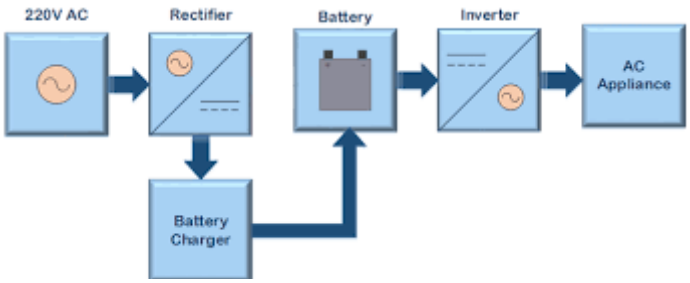

Figure 146 : Online UPS

- **Online (Parallel) UPS:**
  - Multiple UPS units work in parallel for redundancy or load sharing.

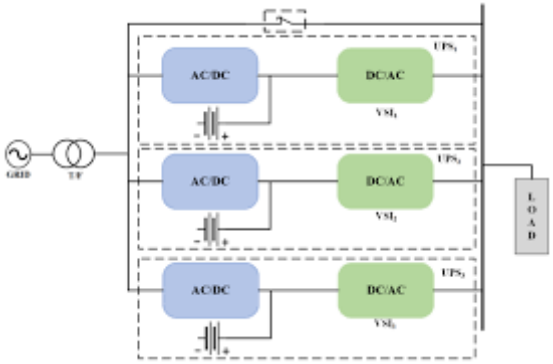

Figure 147 : Online (Parallel) UPS

- **Hybrid UPS:**
  - Combines features of online & offline.
  - Efficient in normal mode, becomes online when needed.

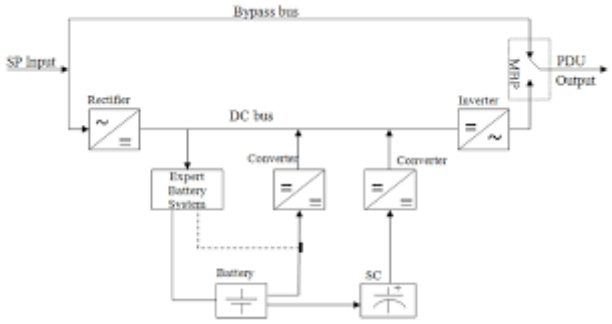

Figure 148 : Hybrid UPS

❖ STEPS FOR SIZING

1. **List all critical loads** connected to UPS (with power ratings in kW).
2. **Classify** each load as:
   - **Static** (electronics, IT, lights).
   - **Mechanical** (motors, HVAC).
3. **Apply the formula** to get total required kVA.
4. **Round up** to the nearest standard UPS size (e.g., 10, 20, 30, 40 kVA...).
5. **Determine backup time** (usually 10–30 minutes or more) and select battery accordingly.

ATS – AUTOMATIC TRANSFER SWITCH

- **Function**
  - Automatically transfers load between utility and generator.
  - Ensures continuous power without manual action.
- **How it Works**
  - Detects utility power failure.
  - Starts generator and shifts load automatically.
  - Returns load to utility once power is restored.
- **Features**
  - Fast response (within seconds).
  - Includes sensors for voltage and frequency monitoring.
  - Can integrate with control panels or BMS.

- **Applications**
  - Hospitals
  - Data centers
  - Commercial buildings
  - Critical systems

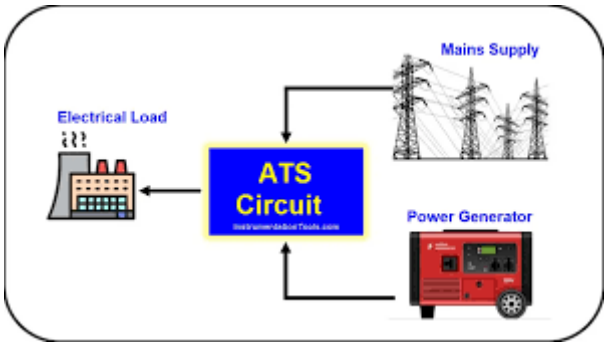

Figure 149 : AUTOMATIC TRANSFER SWITCH

MAT – MANUAL TRANSFER SWITCH

- **Function:**
  - Requires manual shifting of load between utility and generator.
  - No automatic detection or switching.
- **How it Works:**
  - Operator manually turns switch to generator during outage.
  - Switches back to utility manually when power returns.
- **Features:**
  - Simple and cost-effective.
  - No sensors or automation required.
  - Suitable for small-scale use.
- **Applications:**
  - Residential houses
  - Small offices
  - Low-priority or backup systems

Figure 150 : MANUAL TRANSFER SWITCH

ATS TYPES BASED ON SOURCE SELECTION LOGIC

❖ 1 OUT OF 2

- **Description:**
  - One load connected to two power sources (e.g., utility and generator).
  - ATS selects one active source out of the two.
- **Operation:**
  - If source 1 fails, it switches to source 2.
- **Most common type** in standard backup systems.

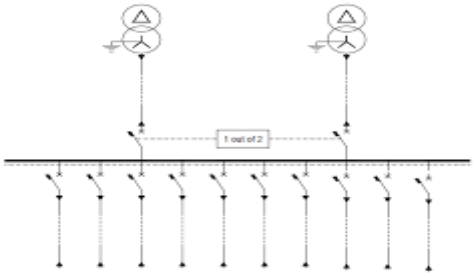

Figure 151 : 1 OUT OF 2

❖ 2 OUT OF 3

- **Description:**
  - One load connected to three sources, and the system selects the best 2 available sources to operate in parallel or load-sharing mode.
- **Application:**
  - Used in systems requiring redundancy, load balancing, or N+1 configurations.

