بسم الله الرحمن الرحيم

Benha University

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Benha University
Faculty of Engineering at Shoubra
Electrical Engineering Dept.

Ameeria Integrated
Technology Education Cluster

Undergraduate Course

Electric Installation Design

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Lecture (7)

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Electrical Load Estimation

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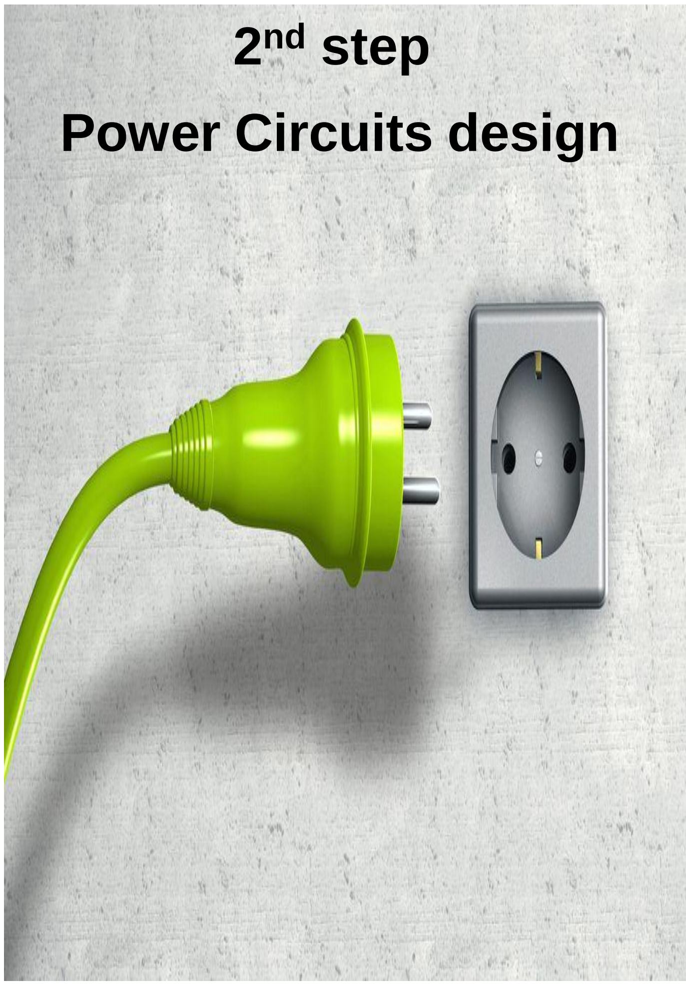
Summary



Sockets Design

↓

Air condition Design

↓

Power & Current Calculation

Circuit Breaker Capacity Calculations

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C.B Capacity Calculation

- After conducting load and diversity factor calculations, now we consider C.B capacity calculations which are as follows:

- $$IC.B = \frac{S(largest\ phase)}{220} \times 1.25$$

- $$IC.B = \frac{S(largest\ load)}{380\sqrt{3}} \times 1.25$$

C.B Standard

#	MCB	MCCB	ELCB	Vacuum
Abbreviation	Miniature circuit breaker	Molded case circuit breaker	Earth Leakage Circuit Breaker	Vacuum Circuit Breaker
Nominal current	10 – 125 A	32 – 1600 A	10 – 100A	1600 – 5000 A
S.C Current	6 – 30 KA	10 – 80 KA	6 – 30 KA	Up to 150 KA
No.of.poles	SP – DP – TP - FP	TP - FP	DP	FP
Adjustment	Fixed	Fixed - Adjustable	Fixed	Fixed

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Motor Loads

- Circuit Breakers of each motor should be greater than starting current of the motor.
- Starting Current of motors can be determined by Code-letter method according to the following table:

Code Letter	KVA/HP at starting	Code Letter	KVA/HP at starting
A	1.6	L	9.495
B	3.29	M	10.595
C	3.72	N	11.845
D	4.25	P	13.25
E	5.3	R	14.995
F	5.95	S	16.995
G	6.1	T	18.995
H	6.7	U	21.195
J	7.55	V	22.4
K	8.495		

As an example

A 3 phase, 380V, 50Hz, 5kVA motor with code letter J, Required calculating Ist.

- **From the table:**

Code letter J mean (kVA) st = (kVA) motor * 7.55

= 5 * 7.55 = 37.75 kVA

- **So:**

Ist= 1.5 * 37.75 = 56.625 Amp,

So the circuit breaker rating will be = 60A

Short Circuit current

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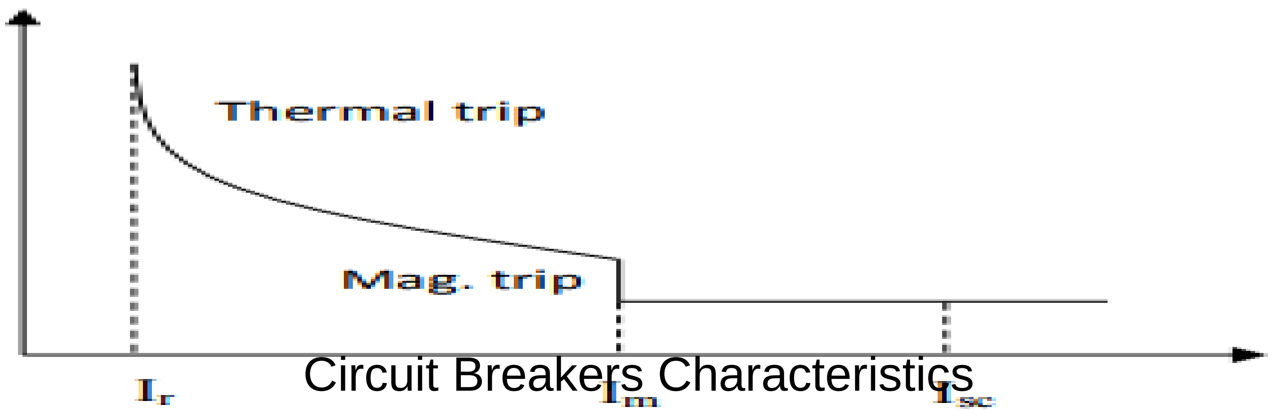
S.C Current

- Due to large current passing through the network during faults, there are many effects of short circuit currents.
- So, the power systems should be designed to stand short circuit currents for a short period of time before the trip process takes place.
- While the types of trips performed by a circuit breaker are:

1. **Thermal trip:** Responsible for protection against over load currents.
2. **Magnetic trip:** Responsible for protection against short circuit currents.

Circuit Breakers Characteristics



Circuit Breakers Characteristics

Where:

(Ir) : is normal breaker current that described as operation current.

(Im): is a current that break trip become by magnetic part.

(Isc) : is a maximum short circuit current or maximum current that breaker can stand for a short trip time.

Short circuit current calculations

$$\text{IS.C} = VPh \ / \ Zsc \ x \ 1.05$$

Where:

(Vph) : is phase voltage.

(Zsc) : is total Short Circuit impedance

Multiplying value by 1.05 represent transformer terminal voltage with no load +5% To determine the impedances values for electrical equipment's.

3rd step

Electrical Panel

Main Distribution Boards (MDB)

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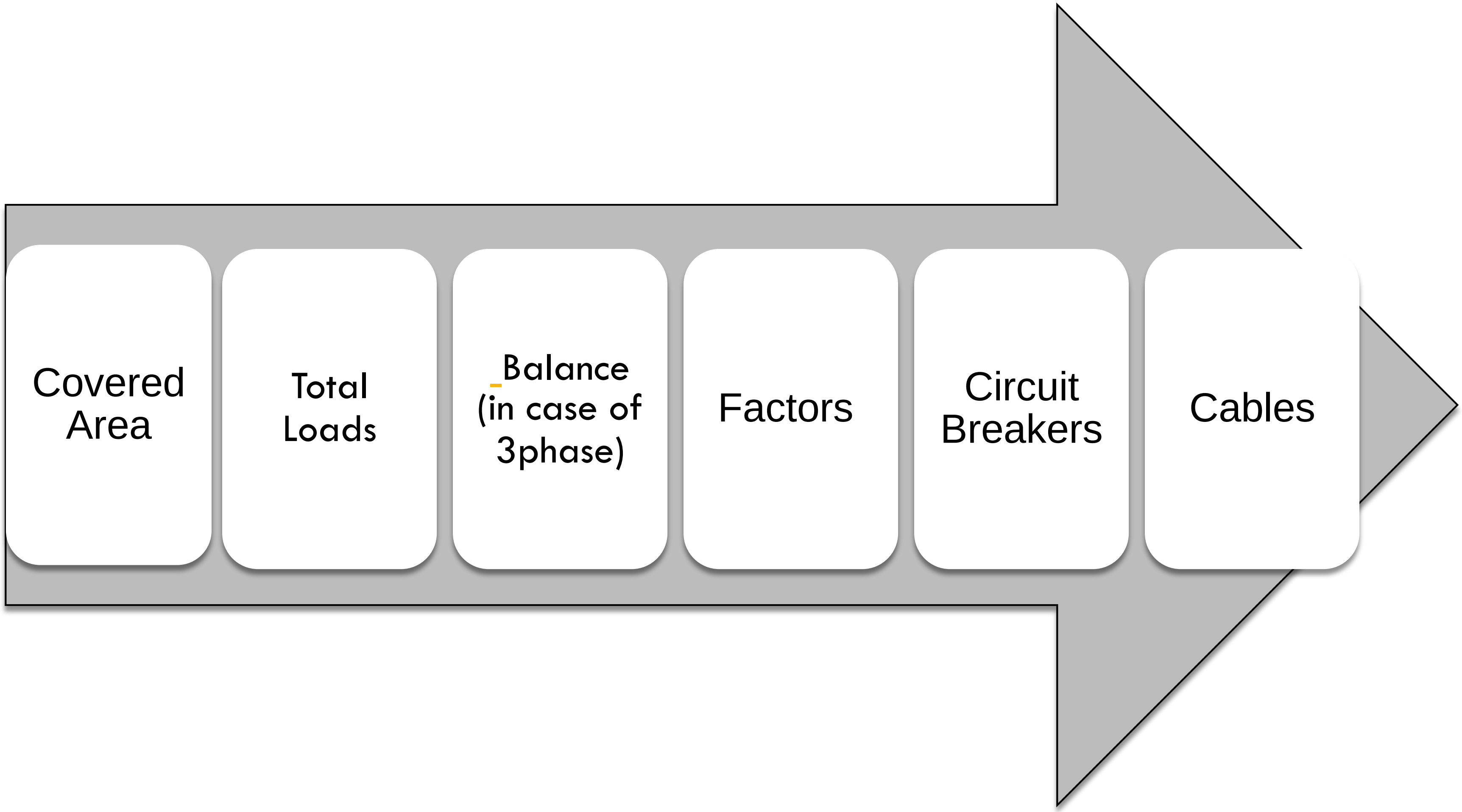
Steps to Design Electrical Panels



