Chapter 2: Electric Materials and Protective Devices

2.1: Cables And Wires.

	Copper	Aluminum
Price	$P_{Cu} \approx 3.5\, P_{Alu}$	Better
Resistivity	Better	$R_{Al} = 1.6 * R_{Cu}$. Needs more Cross-section → More insulation material. Cross. Area$_{Cu}$ = 1.6*Cross Area Al.
Mechanical Strength	Overhead line Better	Needs steel reinforcement / Aluminum Alloy
Weight	$m_{Cu} = 3 * m_{Al}$	Better
Installation Cost	• Heavier at large Cross-Section → Higher labor Cost • Cross-Section ↗ ; Price ↗ 1/ • Need Proper Workmanship.	• used Above 16 mm^2 • Pliable (flexible) . Demanding in termination ; joints . Under Cold-flow Characterics: ALO is formed (at joints high resistive - Adhesive surface). heat generation • NOT for branch circuits 2/ • Almost same insulation Price for thin & thick cables (As Cable get thicker insulation stay same. 3/ • Space when using Conduits.

• Black: Advantages of Copper over Aluminum behind (upto) 16 mm^2

1/ feasibility & availability of workmanship
2/ less insulation cost (thinner diammeter)
3/ less Conduit size (more Space).

2.2: Ampacity, derating and Correction Factor

• Ampacity: Current carrying capacity: maximum sustained operating temperature insulation can withstand under continuous current.

Change Upon Temperature

1) Current flowing in cable (I^2R)
2) Resistance of cable
3) Environment (open air, humidity, ...)

at higher voltage [same cable] → lower ampacity.

- **Derating Factor (cables grouping):** As nº of conductors ↗
  Derating factor ↘
  Ampacity ↘

$$\text{New Ampacity} = \text{Old Ampacity} * \underbrace{\text{Derating Factor}}_{<1}$$

N.B: Derating factor = 35% @ 41 cable in covered racey.

- **Correction Factor:** Correction factor depends on Ambient Temperature

Ampacity Max @ 30°C
↳ @ T > 30° : Correction factor < 1
↳ @ T < 30° Correction factor > 1

- **Insulation and Jacketing**

• Insulation Types: 1/ PVC ; 2/ XLPE ; 3/ EPR ; 4/ Silicon Rubber
5/ MI 6/ MICA ; 7/ PI

1/ Maximum Temperature
2/ Impermeability to water and Impervious to acids and Alkaline
3/ Flammable ; fireproof
4/ Dielectric losses
5/ Composition of Material
6/ Cost
7/ Start Date of Use.

	PVC	TR-XLPE	EPR	Silicon Rubber	MI	MICA	PI
Temperature	[-15, 70]	90°C	9°C++	[-40; 185]	250°C	Fire resisting	80°C
Impermeability	✓	✗	✓ (XLPE < EPR < PVC)	✓	✗ (PVC jacket is needed)	✓ (water proof)	
Flame Retardent	✓ (when compounds added)	✗	✗	✓	✓	✓	
Dielectric losses	High 33KV	Very low 400KV	low 220KV	V.V. H 1KV	V.V. H		Very low 500KV
Composition of Material	Polymer (synthetic process)	Polymer	Polymer	Chemical Synthesis = polymer		Polymer	
Cost	lowest	15% than PVC	≳ ; slightly more XLPE	Very Expens.	V.V.V. Expens	4*XLPE	

1.4: Jacketing

outer cover protection for cable against:
- mechanical stresses
- chemical attacks
  - humidity
  - water
  - acids
  - alkaline

→ PVC or Nylon (impervious to water and acids)
→ Copper Conductor / Steel outer Sheath — not affected by electro-static field

{ a/ Neoprene — against — moisture, corrosion ~~and abrasion~~
{ b/ Metals (lead) — against — moisture
{ c/ Galvanized Steel/Copper — against — mechanical damage

N.B.: When copper is exposed to oxygen, it becomes copper oxide
→ doesn't propagate corrosion

1.5: Flexible and Normal Cables

(instead of one thick cable, use many small thin conductors)
- Better Ampacity
- More current Conduction (higher current density)
- More flexible

- As the conductor diameter ↘; flexibility ↗
- Larger n° of conductors, with SMALLER cross-section.

2.2: Raceways and Bussways

2.1: Busways

- Circular Cross-section ↗; density of current ↘ | due to skin effect

→ Solution

Flat Conductors

large cross-sections, the current passes in the outer layers and decreases gradually to be zero in the inner layers.

→ Classification:
1/ Material of Conductors (Cu or Al)
2/ Number of buses; number of flat conductors.
3/ Current rating (I)
4/ Voltage rating → Insulation
5/ Voltage drop (pf)
6/ Housing (contained / opened)

(3/ and 5/ → cross-section at specific pf)

→ Advantage
- More efficient use of conducting material (bcz of less skin effect) (using less material.)
- Tap-offs [- simpler, - less cost, - time saving
- less Space required
- Low impedance (No coil)

But are Expensive.