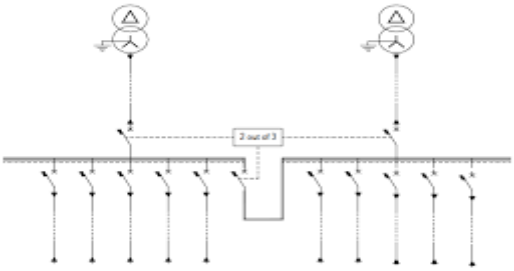

Figure 152 : 2 OUT OF 3

❖ 1 OUT OF 3

- **Description:**
  - One load connected to three sources, but the ATS operates with only one active source at a time.
- **Operation:**
  - Priority order is set: source 1 → source 2 → source 3.
  - If source 1 fails, it goes to 2; if 2 fails, it goes to 3.
- Used in advanced or critical setups with multi-source availability (e.g., grid + generator + solar).

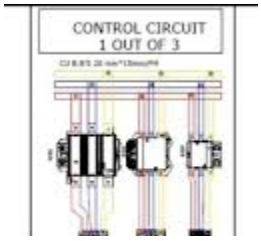

Figure 153 : 1 OUT OF 3

ATS SIZING

❖ **How to Select ATS Rating:**

- The ATS current rating can be selected based on one of the following:
  - The generator's apparent power (in kVA).
  - The rating of the incoming circuit breaker of the EMDB (if more limiting).

❖ **Current Calculation Formula:**

- Generator Rated Current (A)=Apparent Power (VA)/(3×Output Voltage

❖ **Final Selection:**

- Choose the nearest higher standard ATS current rating above the calculated value (e.g., 400 A, 630 A, 800 A...).

SWITCHGEAR (DISTRIBUTER)

❖ FUNCTION

- Acts as the interface between the utility MV supply and the internal electrical system.
- Provides:
  - **Protection** using circuit breakers
  - **Switching** between different feeders
  - **Isolation** for maintenance
  - **Monitoring and control** of the electrical distribution

Figure 154 : SWITCHGEAR (DISTRIBUTER)

❖ MAIN COMPONENTS IN MV SWITCHGEAR ROOM

1. Incoming Section

- Incoming VCB (Vacuum Circuit Breaker) or SF_6 breaker
- Voltage & current transformers (VTs & CTs)
- Earth switch
- Isolator/Disconnector

2. Busbar Section

- Main copper or aluminum busbars (single or double bus system)
- Bus coupler (optional)

3. Outgoing Feeders

- Outgoing VCBs or load break switches
- Cable termination area

4. Protection & Control

- Protection relays (overcurrent, earth fault, etc.)
- Control panel with local/remote operation
- Meters (voltage, current, frequency)
- Communication module (SCADA integration)

5.Other Panels (if applicable)

- Bus riser panel (for vertical distribution)
- Bus coupler panel (to connect bus sections)
- Auxiliary power supply cabinet
- Battery charger panel (for control sup ply)

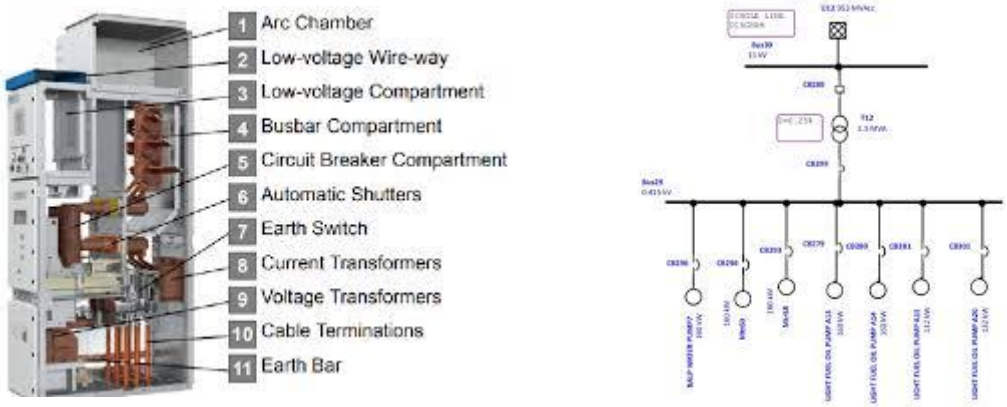

Figure 155 : MAIN COMPONENTS IN MV SWITCHGEAR ROOM

MEDIUM VOLTAGE LOOP SYSTEM

❖ DEFINITION

- A closed loop of medium voltage cable that feeds multiple load points or substations.
- Each transformer/load can be supplied from two sides, ensuring continuity of supply.

❖ PURPOSE

- Enhances reliability by allowing alternate feeding in case of fault.
- Allows maintenance without interruption of supply.

❖ WHERE IT'S USED

- Airports
- Data centers
- Campuses
- Industrial zones
- Large residential compounds

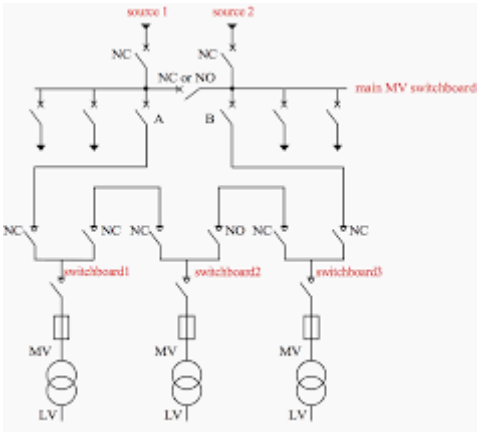

Figure 156 : MEDIUM VOLTAGE LOOP SYSTEM

RMU (RING MAIN UNIT)

❖ COMPONENTS & CONSTRUCTION

Main Components:

- **Incoming Load Break Switches (LBS):**
  - Manual or motorized switches to isolate incoming MV lines.
- **Circuit Breaker Unit (CB):**
  - Usually **vacuum or SF_6 breaker** to protect transformer or outgoing load.
- **Busbar Section:**
  - Internally connects the ring inputs and transformer output.
- **Cable Termination Compartments:**
  - MV cable entry points, often with elbow-type connectors.
- **Earthing Switches:**
  - For safe maintenance and grounding.
- **Protection Relays & Meters:**
  - For transformer or outgoing feeder protection (usually in CB section).
- **Operating Mechanism:**
  - Manual or motorized spring-charged for switching.
- **Pressure Relief Device (in SF_6 units):**
  - Safety release in case of gas pressu re rise.