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1. **Covered Area**

- The building is divided into several floors, each floor with a distribution panel to control the branch circuits that feed the area.
- Some places must be connected to a separate panel (operating room or intensive care).

2. **Total Loads**

load	VA
lighting	1000
lighting	800
lighting	950
sockets	1200
sockets	1500
sockets	1000
water heater	1500
air conditioner	2000
air conditioner	3500
hand dryer	1500

3. Balance

The purpose of load balancing is to make the load close to the three phases. This prevents the main circuit breaker from being separated by mistake.

		R	B	Y
1	lighting	1000		
2	lighting		800	
3	lighting			950
4	sockets	1200		
5	sockets		1500	
6	sockets			1000
7	water heater	1500		
8	air conditioner		2000	
9	air conditioner			3500
10	hand dryer	1500		
	sum	5200	4300	5450

4. Factors

- **Connected load**

It's the sum of continuous ratings of all the electric equipments connected to supply system regardless they are operating or not.

- **Maximum demand**

It's the greatest demand of load on the distribution system during a given period.

The knowledge of maximum demand is very important as it helps in determining the rating of supplying equipments such as (transformers, cables, panels……).

- **Demand factor**

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

		R	B	Y	C.B	Cable
1	lighting	1000			10	3*3mm2-PVC-CU
2	lighting		800		10	3*3mm2-PVC-CU
3	lighting			950	10	3*3mm2-PVC-CU
4	sockets	1200			16	3*4mm2-PVC-CU
5	sockets		1500		16	3*4mm2-PVC-CU
6	sockets			1000	16	3*4mm2-PVC-CU
7	water heater	1500			16	3*4mm2-PVC-CU
8	air conditioner		2000		16	3*4mm2-PVC-CU
9	air conditioner			3500	25	3*6mm2-PVC-CU
10	hand dryer	1500			16	3*4mm2-PVC-CU

				D.f
light	900	720	855	0.9
socket	2100	750	500	0.5
hvac	0	2000	3500	1
sum	3000	3470	4855	VA
A	13.63636	15.77273	22.06818	A
C.B	32 A	MCB		safety *1.25
cable	4*6mm2+6mm2 (E) PVC/PVC-CU			

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5. **Circuit Breaker**

- Now if we have many panels that feed from a main distribution board, this main distribution board will have a design steps as below:

1. If we have a panel board MDB-01 that feed 4-panel board:

   * DP-Ground → 100 kVA.

   * DP-First floor → 120 kVA.

   * DP-Second → 150 kVA.

   * DP-Third → 150 kVA.

   * DP- Roof → 35 kVA.

- **DP-G Breaker**

$(Ic.b) = 100 \times 1.5 \times 1.25 = 187.5$ A – [200 A]

- **DP-F Breaker**

$(Ic.b) = 120 \times 1.5 \times 1.25 = 225$ A – [250 A]

- **DP-S Breaker**

$(Ic.b) = 150 \times 1.5 \times 1.25 = 281.25$ A – [300 A]

- **DP-T Breaker**

$(Ic.b)g = 150 \times 1.5 \times 1.25 = 281.25$ A – [300 A]

- **DP-R Breaker**

$(Ic.b)g = 35 \times 1.5 \times 1.25 = 65.63$ A – [80 A]

- **Main Circuit Breaker will be**

$(Ic.b) = (100 + 120 + 150 + 150 + 35) \times 1.5 \times 1.25 =$

=1040.63 A – [1250 A]

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Note:

- If we have applied demand factors on each panel so there is no demand factors calculations will applied on main distribution board.
- However, if we applied diversity factors on sub panel, so according to number of sub panels we will determine main distribution board diversity factor.

6. Cables

Cables Classifications

- Power cables are used to feed circuits with the required power.
- So, cables selection must be according to transfer a full power to certain load, that mean the cables must transfer the full current with no or limited voltage drop to ensure full power transfer.

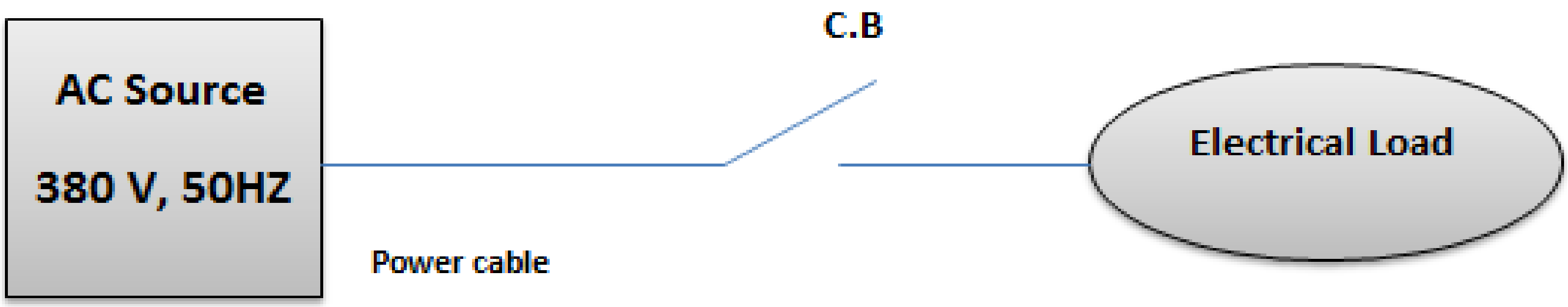
Operating & Meggered Voltages	600/1000	450/750
Conductor Type	Copper	Aluminum
Insulation Material	PVC	XLPE
Number of cores	Single	Multi core
Armored	Armored [STA – SWA]	Non-Armored
Neutral Size	Reduced Neutral	Non-Reduced Neutral

Insulation Classes

- There is a parameter which cables can be classified by, this parameter is insulation class.

Insulation Class	*Standing Temperature*
A	Up to 90 c
B	Up to 110 c
F	Up to 130 c
H	Up to 180 c

How *select a cable for a certain load?*



- This power cable should transfer full power from source to load, so it must stand full load current with limited voltage drop.
- To ensure carrying full load current **De-rating Factors (DF)** must be taken in consideration.

Derating factors

- De-rating factors are the factors that affect cables' life time and their standing current and its dependent on cable laying methods.
- From Cables catalogue we can obtain the De-rating factors ratings.

Df = D1 x D2 x D3 x D4 x D5 x D6 x…..Dn

$$\text{Icable} = \frac{IC.B}{DF}$$

Voltage Drop Calculation

- A long distance cable and its internal impedance may cause a voltage drop more than the allowed percentage.
- Voltage Drop Percentage mustn't more than 5%.

$$VD\% = \frac{Vfactor \times IC.B \times L}{1000 \times 380} \times 100$$

- **Where:**

VD% : voltage drop percentage.

Vfactor : voltage drop for a certain cable (from Cable catalog).