2.2: Cable Bus

. Round Insulated Conductors Cables, enclosed in a ladder raceway

→ LifeCycle Conditions

- Openings
- Spacing between Cables

} . ventilation . easier heat dissipation

→ Advantages:

- making use of dissipated heat
- Relatively Cheaper than Busway

→ Disadvantages:

- Bulky
- Difficulty in making tap-offs.

2.3: Flat Cable assembly ; Lighting Tracks ; Light duty Busway

Flat Cable Assembly: Square Structural Channels (2, 3 or more conductors

Lighting Tracks: not more than 20A; at very low voltage. (no receptacles)

Light duty Busway:

2.4: Cable Tray

- Aluminum (doesn't rust)
- galvanized steel (heavy installation)

- Sufficient Cable Spacing . to facilitate heat dissipation
  - More free air ampacity

→ Advantages:

1/ Ease of maintenance (open)
2/ Ease of installation
3/ Free air ampacity
4/ Allows easy dissipation (ventilation)
5/ Ease of screening power/IT/Telecom cables (to prevent damage at faults)

→ Disadvantages:

1/ Bulkiness
2/ Not always easy to reach (Accessibility)

2.5 : Steel Conduits

→ **Purpose of use:**

1/ Protection against
- corrosion (aggressive ambient temperature - pollution - acidity)
- mechanical injuries

2/ Provide of metal ground

3/ Provide a ground path (since it is embeded or mounted on wall, you can ground device to conduit instead of wiring the device all along to an earth outlet)

4/ Protect surrounding against fire hazards (as results of arcing or overheating of conductors)

5/ Support for conductors

→ **Coating of Conduits**

1/ Hot dip galvanized

2/ Sheradized

3/ Enameling

4/ Plastic-coated PVC

→ **Classification according to NEC**

- RS : heavy wall Rigid Steel conduit → Thickest ; in very corrosive atmosphere
- IMC : Intermediate-Metallic Steel conduit
- EMT : Electrical Metallic Tubing → it break if it is threaded; use screws instead

(IMC, EMT) → Lighter → Thinner → Easier to - handle - wire - bend } distinct labor cost

→ **Application:**

Accessories : elbow ; saddle (support) ; connections ; couplings ; bends

RS & IMC use same fittings.

In underground ; joints are coated with asphalt / or carbon tar epoxy / hot dip galvanized

In very wet area ; conduits are coated with asphalt

→ **Conduit Sizing**

according to: 1/ Number of conductor & their cross-sections
2/ Number of bends used

A conduit shouldn't be wired fully:

1/ to allow heat dissipation

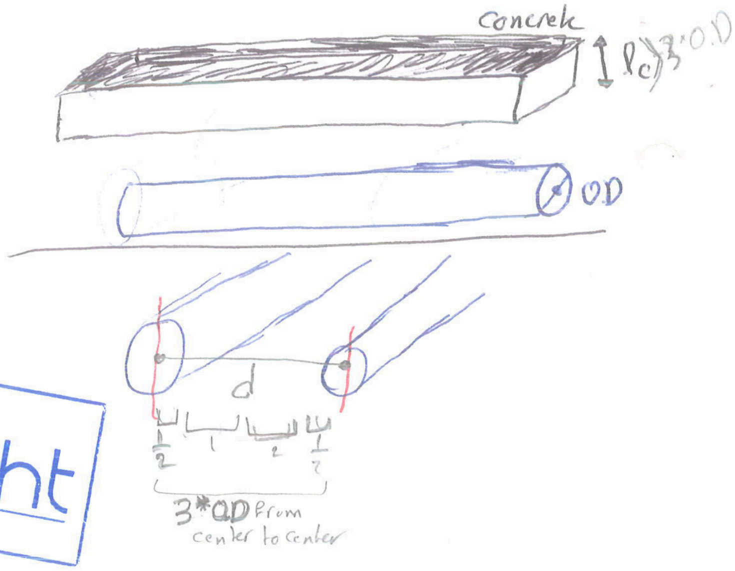
2/ to avoid damage during wiring

3/ Ease of Installation

$$\text{Space Factor} = \frac{\text{Total Outer Cross-Section Area of Cables to be wired}}{\text{Internal Cross-Section Area of the Conduit}} \times 100 < 40\%$$

with 2 * 90° bends.