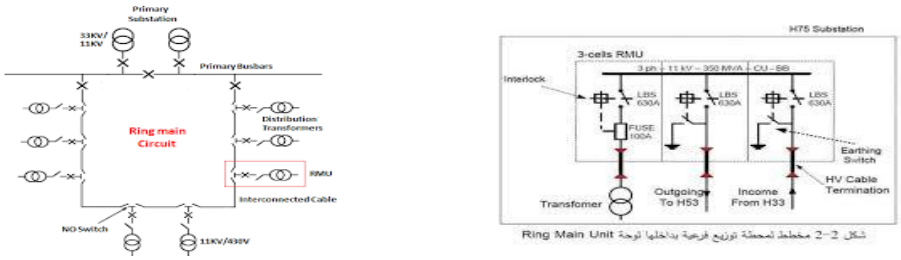

Figure 157 : RMU (RING MAIN UNIT)

❖ FUNCTIONS OF RMU

- **Distribute medium voltage power** to loads such as transformers.
- **Isolate and protect** parts of the network for maintenance or in case of fault.
- **Provide continuity** of supply via ring configuration.
- Used as **interface between MV utility and building transformer**.

❖ TYPES OF RMU (BY TECHNOLOGY)

1. GIS (Gas Insulated Switchgear):
   - Fully enclosed in SF_6 gas.
   - Compact, sealed, maintenance-free.
   - Ideal for indoor use or harsh environments.

Figure 158 : GIS (Gas Insulated Switchgear)

2. Partially GIS:
   - Some compartments are gas-insulated, others are air-insulated.
   - A balance between size, cost, and maintenance.

Figure 159 : Partially GIS

3. AIS (Air Insulated Switchgear):
   - All components are insulated by air.
   - Larger in size, requires regular maintenance.
   - Used in outdoor or budget-sensitive projects.

Figure 160 : AIS (Air Insulated Switchgear)

❖ TYPES OF RMU (BASED ON INPUT & OUTPUT CONFIGURATION)

- **2-Unit RMU**
  - Includes one incoming feeder and one outgoing feeder (typically to a transformer).
  - Suitable for simple applications without a ring (loop) configuration.
- **3-Unit RMU**
  - Consists of two incoming feeders (ring inputs) and one outgoing feeder to the transformer.
  - This is the most commonly used configuration in medium voltage loop systems.
- **4-Unit RMU**
  - Has two ring inputs, one transformer feeder, and one additional feeder (either spare or for an extra load).
  - Useful for systems that require future expansion or more flexibility.
- **5-Unit RMU**
  - A custom setup with multiple ring inputs and multiple outgoing feeders.
  - Typically used in large-scale projects with more than one transformer or distribution point.
- **Expandable RMU**
  - Designed with modular units that can be extended later by adding more sections.
  - Ideal for projects with expected future load growth or phased development.

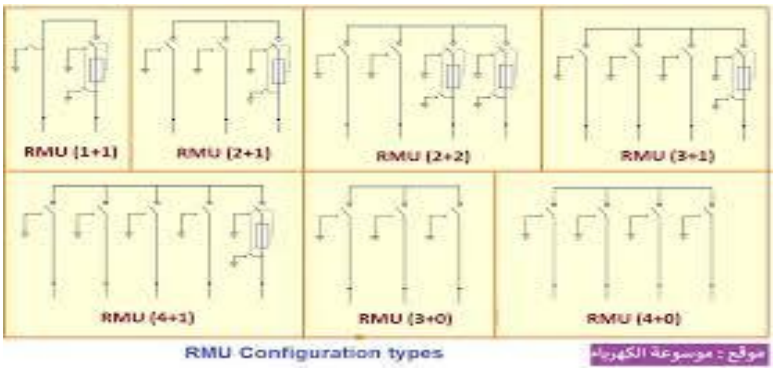

Figure 161 : TYPES OF RMU

WHEN TO USE DISTRIBUTER OR RMU IN A PROJECT

❖ USE MV DISTRIBUTER (SWITCHGEAR) WHEN:

- You need multiple incoming/outgoing feeders.
- Advanced protection, SCADA, and custom logic are required.
- Space and budget allow for larger installation.
- Examples:
  - **Hospitals**
  - **Factories**
  - **High-rise towers**
  - **Main substations**

❖ USE RMU (RING MAIN UNIT) WHEN:

- You need a compact and standardized solution.
- Loads are moderate and don't need advanced control.
- The project requires a looped MV system with minimal space.
- Examples:
  - **Housing compounds**
  - **Schools**
  - **Shops and malls**
  - **Street lighting**

SINGLE LINE DIAGRAM (SLD)

❖ WHAT IS SLD?

- A simplified electrical drawing that represents the power system of a building or facility using single lines and standardized symbols.
- It shows how electrical power is distributed from the utility or generator down to the final loads.

❖ DATA SHOWN ON THE SLD:

- Voltage levels (MV/LV) and transformer ratings
- Sources of power: utility, generator, UPS
- Main switchgear: RMU, MDB, EMDB, DBs
- Ratings of breakers and fuses (ACB, MCCB, MCB)
- Cable sizes and types
- Busbars and interconnections
- Loads and their types (mechanical, lighting, power)
- Protection devices and settings
- Earthing system

- Meters (voltage, current, kWh)
- Phases and frequency

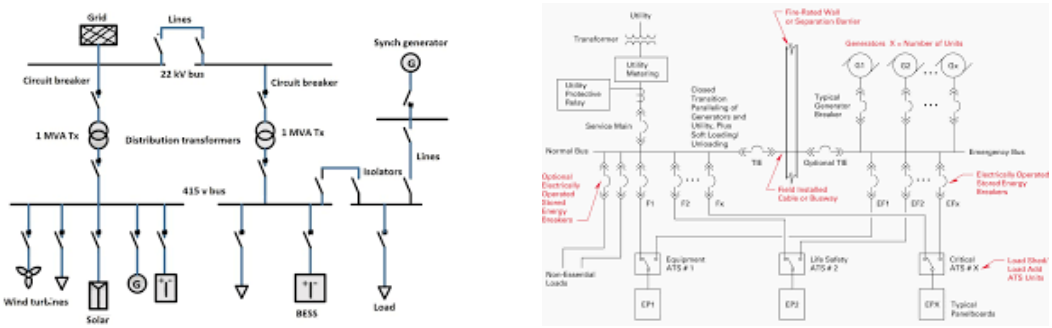

Figure 162 : SINGLE LINE DIAGRAM (SLD)