Ic.b : circuit breaker current

L : cable length

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Multicore Cables, with Stranded Copper Conductors, PVC Insulated and PVC Sheathed

Egytech - code	Nominal cross sectional area		Max. Conductor resistance		Current rating			Approx. overall diameter	Approx. weight
			DC at 20 °C	AC at 70 °C	Laid direct in ground	Laid in ducts	Laid in free air		
	mm^2		Ω/km	Ω/km	A	A	A	mm	kg/km
Four core cables with reduced neutral									
CP1-T105-U13	35 sm	16 rm	0.5240/1.150	0.628/1.390	120	95	110	24.0	1470
CP1-T105-U14	50 sm	25 rm	0.3870/0.727	0.464/0.870	145	115	138	28.1	2115
CP1-T105-U15	70 sm	35 sm	0.2680/0.524	0.322/0.628	175	145	171	31.4	2725
CP1-T105-U16	95 sm	50 sm	0.1930/0.387	0.232/0.464	210	165	209	36.1	3690
CP1-T105-U17	120 sm	70 sm	0.1530/0.268	0.185/0.322	240	195	242	39.5	4675
CP1-T105-U18	150 sm	70 sm	0.1240/0.268	0.151/0.322	270	220	275	43.5	5580
CP1-T105-U19	185 sm	95 sm	0.0991/0.193	0.121/0.232	300	245	314	48.2	7025
CP1-T105-U20	240 sm	120 sm	0.0754/0.153	0.084/0.185	345	290	374	54.2	9060
CP1-T105-U30	300 sm	150 sm	0.0601/0.124	0.077/0.151	390	320	440	60.0	11280

Emergency loads Generators & UPS

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Generators and UPS

- In some projects, power continuity is required for many different reasons like:

1. Data loss as in banks.
2. Emergency as in hospitals.
3. Production quantity as in factories.

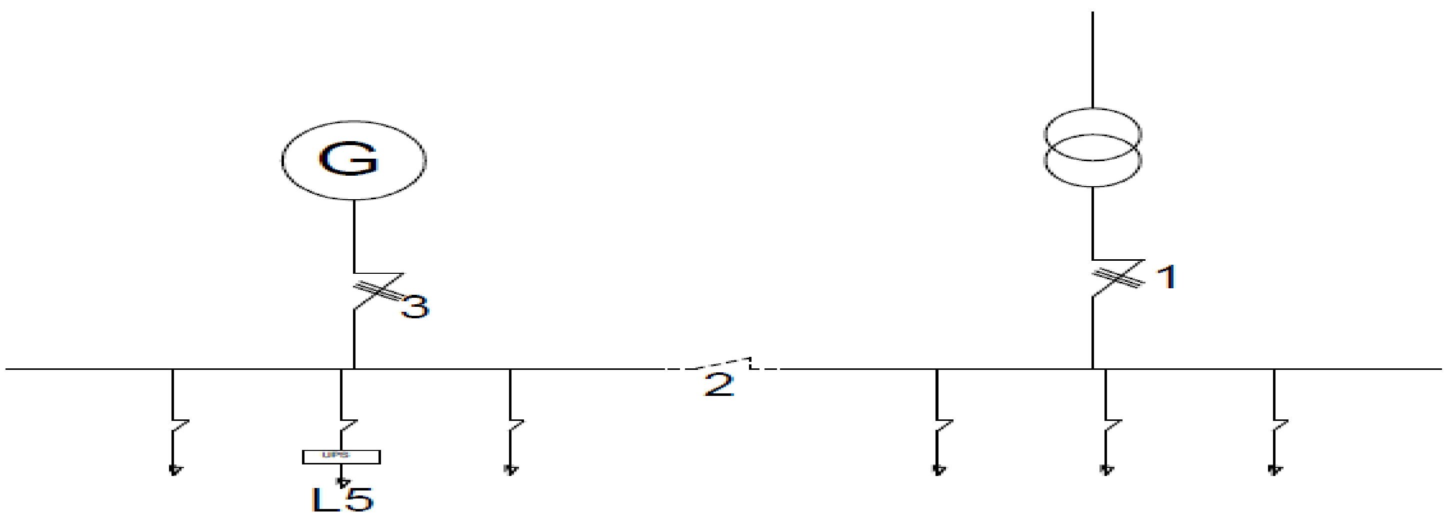
- So the important loads must be fed by a stand by source.
- In case of power interruptions, another source will feed these loads
- ***There are two devices that ensure power continuity:***

A. Generators.

B. UPS

Difference between Generators and UPS

- **Generators** are used as a standby power source with a delay time between current interruption and continuity. On the other hand, **UPS** are used as a power source without any time delay between current interruption and current continuity.
- **Theory of operation:**



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- **Main power source is on:**

  S1 is on   S2 is on   S3 is off

- **Power interruption:**

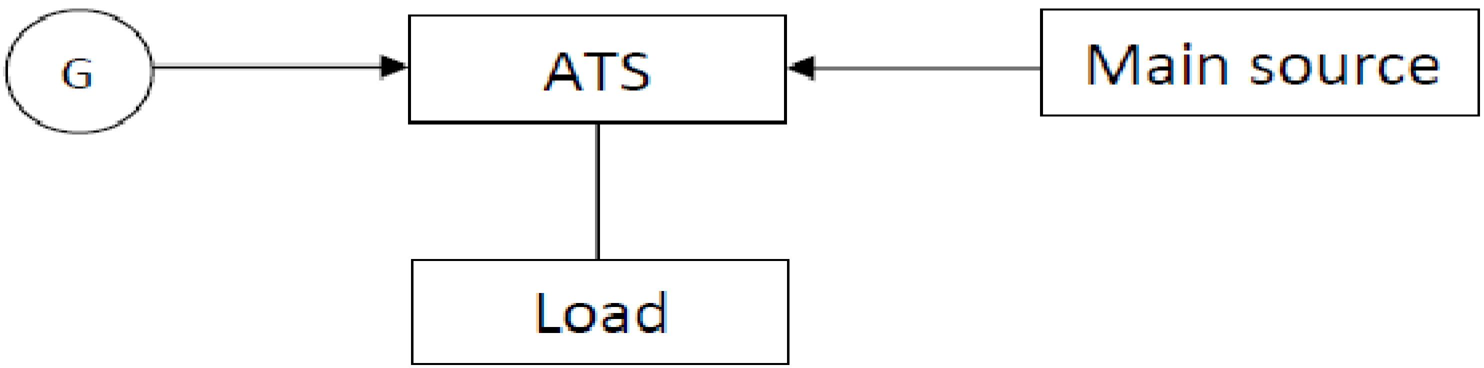
  S1 is off   S2 is on   S3 is on

- **For load (L5)**

*Power continuity is needed without time delay so a UPS is used to feed the load till the Generator starts up.

* UPS is connected before load.

- A controller of three switches called (ATS)
- **ATS panels:**



It's a panel that consists of three switches one is connected to the main source, the second one is connected to the Generator and the third one is connected to the load through a controller (Microcontroller, PLC…).

Generators and UPS selection

- **Generator selection:**

Selection of generators set depend on this points:

* Main Emergency loads board power.

* Mode of generator operation.

* Loads Power Factors. * Ambient Temperature.

* Altitude from sea level.

- **UPS selection:**

Selection of ups depend on this points:

* Nature of load (single or three phase).

* Power of load in kVA. * Discharging time.

Transformers & Medium Voltage Networks Concept

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Transformer Sizing

- Selection of transformers depend on summation of total loads (normal & emergency loads).
- The only difference that in case of oil transformers:

$$\textbf{Oil Transformer Size} = \frac{\textit{Total Loads in } \mathrm{kVA}}{0.8} \ \textbf{kVA}$$

- **Note**

Transformers expressed as kVA not kW, simply transformer losses [Copper losses & Core losses] based on volt-ampere not phase angle, which depend on power factors, so transformers expressed in kVA.

Medium Voltage Concept

- Medium Voltage determined based on loads power:

1. Below 5 MVA → 11 kV
2. From 5 MVA to 15 MVA → 22 kV
3. From 15 MVA to 30 MVA → 33 kV
4. From 30 MVA to 75 MVA → 66 kV

Medium Voltage Network Equipment

1. Ring Main Unit (R.M.U)

- Ring main unit is used in a secondary distribution system. It is basically used for an uninterrupted power supply.
- it also protects your secondary side transformer from the occasional transient currents. Depending on applications and loading conditions.

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- **Classifications:**

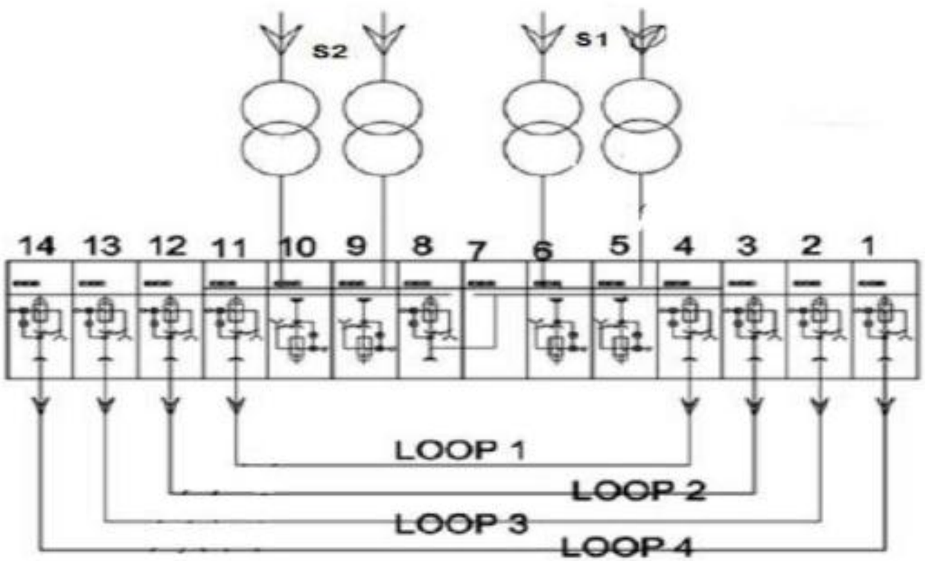
RMU classified based on main electrical parameters which depend on load & operating medium voltage:

A. Rated Voltage.
B. Rated Current.
C. Rated Short Circuit Current.

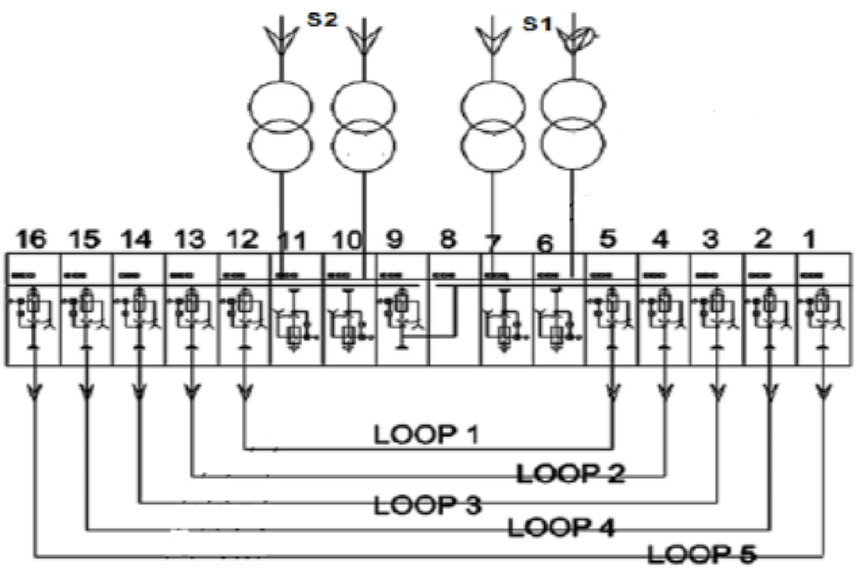
2. Distributers

- There are two main types of distributers

* 14 Cell Distributers.



* 16 Cell Distributers



- **Components of Distributers:**

1. Copper distribution bars.
2. Incoming & Outgoing Cells.
3. Bus Couplers.
4. Batteries & Charger.
5. Current & Voltage Transformers.

Both Distributers & Ring Main Units used to create ring networks

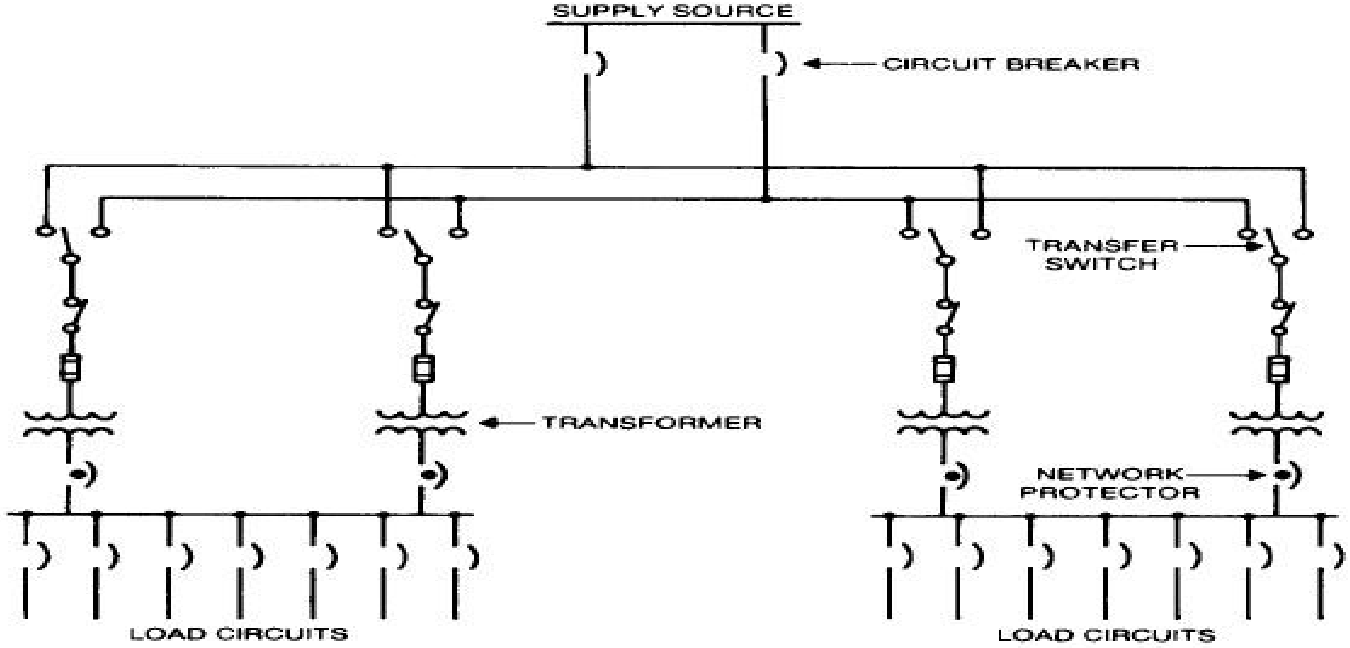
Electrical Networks

- There are two types of electrical networks:

1. **Radial Networks:**

* Used in low voltage networks.

* These networks are a sample networks with lower cost & easier maintenance.



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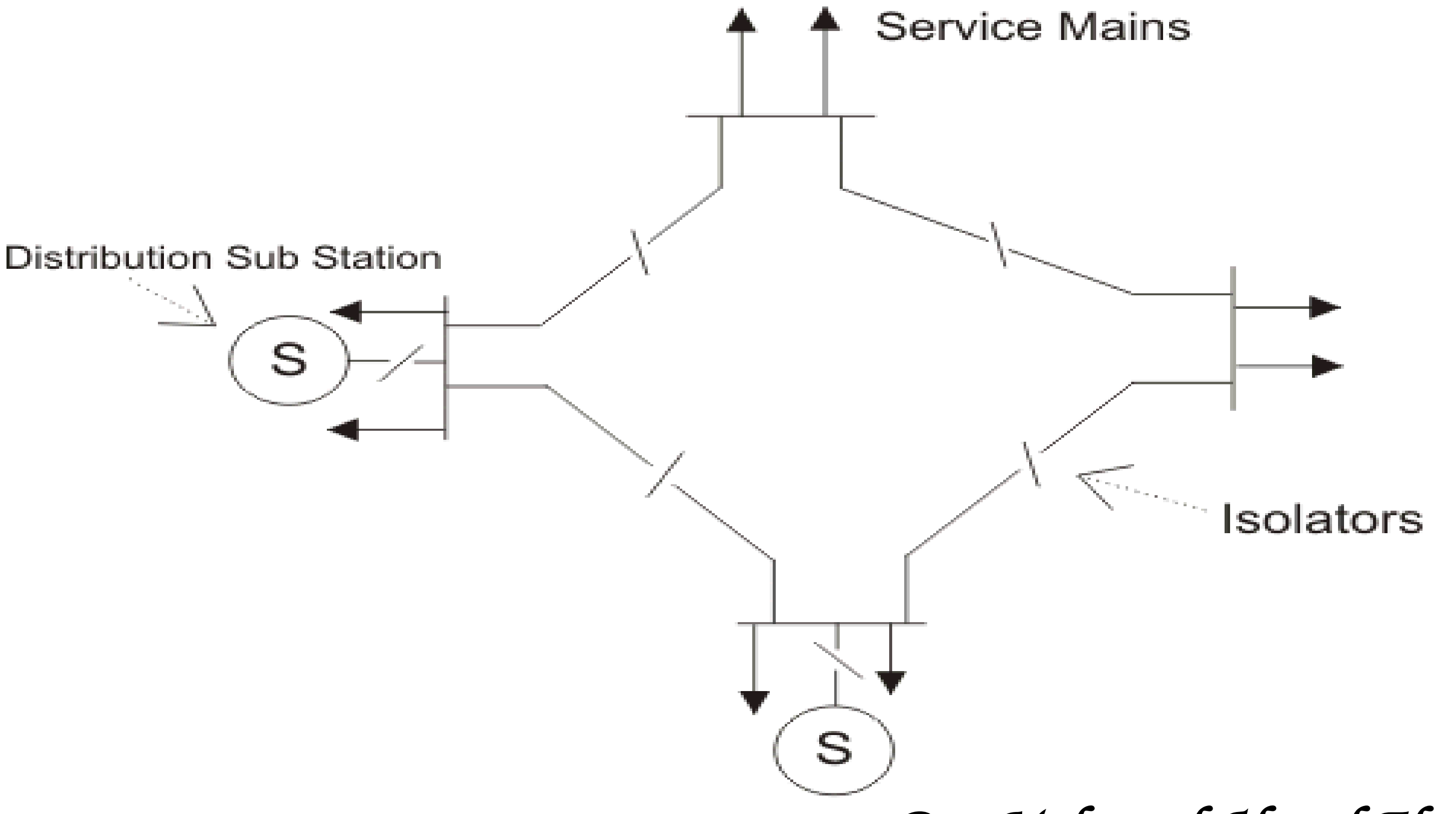
2. **Ring Networks:**

* Used in medium & high voltage networks to create national grid.