→ Steel Conduits in Concrete Slabs



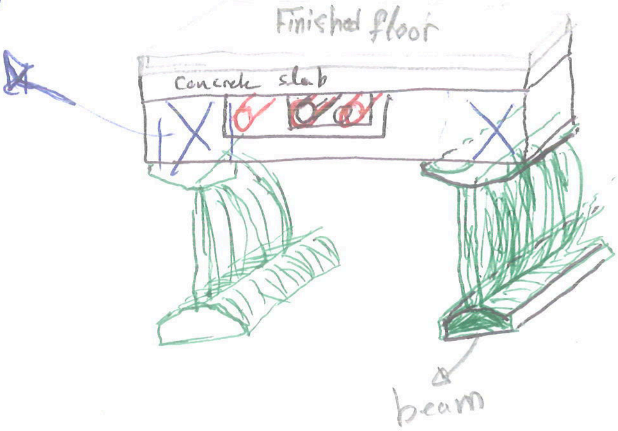
1/ $O.D. \leq \frac{1}{3} * l_c$

Outer diameter (OD) of conduit shouldn't be greater than $\frac{1}{3}$ of the concrete slab

2/ $d > 3 * O.D$

- at least two conduit should be spaced between the two conduits

3/ Conduits running parallel to beams, shall not run above beams, or else conduit crack (different expansion characteristics)



4/ Conduits crossing should be as near to 90°.

5/ Cover over conduit should be 3/4" below finished floor

- heavy trucking → 1.5"

→ Flexible Steel Conduit
- Damps noise
- much easier to install
- provides protection

insight club

→ Junction Boxes

No:
- Splicing
- joints
- tap-off

} housed inside conduits

→ Junction Boxes are used for that.

2.6 Non-metallic Conduits

outdoor
- heavy duty PVC

{ - fiberglass; reinforced epoxy; asbestos cement (Eternit pipe)
  - it doesn't heat up
  - fragile

indoor ← { - PVC rigid
  - flexible
  - high density polyethelene
  - used where protection against corrosion & humidity is needed

Advantage
- resistant to corrosion
- resistant to moisture
- flame retardant
- resistant to heat distortion low temperature effect & sun light.

Disadvantage
- Plastic overheat above certain temp.
- Asbestos has physical strength limitation

We Need GROUND wire ←

2.7: Metal Surface Raceways

- like metallic small channels mounted on Surface:

used on: - dry
- non-corrosive
- non hazardous

} surfaces

when
1/ no recessed cable allowed
2/ economy in construction is favorable

2.8: Under floor Duct (UFD)

- when frequent rearrangement of furniture layout
- VERY expensive
  - Metall
  - heavyduty PVC

→ Configuration

- Feeder Circuit: mainswitch ⟶ Panel board : Placed at Bottom
- Branch Circuit: Panel board ⟶ Outlets : Above | more exposed, more junctions

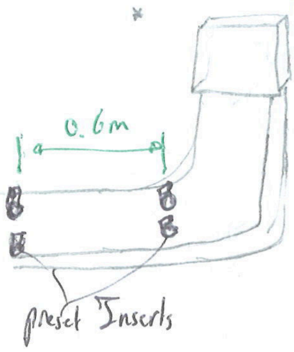
→ Types

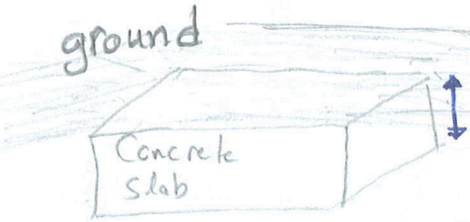
- Single level System:
  - feeder ducts
  - distribution (branch) ducts
  - junction Boxes

  } on same level

- Two level System:
  - Feeder ⟶ lower level
  - Branch ⟶ Upper level

  - More expensive
  - More Space





$3\frac{5}{8}$" single level } Two layers
2.5" Two level system
↳ one layer

→ Advantages and limitations

- Proper & elaborate design must be available
- Coordination (Architect, Civil & Electrical Engineer) must be available
- Increase in total cost of electric System by 50%

Disadvantage
- building height

2.9 Over the Ceiling Raceways

raceways hanging from Ceiling containing [- feeder duct / - branch duct]

→ **Advantages**

- They energize lighting fixtures directly
- rapid change / modification / maintenance at MUCH lower cost
- More flexible
- Network problems are fixed rapidly

→ **Disadvantages**

- Not desired in luxurious locations.
- Poles are descended to connect outlet.

2.3: Wiring Devices

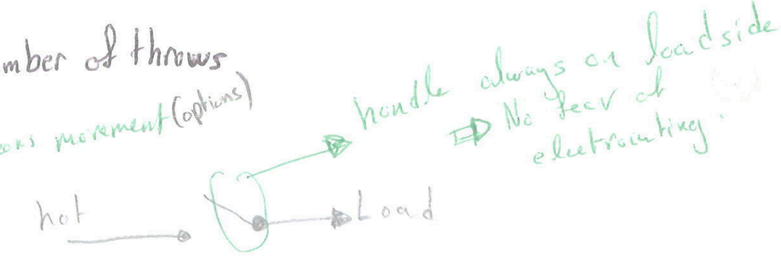
3.1: Switches

→ **Classification Characteristics**

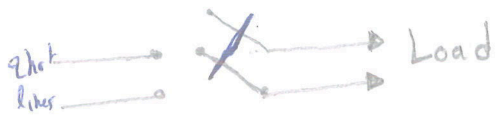
1/ Current rating : maximum current switch can interrupt safely
2/ Voltage rating
3/ Duty : how frequent it is used
4/ Fusibility : presence of a fuse of same rating of switch as a protection for switch
5/ Enclosure : Switch Box ; (place of installation)
6/ Number of Poles ; Number of throws