❖ FUNCTIONS OF THE SLD:

- Provides a clear overview of the electrical distribution system.
- Helps in design, analysis, and coordination of the electrical network.
- Used to calculate short circuit current, voltage drop, and load flow.
- Essential for electrical inspection, testing, and commissioning.
- Serves as a reference during maintenance and troubleshooting.
- Required for approvals from utilities or consultants.

ETAP AND MANUAL CALCULATION

LEACTURE SUMMARY

DERATING FACTORS AND THEIR EFFECTS ON CABLE SIZING

Derating factors (also called correction factors) are used to adjust the current-carrying capacity of electrical cables under different installation and environmental conditions. They are multiplicative, not additive. This means the base current rating is multiplied by the combined derating factors to obtain the effective current-carrying capacity:

$$I_{effective} = I_{base} \times k1 \times k2 \times \ldots$$

Where:

- Ibase: Nominal current rating under standard conditions
- ki: Individual derating factor (less than or equal to 1)

❖ GROUPING FACTOR (K_1)

- When multiple cables are installed close to each other (bundled or in conduit/tray), mutual heating reduces heat dissipation.
- **Effect**: The more cables grouped together, the lower the current capacity of each.
- **Typical values**: From 0.85 to as low as 0.5 depending on the number of circuits and spacing.

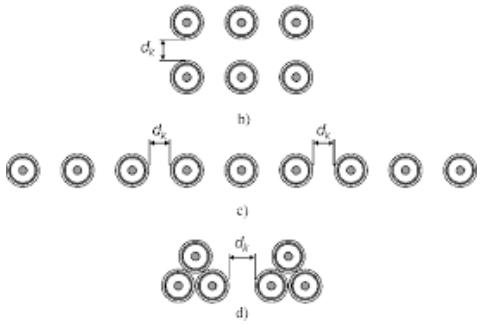

Figure 163 : GROUPING FACTOR (K_1)

❖ AMBIENT TEMPERATURE (K_2)

- Cables are rated based on standard ambient temperatures (e.g., 30°C for air, 20°C for buried cables).
- **Effect**: Higher temperatures reduce insulation life and ampacity.
- **Correction**: Use a temperature correction factor based on actual ambient temperature and insulation type (e.g., PVC, XLPE).

❖ INSTALLATION METHOD (K_3)

- Refers to how the cable is installed: in air, conduit, buried directly, in ducts, etc.
- **Effect**: Different methods affect heat dissipation and cooling.
- **IEC 60364-5-52** and cable manufacturer catalogues provide base current capacities for each method.

Figure 164 : INSTALLATION METHOD (K_3)

❖ DEPTH OF BURIAL (K_4)

- For underground cables, burial depth affects the thermal resistance of soil.
- **Effect**: Deeper burial generally increases soil thermal resistance, reducing current capacity.
- **Typical**: Derating is applied if burial depth exceeds standard values (e.g., >0.7m).

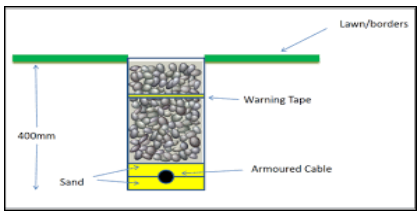

Figure 165 : DEPTH OF BURIAL (K_4)

❖ GROUND (SOIL) TEMPERATURE (K_5)

- Similar to ambient air temperature but for buried cables.
- **Effect**: Higher soil temperature leads to lower ampacity.
- **Standard**: Base values are often calculated for 20°C soil; correction is needed for higher values.

VOLTAGE DROP (V.D.)

❖ DEFINITION

Voltage drop is the reduction in voltage along a cable run due to the resistance and reactance of the conductor. It leads to insufficient voltage at the load, especially for lighting and sensitive equipment.

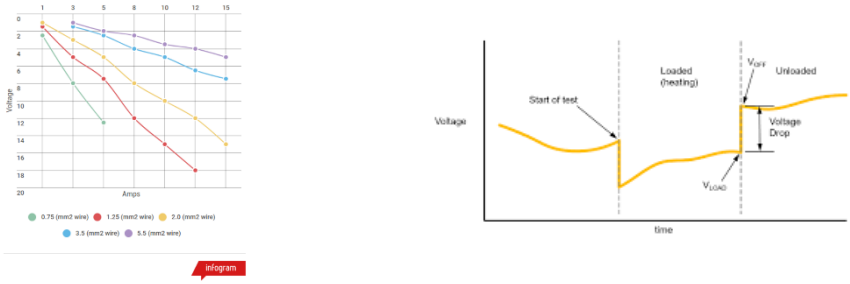

Figure 166 : VOLTAGE DROP (V.D.)

❖ EFFECT OF VOLTAGE DROP ON LUMINAIRES AND LOADS

- Luminaires may not operate effectively due to undervoltage.
- Can result in dim lights, flickering, and reduced lamp life.
- In motors, it can cause starting failure, overheating, or malfunction.