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LEC (4) Summary

C.B capacity calculation

Short circuit current

MDB design steps

Meduim voltage network

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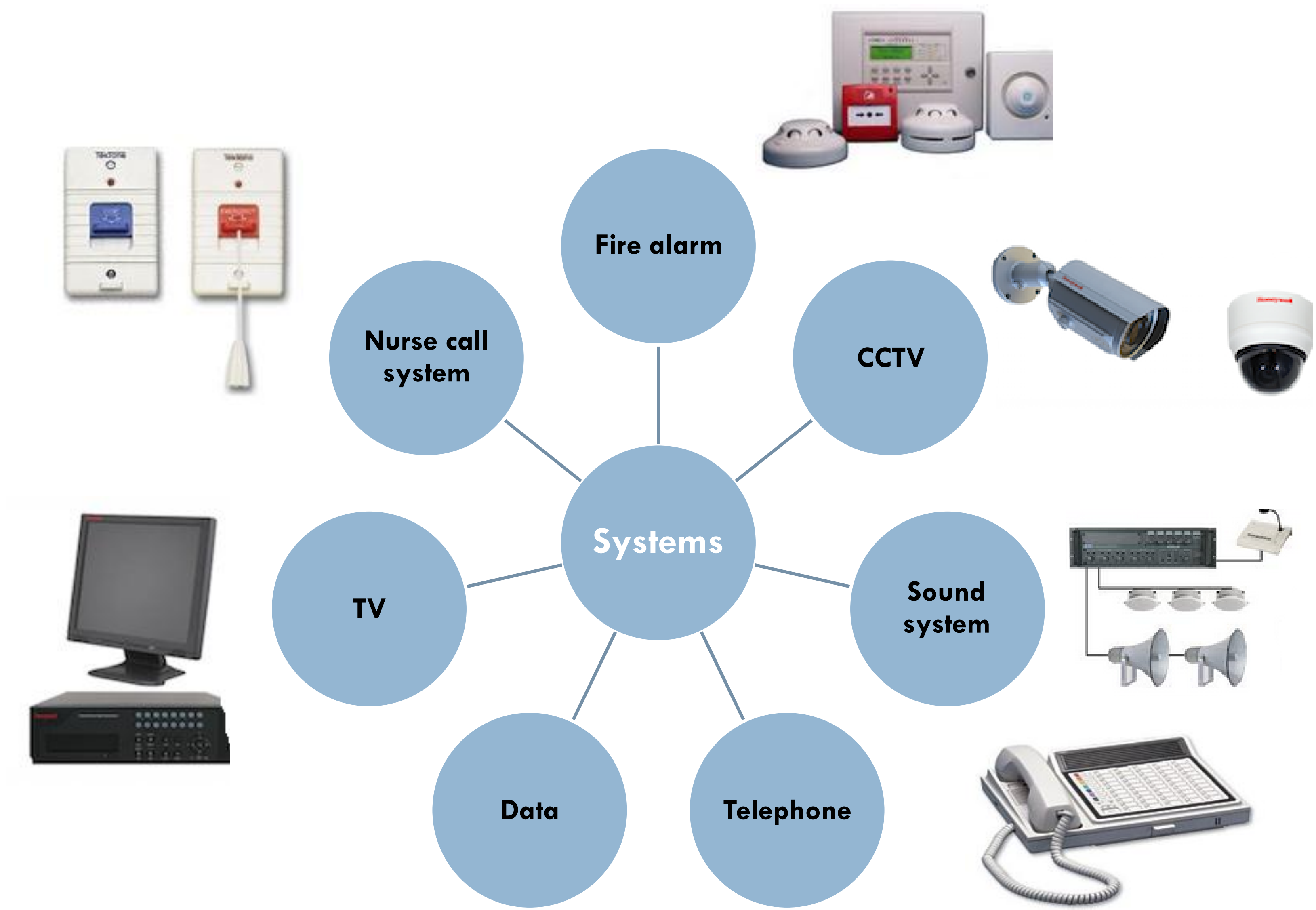
4^{th} step

Light Current Systems

Light Current Systems



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1. Fire Alarm System

- System is aimed at early warning for the presence of fire, allowing the opportunity to declare a state of emergency in place and thus the speed of fire fighting and personnel out of place.

- **The purpose of The alarm Systems and Fire Detection**

1. Fire detection and location.
2. Building occupants warning in case of fire to enable them to escape.
3. Fire-fighting in the first stages.
4. Report the nearest fire station.

Fire Alarm System Components

Detectors
- Smoke
- Heat
- Multi

Alarm
- Bell
- Flasher
- Speaker
- Horn

Call point

Modules
- control module
- monitor module
- door holder

control panel
- conventional
- addressable

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2. Telephone System

- A communication system that transmits sound between distant points and consists of (patch panel-main distribution frame-sub distribution-outlets-cable).

- **Main Component for Telephone System.**

a) (EPABX) Electronic private automatic branch exchange.
b) Main distribution frame (M.D.F).
c) Intermediate distribution frame (I.D.F).
   Or Sub distribution frame (S.D.F)
   Or Telephone junction box (T.J.B)
d) Telephone out lets.
e) Cables of telephone

3. Data Network System

- Networks where devices are connected through a series of wire and cable or wireless on different types and forms and through which the sharing data and information transfer.

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- **Main components for Data Network**

a) **Data Outlet** (RJ 45 and may be wireless).

b) **Patch Panel.**

Function of Patch panel arrangement and organization cables coming from various points of the network. And it is placed in each floor.

c) **Data Switch** (May be (6-12-24-36-48) port).

d) **Data Cable.**

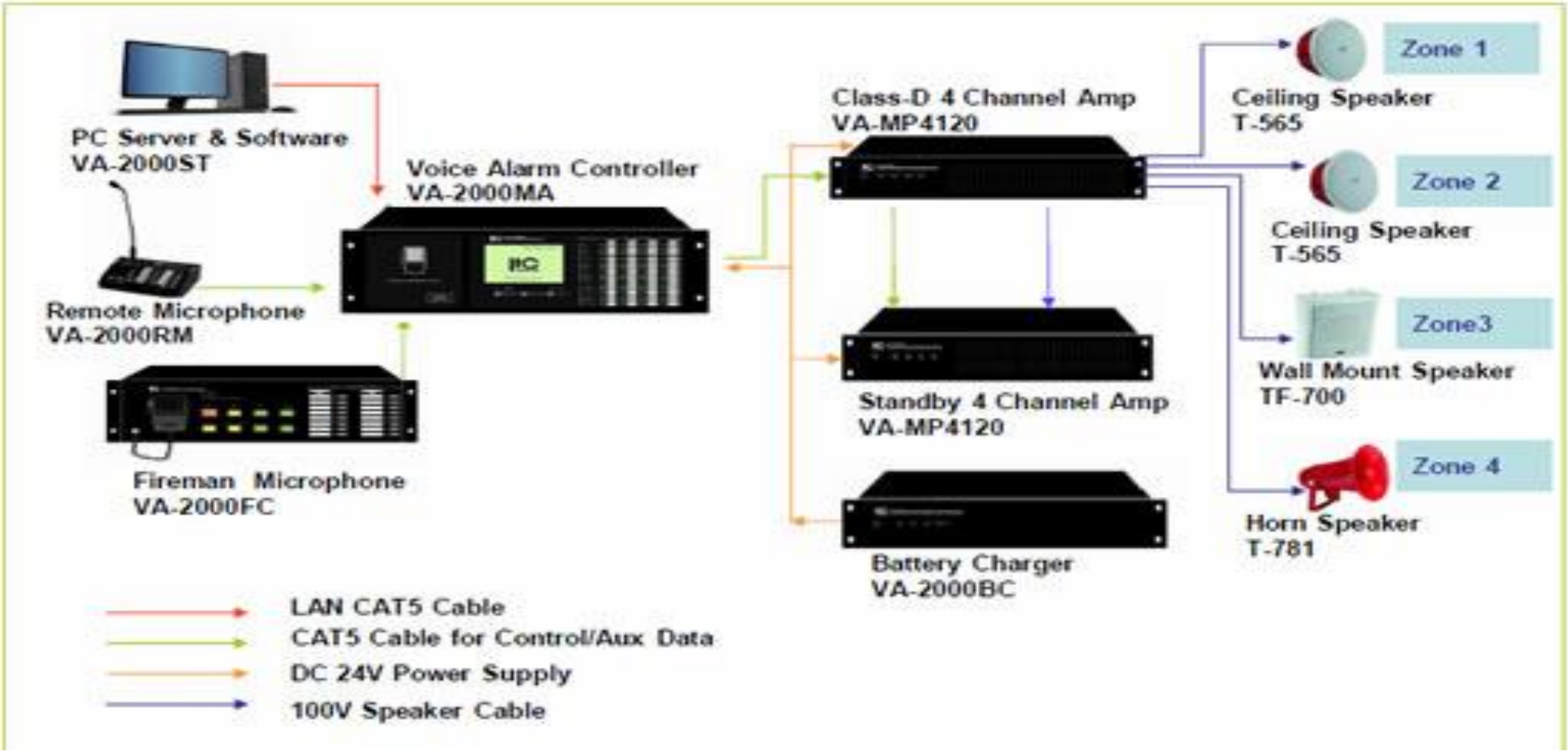
* category.5

* category.5e

* category.6

4. Sound System

- Any system of sounds, as in the speech of a language and consist of (speaker-microphone-amplifier-matrix-rack-cable).