→ **Types of Switches**

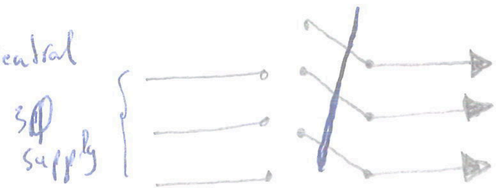
1/ Single pole - Single Throw → means movement (options)



2/ Double poles - Single throw

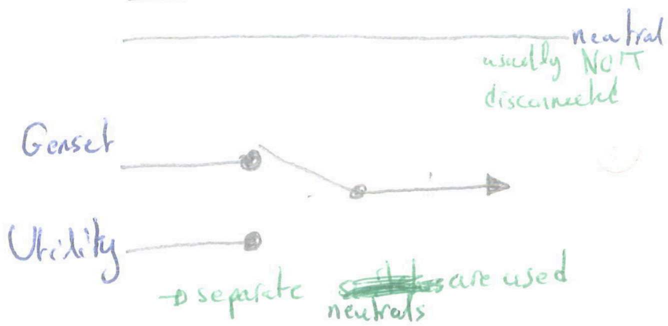


3/ 3 poles - single throw with solid Neutral



4/ Single pole - double throw.

switch between two supplies



5) Two Single Pole – double throw

→ (rooms, corridors) when you have two switches to same device (lamp)

- ground not counted as pole
- Neutral is connected to ground at entrance of building
-

6) Contactors (modified Switches)

- made of copper blocks - silver coating
- Activated by electromagnets
- could be tele - controlled

7) ATS (Automatic Transfer Switch)

- Voltage sensors activate the transfer (between two supplies)

(Automatic طاوس)

8) Relays

- electrically operated contactors

9) Time Switches

3.2 : Receptacles (outlets)

- point where we tap power to a load
- classified according to: 1) Voltages
  2) Current rating
  3) # of poles
  4) # of wires

3.3 : Lamp Holders

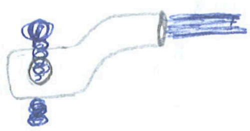
Edison Screw – Bayonet – Goliath

insight club

3.4 : Panel Boards

- Utility ——— switchgear ——— bus bars
- Panel boards are made of: - circuit breakers
  - switches
  - fuses

➡ Composed of:



- Lug : terminal of a connector
- Incoming feeder
- Bus bar (for distribution)
- Cables Conduit
- Gutter Space
- Switchgear (only used on hot lines)

- Neutral is continuous connected to neutral bar.

→ Classified by

- # of phases & neutral of incoming supply
- Voltage rating
- # of single, 2, 3 pole switchgears used
  - ↳ + their ratings
- Spare space for probable future load switchgears
- Either surface mounted or flush type

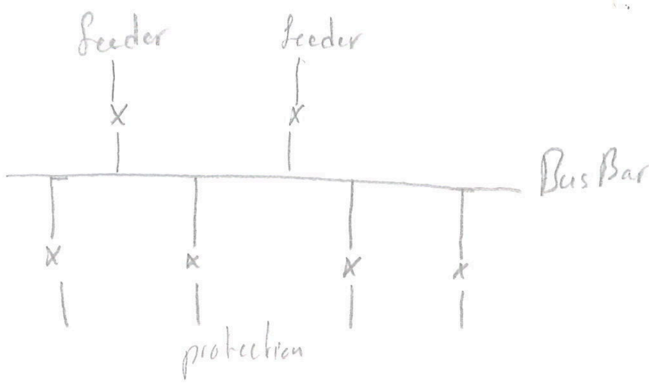
→ Panel Boards Could be

1/ Three Phase
- three hot lines
- Common neutral
- Balance (distribution) the loads (circuits) on 3 phases
- Three phase loads

2/ Single Phase

3.5 Switch Boards

more complicated panel board
- → complicated protection system
- → higher voltage
- → metering
- → directly distributed wire



3.6 Fuses

- base + fusable element

→ Classified into:

- plug-in porcelain cap:
  - up to 35A
  - 150V
  - distance between terminals should be large enough to avoid discharges.
- Cartridge fuse:
  - up to 6 000 A

pure Sands with medium grains

Disadvantages
- impurities may cause leakage discharges
- Only protect short circuit faults → Dual element fuse
  - → dual functions
    - ① short circuit fault
    - ② Overload fault

3.7 Circuit Breaker

- electro-mechanical device

→ Main Components

- Phenolic case (box)
- lever for on-off
- off/on indicator
- Line Connectors (incoming / outgoing)
- thermal element (Bimetal) → elongates when overheated causing the tripping of CB (circuit breaker)
- Air Chutes → chop & quench arc produced by S.C.
- magnetic coil → very fast pull on CB when S.C occurs. (higher S.C → higher pull)
- permanent magnet → force arc into air chutes to ↗ Interrupting Capacity (IC) of C.B

3.8: Advantage & limitations of fuses & Circuit Breakers.