❖ ALLOWED VOLTAGE DROP ACCORDING TO STANDARDS

STANDARD	LIGHTING CIRCUITS	POWER CIRCUITS	REMARKS
IEC (GENERAL UTILITY)	3%	5%	Normal supply from public grid
IEC (PRIVATE SOURCE)	6%	8%	Like generators or isolated power systems
IEEE	3%	5%	Same as IEC for general utility
NEC / AMERICAN	3% (sub-main)	1.5% (sensitive loads)	Sensitive: electronics devices
	15% (fire pump starting)	5% (fire pump running)	Special exception for emergency equipment

❖ VOLTAGE DROP CALCULATION

Voltage Drop (V.D)= (mV/A/m)×L×IL/1000

Where:

- mV/A/m: Voltage drop per ampere per meter (from cable datasheet)
- L: One-way length of cable (in meters)
- IL: Load current in amperes

❖ FOR PARALLEL CABLES

If multiple cables are run in parallel to share the load:

Effective (mV/A/m) = Single Cable (mV/A/m)/No. of Cables in Parallel

Then use the same formula for voltage drop.

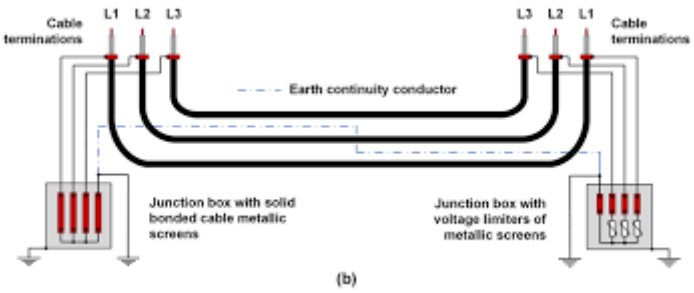

Figure 167 : FOR PARALLEL CABLES

METHOD OF CALCULATION

❖ VOLTAGE DROP (V = I × R)

Voltage drop occurs due to the resistance and reactance in the cable, causing a reduction in voltage at the load side. To ensure proper operation of equipment, the voltage drop must remain within the limits defined by standards (IEC, IEEE, NEC, etc.).

❖ EUROPEAN METHOD FOR VOLTAGE DROP CALCULATION

V.D=(mV/A/m)×L×IL /1000

Where:

- **mV/A/m**: Voltage drop per amp per meter (from cable datasheet)
- **L**: One-way cable length (in meters)
- **I_l**: Load current (A)
- Division by 1000 converts millivolts to volts.

❖ METHOD USING OLD VOLTAGE DROP SHEET (MANUAL METHOD)

The sheet is usually divided into **3 sections**:

1. **Load Data Section**

This part defines the basic electrical parameters for the load circuit:

- Panel Name (e.g. MDB-1, SMDB-A)
- Demand Load (kW)
- Power Factor (pf)
- Number of Phases (1ϕ / 3ϕ)
- Current (A): I= P/sqrt(3)·V·pf (for 3-phase)

2. **Cable Data Section**

This part collects the cable information required for the calculation:

- Cross Sectional Area (e.g., 25 mm^2)
- Cable Length (L) (meters)

- Cable Resistance from catalogue in mV/A/m
- Number of Cables in Parallel (if used)

- If parallel cables are used:

  Effective (mV/A/m)=(mV/A/m) single cable /number of cables in parallel

3. Calculation Section

This is where the actual voltage drop is calculated:

- Voltage Drop (V.D):

$$V.D=(mV/A/m)\times L\times I/1000$$

- Feeder Panel Voltage Drop (if the circuit feeds a sub-panel)
- Total Voltage Drop: Includes feeder and final circuit
- Voltage Drop Percentage:

SHORT CIRCUIT

❖ DEFINITION

A **short circuit** is an abnormal electrical connection between two points of different potential, allowing current to flow through an unintended path with very low impedance. This leads to a sudden surge in current, which can damage equipment, cause fires, or lead to arc flash incide nts.

Figure 168 : SHORT CIRCUIT

❖ CAUSES OF SHORT CIRCUITS

1. **Damaged insulation**
   - Due to aging, heat, or mechanical stress
2. **Improper wiring or loose connections**
   - Especially in panels or junction boxes
3. **Moisture or water ingress**
   - Causes insulation breakdown or corrosion
4. **Faulty equipment**
   - Like motors, transformers, or control devices
5. **Overloaded circuits**
   - Leading to overheating and eventual breakdown
6. **Rodents or foreign objects**
   - Chewing wires or falling metallic parts
7. **Mechanical damage to cables**
   - From drilling, excavation, or crushing

❖ TYPES OF SHORT CIRCUIT FAULTS:

Fault Type	Description	Severity
1. Line-to-Ground (L-G)	One phase conductor touches the ground or grounded structure	Most common in low voltage systems
2. Line-to-Line (L-L)	Two phase conductors come into contact	Medium severity
3. Double Line-to-Ground (L-L-G)	Two phase conductors touch each other and the ground	More severe than L-G or L-L
4. Three-Phase Fault (L-L-L or L-L-L-G)	All three phases are shorted together (with or without ground)	Most severe and rare but critical

MANUAL METHOD FOR CALCULATING SHORT CIRCUIT CURRENT

To calculate the **short-circuit current (Isc)** at a load point (such as a distribution board or panel) by considering:

- Transformer impedance
- Cable impedance

❖ BASIC FORMULA

Isc = V / (Zcable + Ztransformer)

Where:

- ***Isc***: Short-circuit current at fault location (A or kA)
- ***V***: Phase-to-phase voltage (typically 380V or 400V)
- ***Zcable***: Total impedance of the cable (in ohms)
- ***Ztransformer***: Transformer impedance (in ohms)

❖ TRANSFORMER IMPEDANCE (Z_{TRANSFORMER}):

Case 1: *If short-circuit current of transformer is known:*

$$Z_{transformer} = V / I_{sc(transformer)}$$

Case 2: *If %Z is provided:*

$$Z_{transformer} = (3 \times V^2 \times Z\%) / S_{transformer}$$

Where:

- *V*: Phase-to-neutral voltage (e.g., 220V in a 380V system)
- *Z%*: Transformer impedance percentage
- *S transformer*: Transformer apparent power (kVA)

❖ TRANSFORMER SHORT-CIRCUIT CURRENT (OPTIONAL):

If needed:

Isc(transformer) = Ssc / (√3 × V)

Where:

- *Ssc*: Short-circuit apparent power (kVA)
- *V*: Phase-to-neutral voltage

❖ TRANSFORMER SHORT-CIRCUIT POWER:

Ssc = Sbase / Z%

❖ CABLE IMPEDANCE (Z_{CABLE}):

From cable catalog (given in mV/A/m):

Zcable (per meter) = (mV/A/m) / (√3 × 1000)

Then total cable impedance:

Zcable(total) = Zcable × Length

Where *Length* is in meters.