- **Main Component for Sound System**

a) Loudspeakers.
b) Microphones (Wire- Wireless).
c) Power amplifiers.
d) Matrix.
e) Attenuators.
f) Radio FM / AM.
g) CD / DVD Player.
h) Cables.
i) Rack

5. Closed Circuit Television (CCTV) System

- CCTV (closed-circuit television) is a TV system in which signals are not publicly distributed but are monitored, primarily for surveillance and security purposes.

- **Main components for CCTV**

a) Camera.

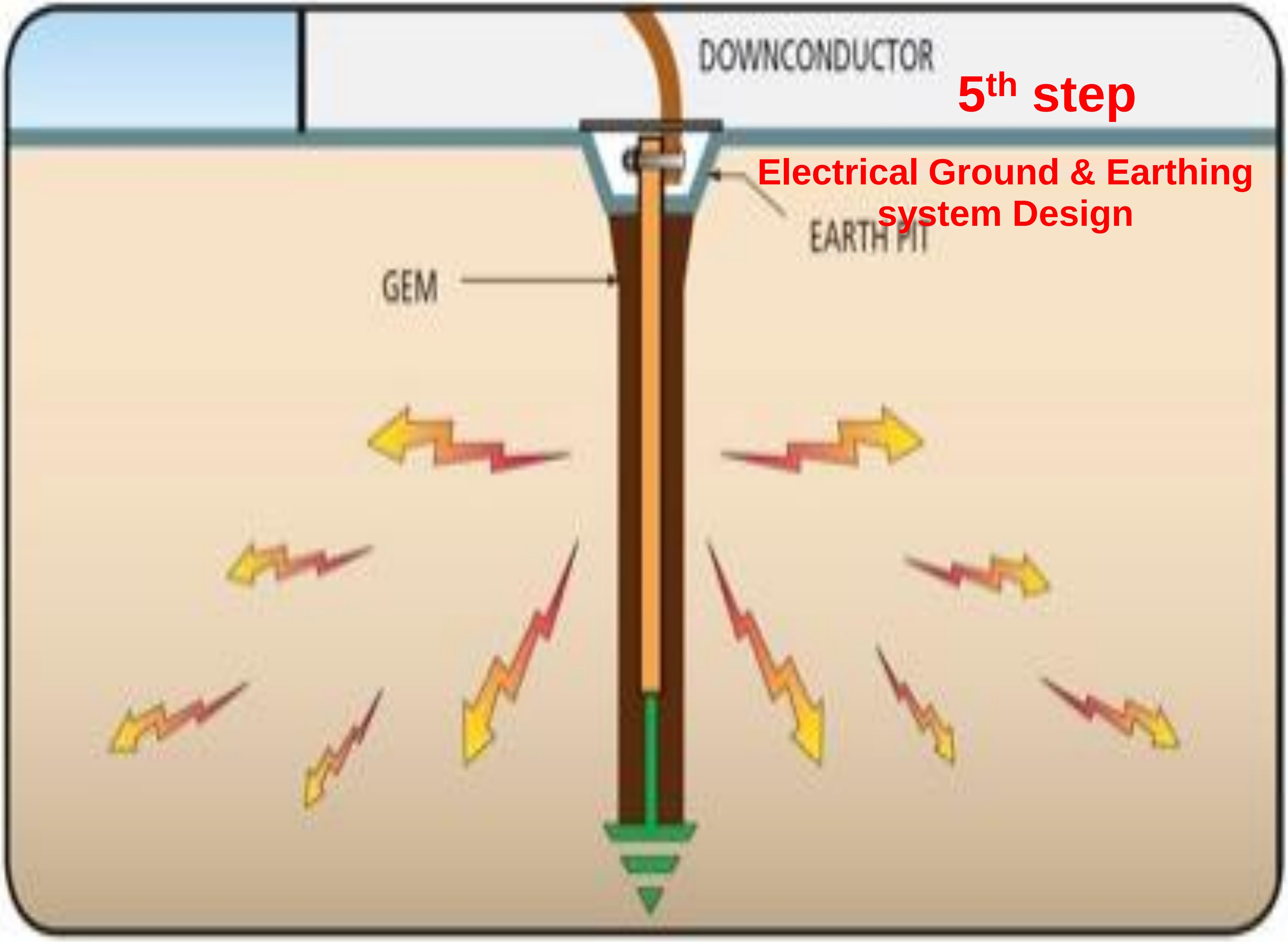
b) Video Matrix.

c) Digital Video Recorder [DVR].

d) Monitor.

e) Control Keypad.

f) Cables



DOWNCONDUCTOR
5th step
Electrical Ground & Earthing system Design
EARTH PIT
GEM

Differences between Grounding & Earthing

1. **Grounding**

Is the process of removing the excess charge on an object by means of the transfer of electrons between it and another object of substantial size. When a charged object is grounded, charge is balanced by the transfer of electrons between the charged object and a ground.

2. **Earthing**

Is used to protect us from an electric shock it does this by providing a path for a fault current to flow to earth. It also causes the protective device to switch off the electric current to the circuit that has the fault by help of fuse.

Function of Earthing system

1. **Equipment Earth**

Path for fault current, lower touch voltage, protection against electric shock.

2. **Lightning Earth**

Low resistance path to diverse the current under lightning attack.

3. **Telecom Earth**

Reduce noise and interference, stabilize DC supply voltage.

4. **Computer Earth**

Reduce interference, maintain supply voltage.

Types of Earthing system

- There are two types of Earthing Systems:

1. **Function Earthing.**

  * This is the earthing of neutral points.

  * A neutral point is connected to the earth point to get the potential of the neutral point to be zero.

2. **Protection Earthing**

  * This is the earthing of the electrical equipment body for human protection.

Earthing Systems terminology

- According to IEC 60364 distinguishes three families of earthing arrangements, using the two-letter codes TN, TT, and IT.

- **The first letter** indicates the connection between earth and the power-supply equipment (generator or transformer):

  * "T" : Direct connection of a point with earth.

  * "I" : No point is connected with earth (isolation), except perhaps via a high impedance.

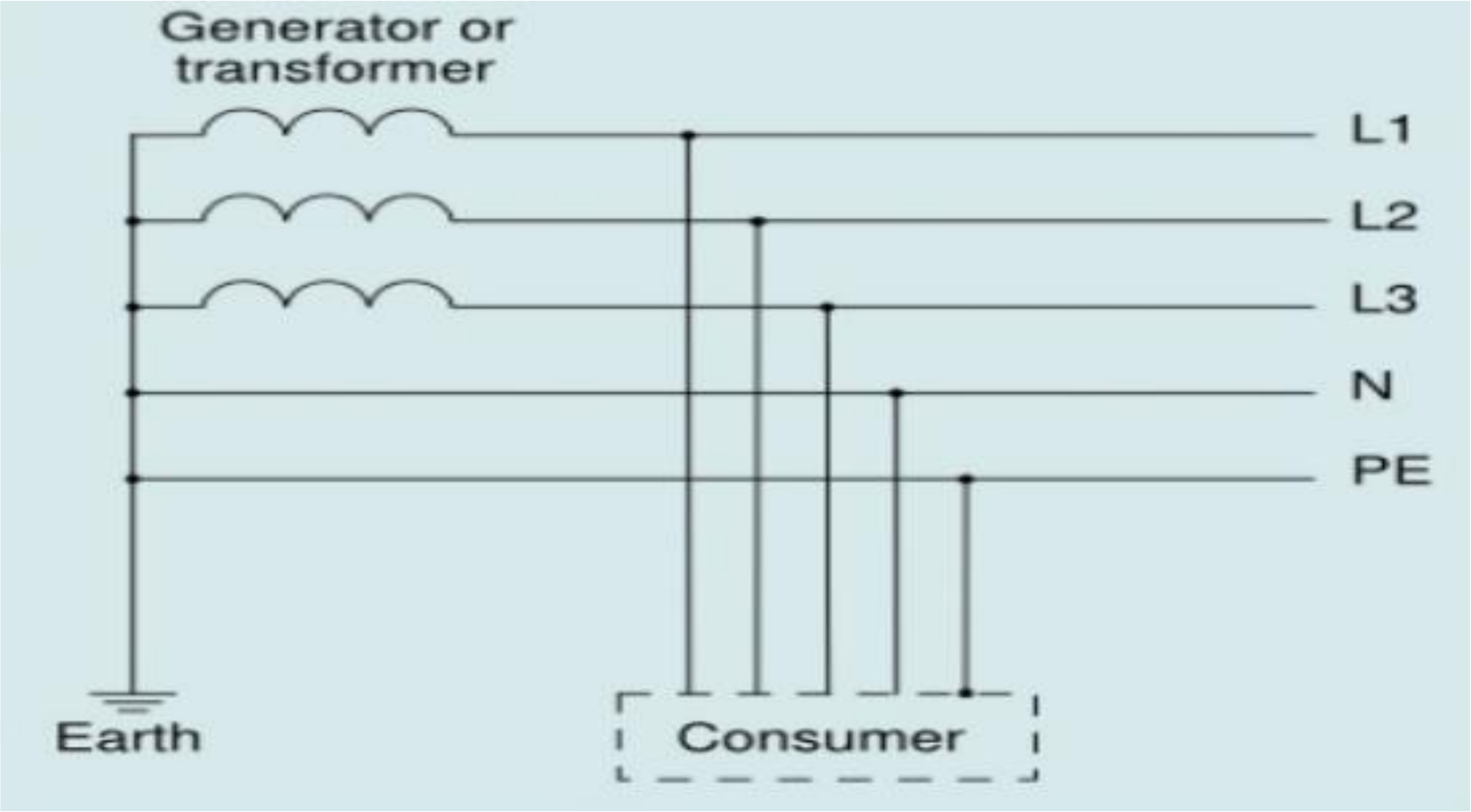
- **The second letter** indicates the connection between earth and the electrical device being supplied:

  * "T"   : Direct connection of a point with earth.