→ Fuse

- Advantages:
  1/ Simple and fail proof (doesn't miss → neither works or destroyed)
  2/ Constant Characteristics: doesn't change with temp.
  3/ Simple Construction lower first cost
  4/ High IC due to its support to higher current
  5/ No maintenance: (replaced when it blows)
  6/ Instantaneous & energy limiting (it breaks at the limit)
- limitation:
  1/ Single pole (only one phase)
  2/ Needs a switch for operation?
  3/ Use of exact size for the fusible element
  4/ Self-destructive
  5/ Non-adjustable: no calibration
  6/ Non-indicating (On/off)
  7/ Non-remote Control

→ Circuit Breakers

- Advantages:
  1/ Usable As Switch
  2/ Can be multipole
  3/ No need of replacement at faults
  4/ Resettable
  5/ Indicate trip (on/off)
  6/ Remote Controlled
  7/ Adjustable over a certain range.

* limitations:
1/ low to medium IC
2/ Periodic maintenance
3/ High initial cost
4/ Aging
5/ time delay when opening

Circuit Breaker Classification

1/ rated voltage
2/ rated current
3/ interrupting Capacity (IC)
4/ Casing
5/ # of phases
6/ # of poles

Chapter 3: Distribution Systems and Emergency Supply

3.1: Single and 3 Φ Systems

- large Load → requires medium voltage distribution
  → lower current → { - smaller cable sizes, - lower losses } → lower cost

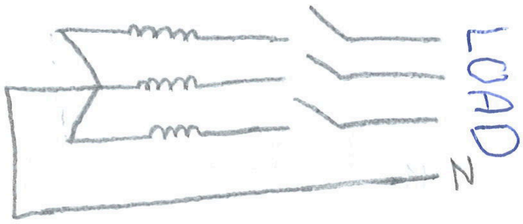
However larger n° of transformers needed

→ Study to choose optimum

1/ Installation Costs: · conduits
   · cables
   · transformers .....

2/ Running Costs: . including losses.

Distribute loads equally on the 3 Φs
↳ make $I_N = 0$ to get balanced loading



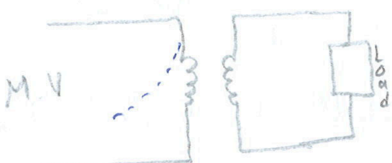
3.2: Grounding

2.1: Reasons for Grounding

1/ Prevent sustained contact between the L.V. side & Medium Voltage side in the event of insulation failure

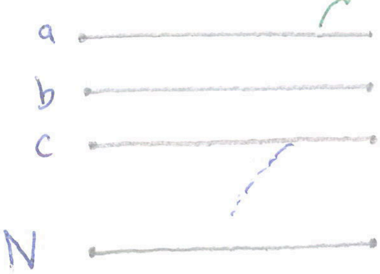
Insulation failure at M.V. → leakage to L.V. side → Stress on the L.V. insulation (above its insulation rating) → Insulation flashover → personnel or equipment damage.

Remark:



- Insulation failure leads to an electric discharge that needs an exit → try to discharge or exit through lower voltage side
  → with grounding, the discharge goes to the lowest voltage level (which became the ground).

2) To prevent arcing grounds when there is insulation failure in one of the phases, by ~~trip~~ causing the C.B. to trip.



If one of the insulators is broken → it starts to leak $V_{LL} = \vec{V}_\varphi + \vec{V}_\varphi$

→ If $\vec{V}_{\varphi_C} = 0$, the neutral is pushed to V_φ (C discharges to ground)

→ $V_N \pm V_\varphi$; $V_{aN} = \vec{V}_N + \vec{V}_\varphi = \sqrt{3}\,\vec{V}_\varphi$ while it used to be only $\vec{V}_\varphi$ (e.g. $V_\varphi = 220 \to 380$)

→ A short circuit appears between the two faulty phases → C.B. trips.

- This happens every 1/2 Cycle.

3/ To protect against surge voltages

➡ Cause of surges

1/ External : lightning : 300 kV in μ second

2/ Internal : due to Switching : in m seconds (more hazardous, stays longer)

4/ To locate faults with ease

5/ To establish a neutral zero potential for safety on body of grounded equipment

- * neutral should not be interrupted
- * neutral should be connected at ground service entrance.