❖ ALTERNATIVE FAST METHOD USING %Z ONLY:

Isc = (Stransformer × 100) / (√3 × V × Z%)

Where:

- *S transformer*: Transformer rating (kVA)
- *V*: Line-to-line voltage (V)
- *Z%*: Transformer impedance percentage

❖ STEP-BY-STEP SUMMARY TABLE:

Step	Description
1	Get voltage, transformer rating, %Z, cable size, and length
2	Calculate Z transformer: $(3 \times V^2 \times Z\%) / S$
3	Calculate Z cable: (mV/A/m) / ($\sqrt{3} \times 1000$), then multiply by length
4	Find total impedance: Ztotal = Ztransformer+ Zcable
5	Compute short-circuit current: Isc = V / Ztotal
6	Convert result to kA if needed

SHORT CIRCUIT PROTECTION

❖ PROTECTION DEVICES

The following devices are commonly used to protect electrical systems from short-circuit faults:

1. **Circuit Breaker (CB):**
   - Opens the circuit automatically when short circuit current exceeds the breaker's limit.
   - Has an interrupting capacity (Icu or Ics) that must exceed the expected fault current.

Figure 169 : Circuit Breaker (CB)

2. **Fuse:**
   - Melts to disconnect the circuit when a short circuit or overcurrent occurs.
   - Fast operation and simple design.

Figure 170 : Fuse

3. **GFCI (Ground Fault Circuit Interrupter):**
   - Detects ground faults (leakage current to earth).
   - Not for high short-circuit currents, but used for personnel protection.

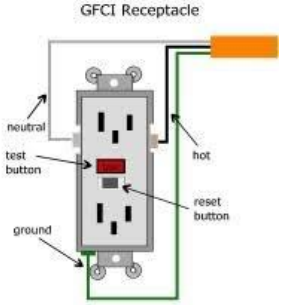

Figure 171 : GFCI (Ground Fault Circuit Interrupter)

IMPACT OF SHORT CIRCUIT

Short circuit faults can lead to:

- **High current flow** (10 to 20 times rated current or more)
- **Overheating** of conductors and insulation
- **Fire risk**
- **Equipment damage** (motors, cables, distribution boards)
- **Voltage dip** across the system

PROTECTION DEVICE SELECTION RULE:

When selecting a protective device for short circuit protection, it must meet both conditions below:

1. Breaking Capacity Condition:

$$I_{protection} \geq I_{short\text{-}circuit}$$

- The device must be able to withstand and interrupt the maximum short circuit current at its installation point.

2. Tripping Time Condition (Thermal Withstand):

$$T_{trip} \leq t_{cable\ withstand}$$

- The trip time of the device under fault conditions must be less than the cable's thermal withstand time.
- Prevents the cable from overheating and damaging the insulation during the fault.

SLD NAD FINAL CALCULATIONS

LEACTURE SUMMARY

RELATED DOCUMENTS

❖ INPUT DOCUMENTS (ARC DWG)

1. **RCP (Reflected Ceiling Plan)** – for lighting fixture locations.

Figure 172 : RCP (Reflected Ceiling Plan)

2. **Elevations & Sections** – for mounting heights and coordination.

Figure 173 : Elevations & Sections

3. **Furniture Layout** – to avoid clashes and for socket placement.

Figure 174 : Furniture Layout

4. **Equipment Schedule** – for power and load calculation.

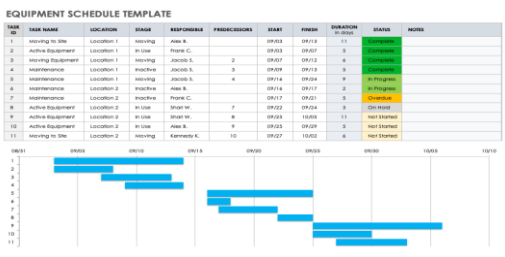

Figure 175 : Equipment Schedule

❖ OUTPUT DOCUMENTS (IFC)

1. **Lighting Layout Plan** – with reference to Dialux results (no Dialux layout included).

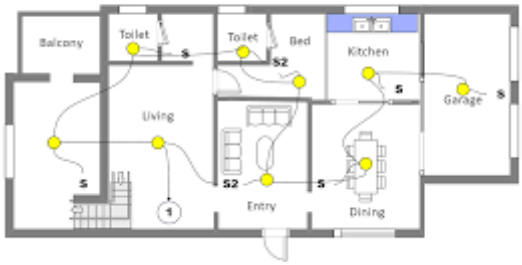

Figure 176 : Lighting Layout Plan

2. **Power Layout Plan** – including socket and equipment power points.

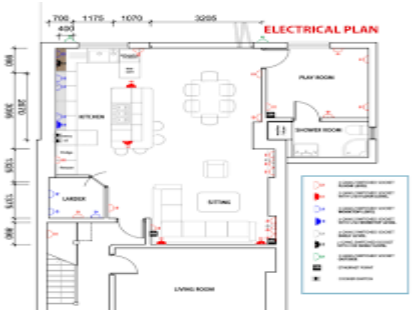

Figure 177 : Power Layout Plan

3. **Panel Schedule** – for each DB (Distribution Board).

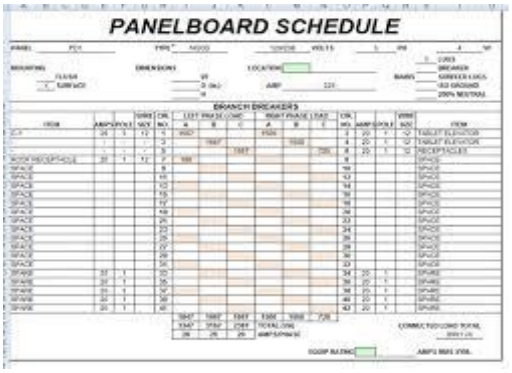

Figure 178 : Panel Schedule

4. **SLD (Single Line Diagram)** – for electrical system distribution.