  * "N" : Direct connection to neutral at the origin of installation, which is connected to the earth

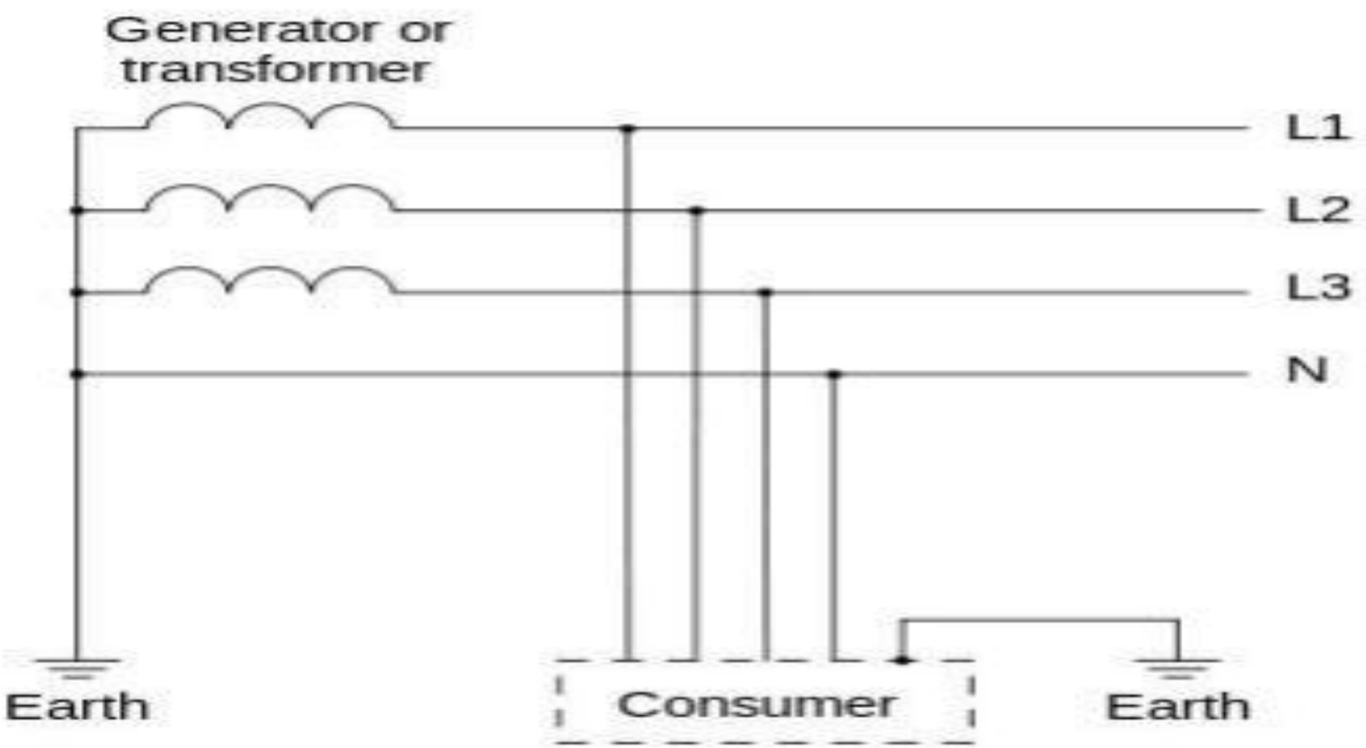
A. TN network

- In a TN earthing system, one of the points in the generator or transformer is connected with earth, usually the star point in a three-phase system.
- The body of the electrical device is connected with earth via this earth connection at the transformer.
- The conductor that connects the exposed metallic parts of the consumer's electrical installation is called protective earth.
- The conductor that connects to the star point in a three-phase system, or that carries the return current in a single-phase system, is called neutral (N).


Generator or transformer
L1
L2
L3
N
PE
Earth
Consumer

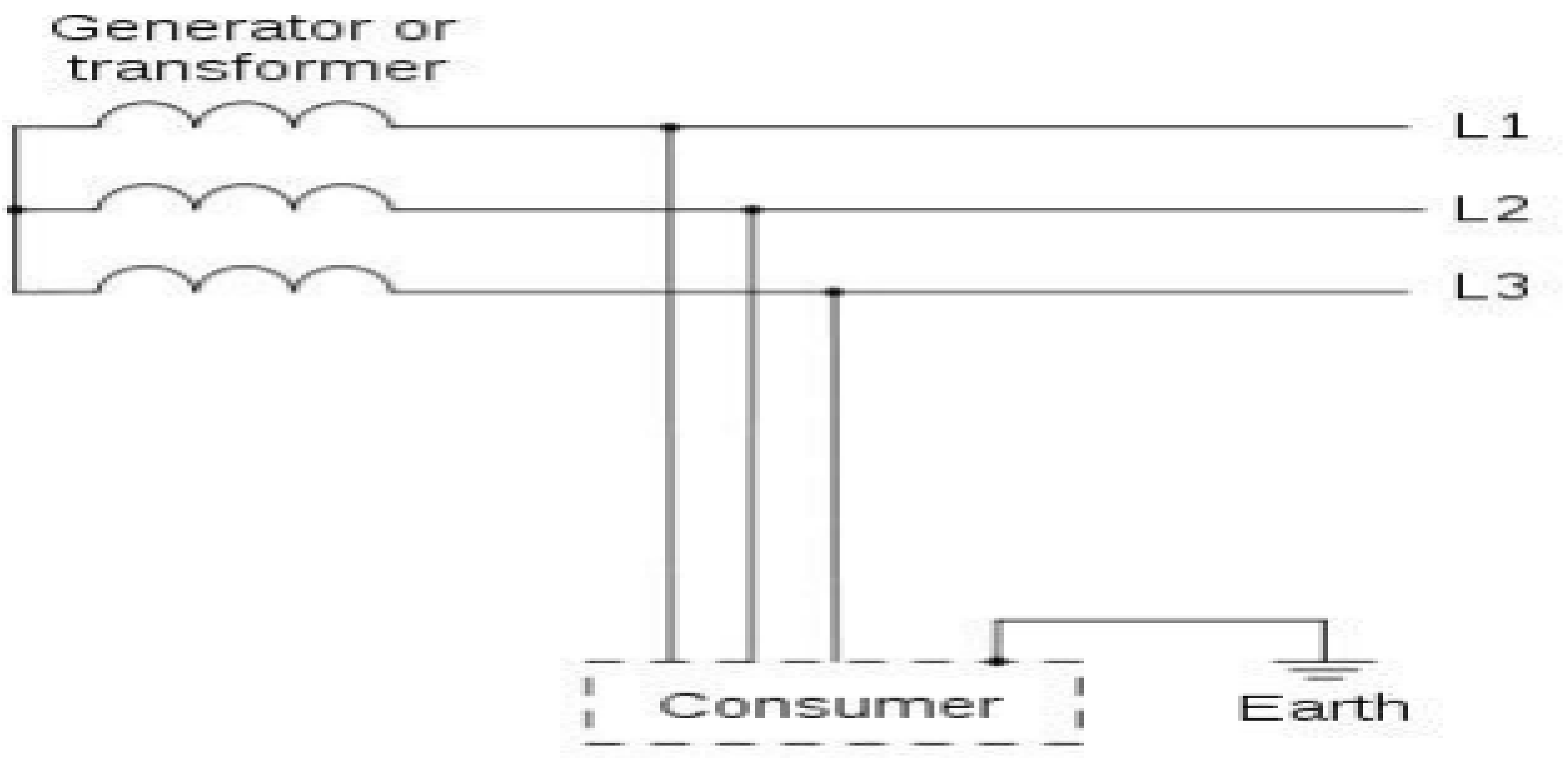
B. TT network

- In a TT (Terra-Terra) earthing system, the protective earth connection for the consumer is provided by a local earth electrode, and there is another independently installed at the generator. There is no 'earth wire' between the two.
- The fault loop impedance is higher, and unless the electrode impedance is very low indeed.
- The big advantage of the TT earthing system is the reduced conducted interference from other users' connected equipment.
- TT has always been preferable for special applications like telecommunication sites that benefit from the interference-free earthing.