2.2: Methods of Grounding

- $R_{ground} < 5\Omega$
- Connect body of equipments to ground

	follow	constant	half
HOT : S = cross-section of hot conductor	$S \leq 16mm^2$	$16mm^2 < S \leq 35mm^2$	$S > 35mm^2$
Ground	S	$16\ mm^2$	S/2

1/ Connect Ground to Metallic Cold Water Pipes of Utility Distribution System.

Disadvantage : Cause cathodic problems

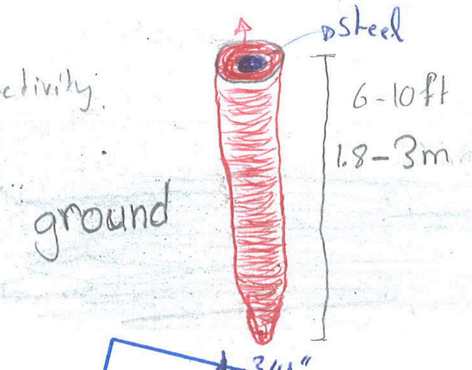
$R_{neutral\ \&\ ground} < 5\ \Omega$

2/ Copper-weld rods (or Alumo-weld rods)

- Rods:
  - → steel core (strength)
  - → Coating Copper (Aluminum): higher conductivity.
- Connect to Neutral
- measure resistance: if $R < 5\Omega$ → ✓

  if not put another one in parallel

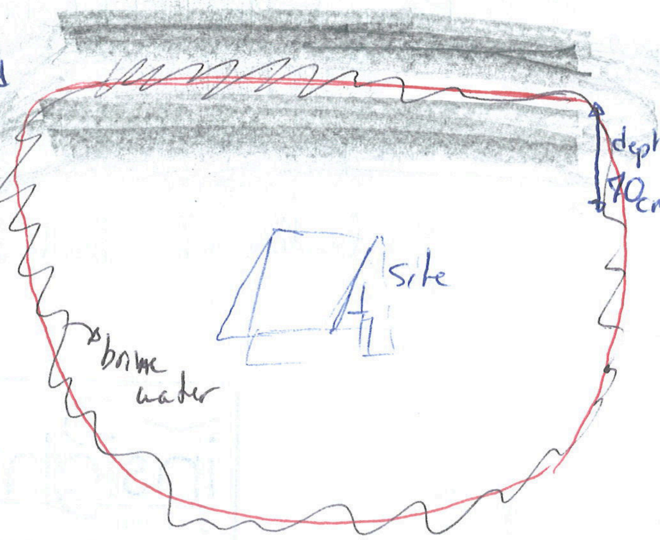
  → $R' = R/2$ → until → ✓



3/ Instal a number of 2 ft² (18.5 cm²) Copper Plates & connect them in parallel to neutral with 25 mm² bare copper conductor

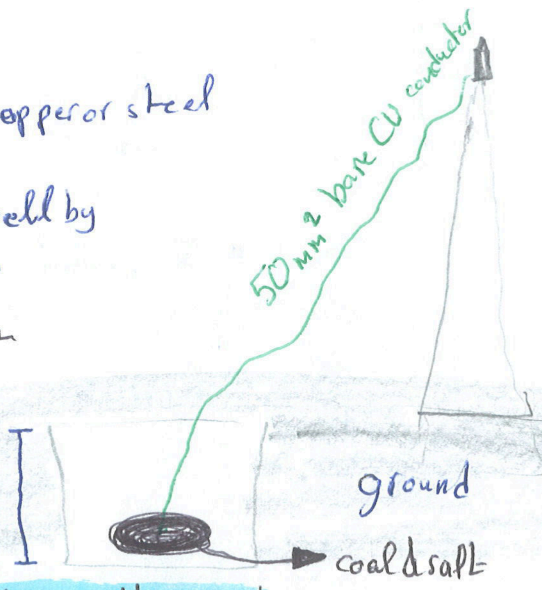
4/ For ROCKY grounds:

- Cross Section of bare Conductor = <u>50 mm²</u>
- depth under ground: 70 cm
- Around Project Site.
- $R < 5\Omega$
- pour on it Brinewater



5/ For High masts:

- Dig a 6m depth well.
- ~~Install 50 mm² bare CU conductor~~
- Install spike on the mast, made up of copper or steel
- Fill the well with coal & salt.
- connect spike to the bottom of the well by a 50 mm² bare CU conductor.



N.B: Create a separate grounding system at large distance from the well for neighboring L.V. { electrical equipments. / Telecom / electronic equipment

2.3: How Electric Shocks are Produced, Eliminated or Minimized

$I_{phase} = I_{Neutral} + I_{fault}$

↳ if $I_{phase} = I_{neutral}$ → No Leakage

$R_{human} = R\ \Omega$

GFI : Ground Fault Interrupter

$I_{phase} - I_{neutral} = I_{fault}$ (differen[ce]) → 0 No fault; ≠ 0 → Fault even 4–6 mA

1/ Very High precision device (detects 4 to 6 mA)

2/ Could be installed either on Outlet or on Panel Board → more expensive, higher rating, But covers all outlets.