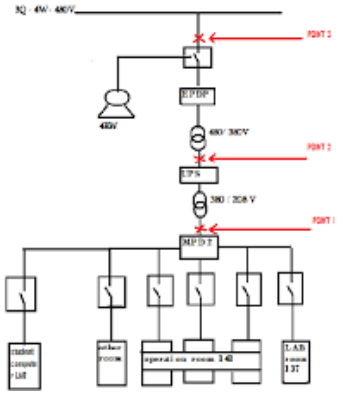

Figure 179 : SLD

5. **Cable Sizing Sheet** – with circuit load, length, voltage drop, and breaker selection

FROM	TO	LOAD	IB	ICB	CB	CABLE	LENGTH		
							Horizontal	Vertical	Total
Trans-1	MDB-A1	1219.5	1847.727273	2309.659091	2500	6// (3X240 + 1X120 +1X120 MM2) CU /PVC/PVC	6.629	0	6.629
MDB-A1	SMDB-A1-B1	243	368.1818182	460.2272727	630	2// (3X185 + 1X95 +1X95 MM2) CU /PVC/PVC	17.99	0	17.99
MDB-A1	SMDB-A1-B2	243	368.1818182	460.2272727	630	2// (3X185 + 1X95 +1X95 MM2) CU /PVC/PVC	30.447	5	35.447
MDB-A1	MCC-01	111	168.1818182	210.2272727	250	(3X120 + 1X70 +1X70 MM2) CU /PVC/PVC	41.312	0	41.312
MDB-A1	SMDB-A1-FF	163.5	247.7272727	309.6590909	400	(3X240 + 1X120 +1X120 MM2) CU /PVC/PVC	6.59	10	16.59
MDB-A1	SMDB-A1-GF	286	433.3333333	541.6666667	630	2// (3X185 + 1X95 +1X95 MM2) CU /PVC/PVC	6.87	5	11.87
MDB-A1	SMDB-A1-RF	173	262.1212121	327.6515152	400	(3X240 + 1X120 +1X120 MM2) CU /PVC/PVC	6.3785	15	21.3785
EMDB	ESMDB-A1	95.6	144.8484848	181.0606061	200	(3X70 + 1X35 +1X35 MM2) CU /PVC/PVC	13.771	0	13.771
EMDB	EMCC-SUBM.PUMP-05	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	3.979	5	8.979
EMDB	EMCC-DOMESTIC PUMP	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	6.264	5	11.264
EMDB	fire jockey pump	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	8.536	5	13.536
EMDB	EMCC-SUBM.PUMP	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	30.531	5	35.531
EMDB	EMCC-01	92.3	139.8484848	174.8106061	200	(3X70 + 1X35 +1X35 MM2) CU /PVC/PVC	36.278	5	41.278
EMDB	EMCC-SUBM.PUMP-01	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	42.508	5	47.508
EMDB	EMCC-03	91	137.8787879	172.3484848	200	(3X70 + 1X35 +1X35 MM2) CU /PVC/PVC	45.679	5	50.679
EMDB	EMCC-SUBM.PUMP-02	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	60.993	5	65.993
EMDB	EMCC-SUBM.PUMP-03	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	103.846	5	108.846
EMDB	EMCC-02	91	137.8787879	172.3484848	200	(3X70 + 1X35 +1X35 MM2) CU /PVC/PVC	113.737	5	118.737
EMDB	EMCC-SUBM.PUMP-04	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	128.482	5	133.482
EMDB	EMCC-SUBM.PUMP	2.8	4.242424242	5.303030303	25	4X6 MM2 CU/PVC /PVC	136.295	5	141.295
EMDB	ESMDB-A2	79.8	120.9090909	151.1363636	160	(3X70 + 1X35 +1X35 MM2) CU /PVC/PVC	213.8	0	213.8
UPS-1	DB-A1-UPS	6.3	9.545454545	11.93181818	25	4X6 MM2 CU/PVC /PVC	0.498	0	0.498

Figure 180 : Cable Sizing Sheet

CRITICAL LUMINARIES

- **Built-in Battery**: These are emergency luminaires with an integrated battery inside the fixture itself. Used mainly for localized emergency lighting. (4 lines)

Figure 181 : luminaries Built-in Battery

- **UPS Fed**: These luminaires are connected to the Uninterruptible Power Supply to ensure no power interruption, typically for critical task areas. (3 lines)

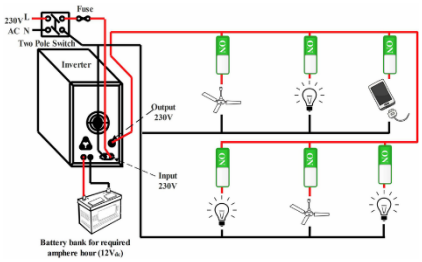

Figure 182 : luminaries UPS Fed

- **Central Battery System**: These lights are powered from a centralized battery system located in a separate room or panel, and commonly used in corridors and escape routes. (3 lines)

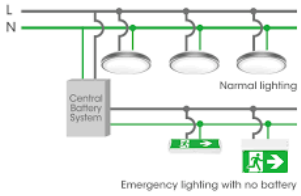

Figure 183 : Central Battery System

ROADMAP FOR ELECTRICAL DESIGN

1. **Prepare the Architectural Plan**
    - Do not delete any elements.
    - Just hide unnecessary layers for clarity during electrical work.
2. **Lighting Design with DIALux**
    - Perform lighting calculation and layout using DIALux.
    - Select proper luminaire types and placements.
3. **Create the Legend**
    - Define all symbols used in the drawings (lighting, sockets, switches, etc.).
4. **Classify Luminaires**
    - Identify and label:
        - Normal luminaires
        - Emergency luminaires
        - Critical luminaires (UPS, built-in battery, central battery)
5. **Wire the Luminaires**
    - Draw wiring routes for all luminaires and connect them to the respective circuits.
6. **Determine Switch Locations**
    - Place switches logically per room use.
    - In **wet areas**, use **ELCBs** (Earth Leakage Circuit Breakers) for safety.
7. **Mark Exit Sign Locations**
    - According to emergency evacuation path and code compliance.
8. **Design Power Outlets & Switches**
    - Include:
        - Normal sockets
        - Industrial sockets
        - Power sockets
        - Disconnect switches for heavy loads
9. **Cable Sizing**
    - Begin from UPS, then to Generator, and finally to Transformer
    - Ensure voltage drop and protection are considered.
10. **Prepare Panel Schedules**
    - Include:
        - Circuit name
        - Load
        - Breaker size
        - Cable size
        - Phase type
11. **Create SLD (Single Line Diagram)**
    - Show the main distribution system and circuit flows.
    - Include voltage drop and short circuit calculations.