3/ cut the Circuit with 0.5 seconds

4/ On Panel Board: Protects all outlets — But expensive

5/ Mandatory in bathroom

B.S: Earth Leakage Differential Protection

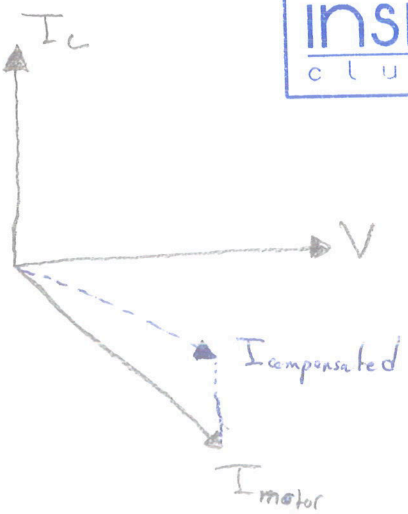
- used in Bathrooms
- no sockets placed at less than 2.5 m from bath tub.

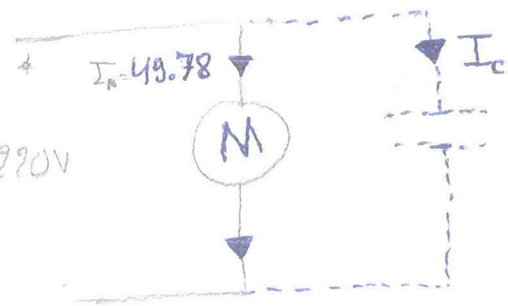
3.3: Power Factor (PF) Correction :

- Majority of loads are lagging
- power factor correction is Compensated by → Capacitor; → Synchronous Motor (S.M.)

Desired pf = 0.9 lagging

- leading pf is bad for switches.





@ pf = 0.6 lagging

$I_{active} = 29.87A$ (same)

$I_{reactive} = 39.82A$

@ pf = 0.9 lagging

$I_{active\ compensated} = 29.87$ (same)

$I_{reactive\ compensated} = 14.47A$

I_{load} stays same

I_s; $I_{reactive}$ changes

$I_s = \sqrt{I_{active} + I_{reactive}}$ → system

3.4: Supply Irregularities

① → Interruption in the Supply

* **Assessment of Risk Failure:**

1/ High Load Factor: risk of failure higher due to electrical & mechanical stresses
2/ Atmospheric Conditions: severe weather conditions (sunlight, temperature, humidity, ...)
3/ External Conditions: salts, dirt, acids, ... are corrosive & attack equipment.
4/ Abnormal Conditions: Surge voltage (lighting) or temporary overload
5/ Standard Maintenance: preventive maintenance to have fewer problems in future.
6/ Replacement Policy: replacement of equipment after its lifetime is over even if it is still working

* **Consequence of Interruption:**

1/ Time at which it takes place
2/ Length of time for which supply is back after breack down.
- depends on two factors:
  - 1/ → system type
    - → radial supply system: One supply
    - → ring supply system: bidirectional
  - 2/ → fault type
    - → transient (over head, auto reclosure)
    - → sustained (O/H: in hours, U/G in days)

3/ Direct Monetary value loss of production:
- loss of material
- explosion
- damage of equipment
- delay in delivery (penalty)
- financial losses
- Labor cost not being productive

4/ Cost of Consequential damage of plant (chemical or metallurgical plants)
5/ Frequency of interruptions + their duration

② → Voltage Irregularities

The occur due to two main causes:

1/ Switching of large load causes voltage depression. (high starting current ⇒ higher voltage drop)
→ Consequences:
- on Motor: it draws higher current, thus higher losses,
  - more current, heats up ($P=I^2R$)
  - lower efficiency.
- on HID lamps: cut off at voltage drop larger than 15%

2/ Random Large Load Variation: (welding & arc furnaces)

* **Solution:**
a/ Ample Capacity: Higher power Source Compared to Switched load
b) Suitable cable sections to handle transient currents
c) A high pf > 0.85 lagging system (thyristor switched Capacitor)

Advantages

- lower subscription with utility
- lower Connection fees
- lower deposit sums.
- I^2R reduced (less losses)
- cheaper { conduit, breaker, starters } | lower I rating
- Avoidance of penalty on KVARH @ pf < 0.8

Also
- smaller size generator
- smaller cables cross-section

limitations

1) Cost of Capacitor Bank
2) Location (Space)
3) Higher Cost of Breakers → { at capacitive switching; $V_{breakers}$ could reach $3 * V_{max}$; Special Circuit Breaker designed of Higher Cost.
4) The voltage on the switch of pure capacitive load, appears $3 * V_{max\,system}$

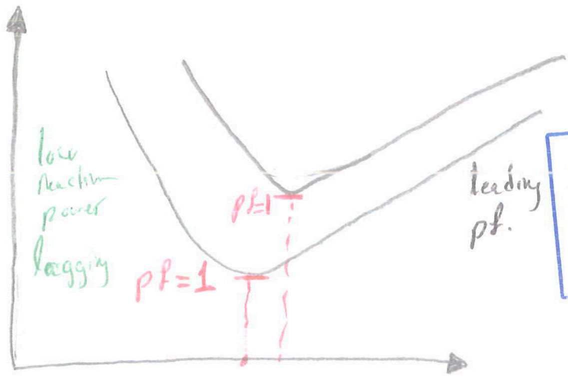
- For same size Capacitors perphase; it is better to connect them in Δ.

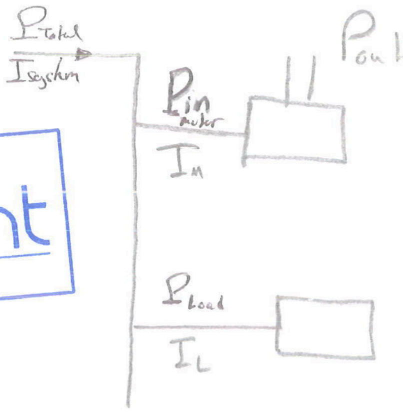
Synchronous Motor

- More complicated adjustment of its I_F to control System pf.
- much more expensive than induction motors

But
- Deleted cost of capacitor Bank
- Delete cost of their Space

} make it feasable in:
- driving mechanical load at contant Speed
- control system pf.





- $P_{in}^{motor} = \dfrac{P_{out}^{motor}}{\eta}$
- $P_{Total} = P_{Load} + P_{input}^{motor}$; $Q_{Total} = Q_{Load} + Q_{motor}$ — Q could be leading < 0 or lagging > 0
- $\vec{I}_{system} = \vec{I}_L + \vec{I}_M$

③ → Frequency Variation

It is due to large load shedding.

. Speed of generator ↗ ; motor frequency ↗ , it motor becomes overloaded

3.5: Emergency, Vital and Standby Supplies

1. Vital Loads: are load that should be uninterrupted to avoid High cost of interruption and or plant damages
   A must
   (Chemical plant, food treatment, metal furnaces, ...)

2. Emergency Loads: Supplied for protection of lives
   mandatory by law
   (exit signs, fire pumps, sprinklers, fans, ...)

3. Critical Loads: 1- Chemical and metal industries
   2- Loss of data upon electricity cutoff.
   3- Intensive care
   4- Incubators for babies

. Vital Supply
. Standby Supply: Factors to consider: 1/ Safety and Prestigue. 2/ Material losses and plant damages

3.6: Supply Sources

① Generating Sets

Advantages:

1. Unlimited KVA capacity (provided fuel is available)
2. Peak Shaving: Avoidance of high rates of utility at peak hours (high rates)
3. Very long life (150 000 hr).

Disadvantages:

1. Noises: apply silencer (extra cost) → lower efficiency to cool the generator using fan powered by it.
   → more heat
   → shorter life span
2. Vibration: (damping layer: rubber pads)
3. Nuisance of exhaust gases piping
4. Fuel storage
5. Need regular maintenance and testing

(2) Battery

Disadvantages:
- Used for limited rating of emergency power
- Need very large Space
- production of fumes
- for fractional KW equipment

Advantages:
- Instant in its supply (medical creticel leads, UPS computers, lighting, ---).

- Comparison Between Engine and Battery
  1. Area Needed → Generators better all
  2. duration of Service → Generators
  3. AC or DC
  4. Space for large Capacities → Generators
  5. Ventilation: is large for gen-set to be cooled
     ; battery to remove fumes
  6. Life Span → Generators
  7. Large Space for battery : Generators
  8. Vibration & Noise: • Not in battery → Batteries
     • Generator need dampers

- Electric Power Production Cost:

$$P_c = \beta C + F + OM$$

β: Capital charge factor (I & N)
(I: discount rate)
(N: life Span)

C: Capital Cost of Plant (cost of KW)

F: Annual Cost of Fuel

OM: Operation & Maintenance

- Co-generation:
  - Generation of electricity and RECUPERATION of heat ~~from~~ dissipated from exhaust gases, & engine cooling water.
  - Recuperated heat could be used to:
    → heat fuel to 110°C for better combustion
    → Heat air → furnaces
    → Produce steam for heating of factories and laundries.
    → Used for Air conditioning (heat the refrigerant gas to high pressure, released in tank where cooling pipes pass, to expand to atmospheric pressure. When it expands, it absorbs heat from water → water is cooled