ADDITIONAL DESIGN NOTES

❖ BUSWAY BETWEEN TRANSFORMER AND MAIN PANEL

Use a busway trunking system instead of traditional cables to carry high current loads between the transformer and the main distribution board.
This allows:

- Better heat dissipation
- Space saving
- Cleaner installation
- Tap-off boxes can be used to feed other loads (e.g., subpanels, equipment) along the route.

Figure 184 : BUSWAY

❖ ELEVATOR VS. ESCALATOR MOTOR LOCATION

- **Elevator**: The motor is typically located at the top (in the machine room or MRL top space).

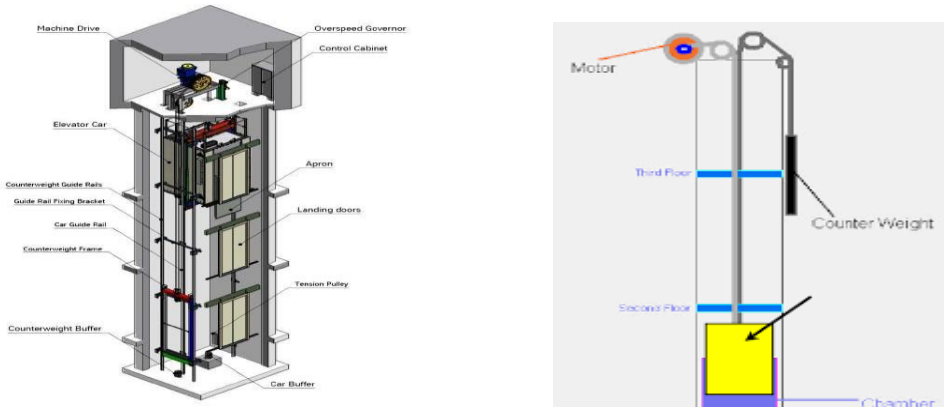

Figure 185 : Elevator

- **Escalator**: The motor is usually installed at the bottom, beneath the steps.

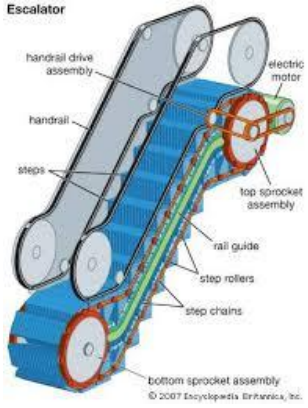

Figure 186 : Escalator

DERATING FACTORS FOR CABLES

When selecting cable sizes, we must apply correction (derating) factors to ensure the cable operates safely under different installation conditions. The key derating factors are:

❖ AMBIENT TEMPERATURE DERATING

- Cables are rated at a standard ambient temperature (usually 30°C for IEC).
- If installed in hotter environments, the cable's capacity must be derated (reduced).
- Example:
  At 45°C, the derating factor might be 0.82 → multiply the rated current by 0.82.

❖ GROUPING (BUNDLING) DERATING

- When multiple cables are installed close to each other (e.g., in tray or conduit), heat dissipation is limited.
- More cables = higher derating.
- Example:
  3 cables touching → derating factor may be 0.8
  9 cables touching → derating factor may drop to 0.5 or lower.

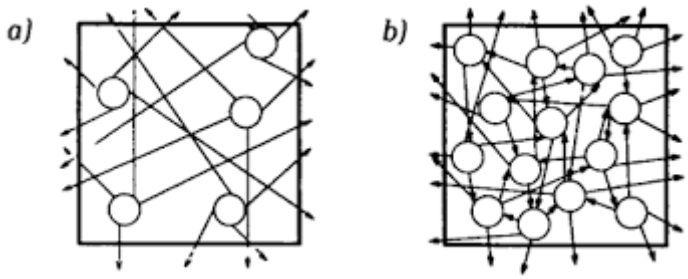

Figure 187 : GROUPING

❖ INSTALLATION METHOD DERATING

- The way cables are installed affects heat dissipation:
  - In conduit in wall or buried = less cooling → higher derating
  - In air or on cable trays = better cooling → lower derating
- Each method has its own base current rating and correction factors (see IEC 60364-5-52).

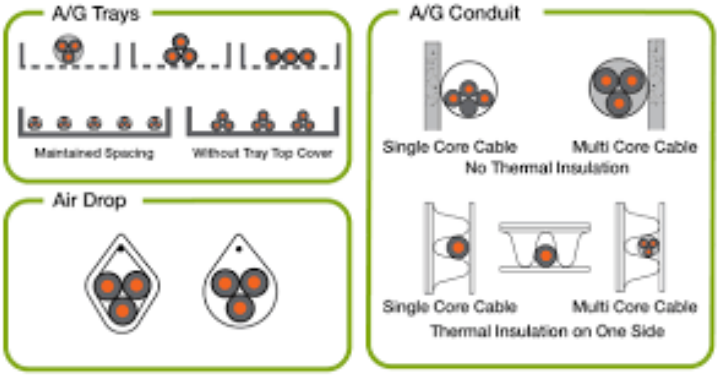

Figure 188 : Installation Method

Final Current = Nominal Capacity × k_1 (Temp) × k_2 (Grouping) × k_3 (Installation)

THE END