Generator or
transformer
L1
L2
L3
N
Earth
Consumer
Earth

C. IT network

- In an IT network, the electrical distribution system has no connection to earth at all, or it has only a high impedance connection.
- In such systems, an insulation monitoring device is used to monitor the impedance.

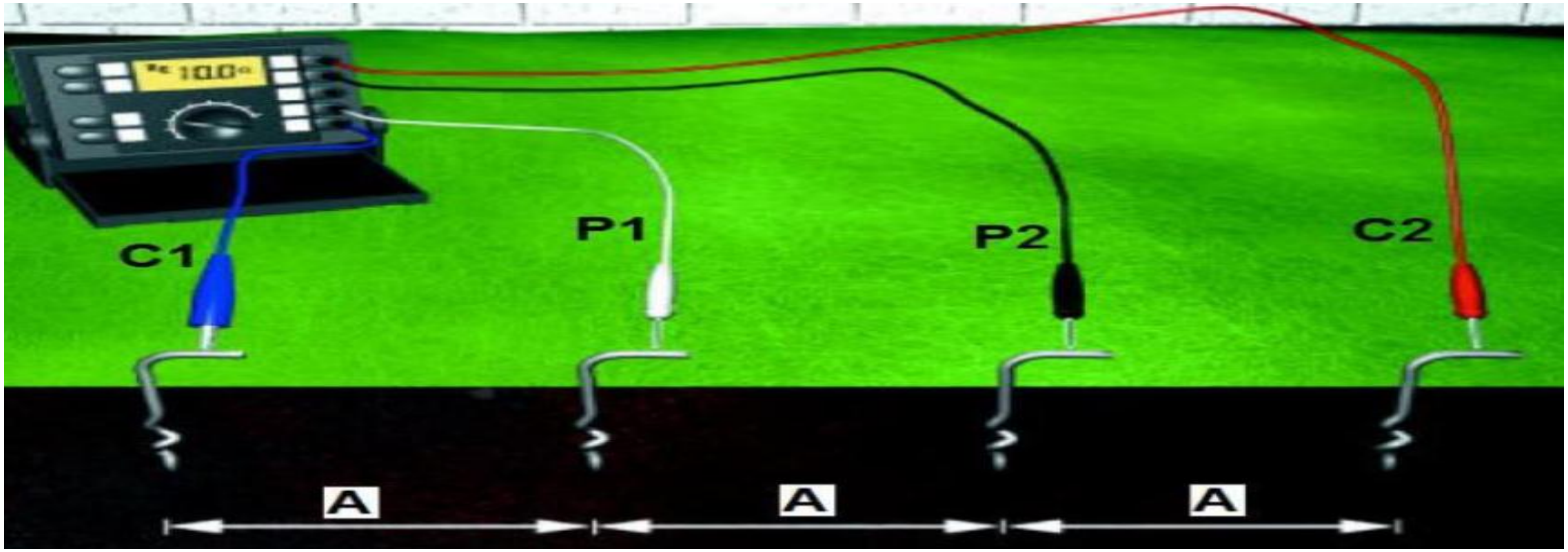

Generator or transformer
L 1
L 2
L 3
Consumer
Earth

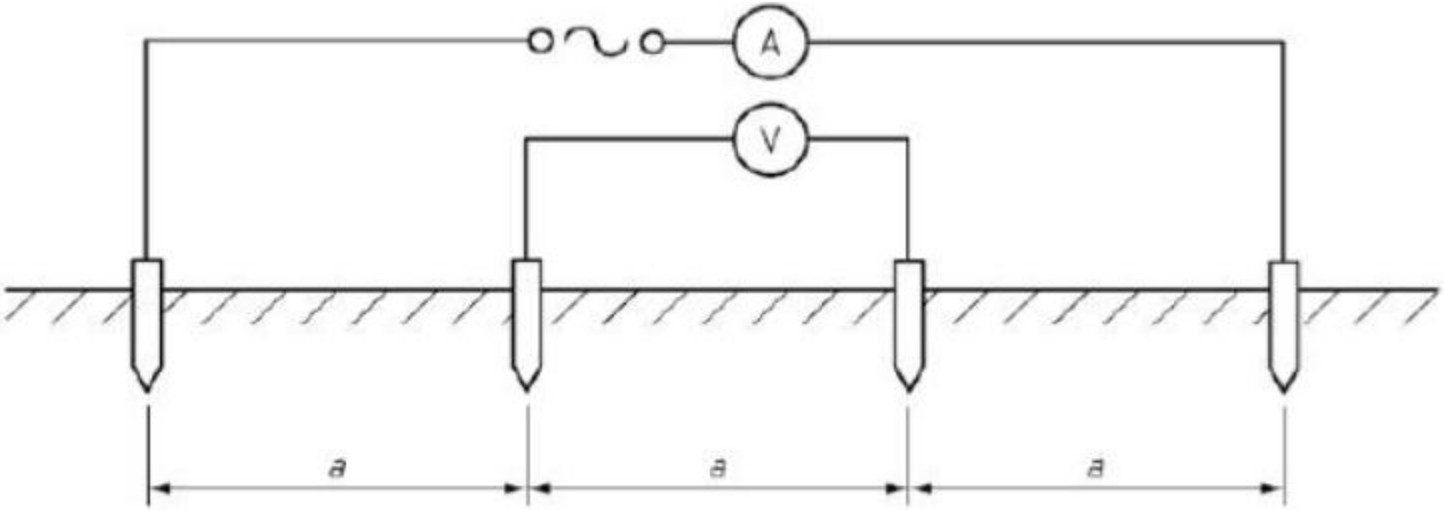
Soil Resistivity Measurements

- **Use the following items:**

1. Earthing Megger.
2. Four Rods 60cm with diameter 13 mm.
3. Four Flexible Cables.

- Put four rods as shown in figure with equal distances & depth of 30cm.
- Connect earthing megger to make points C1& C2 as a current points & points P1 & P2 as a potential points.





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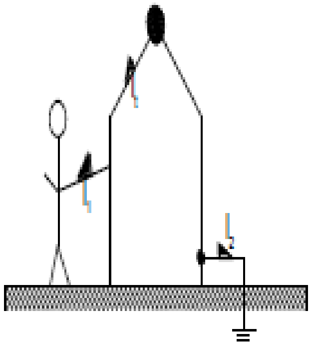
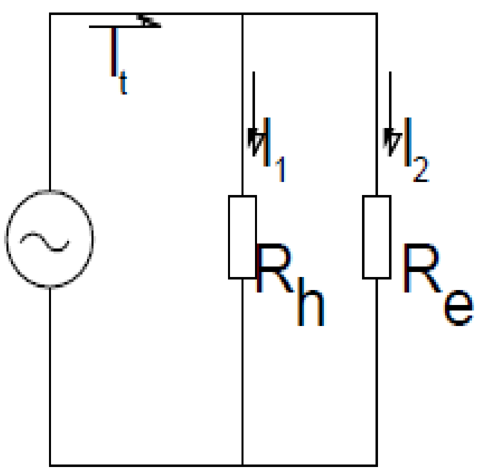
Earthing system design



- **Where**

1. **R**h….. Human Resistance.
2. **R**e….. Earthing Resistance.

- The sole purpose of any earthing system is to protect humans from (I_1)
- So for $I_1 \lll I_2$ or ($I_1 \cong$ zero) .
- So it's required $R_e \lll R_h$.
- For power systems: $R_{earthing} = 2 \cong 4\ \Omega$.
- For light current systems: $R_{earthing} = 0.5\ \Omega$



Earthing Systems Resistance Calculation

1. ***Resistance of one vertical electrode is given by:***

$$\boldsymbol{R} = \frac{\boldsymbol{\rho}}{\mathbf{2}\boldsymbol{\pi}\boldsymbol{L}}\left[\log\left(\frac{8\,L}{d}\right) - \mathbf{1}\right]$$

- ***Where:***

  * R : is resistance of single rod in ohms.

  * L : is rod length in meter.

  * d : is rod diameter in meter.

  * ρ: is soil resistivity in ohm meter.

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Earthing Systems Resistance Calculation

2. ***Total Resistance of (n) rods :***

a) ***Vertical parallel rods arranged as hollow square***

$$Rn = R \left(\frac{1 + a\lambda}{n}\right)$$

$$a = \frac{\rho}{2 \pi R S}$$

- ***Where:***

*R: is resistance of single rod in ohms.

*S: is the distance between rods in meters.

*ρ: is soil resistivity in ohms meter.

*λ: is a factor given by below table.

*n: is number of rods.

Factors for vertical electrodes arranged in a hollow square

Number of electrodes (n) along the side of the square	Factor λ	Number of electrodes (n) along the side of the square	Factor λ
2	2.71	9	7.65
3	4.51	10	7.90
4	5.46	12	8.22
5	6.14	14	8.67
6	6.63	16	8.95
7	7.03	18	9.22
8	7.30	20	9.40

b) ***Vertical Parallel rods arranged as straight line***

$$Rn = R\left(\frac{1 + a\lambda}{n}\right)$$

$$a = \frac{\rho}{2\,\pi\,R\,S}$$

- ***Where:***

  *R: is resistance of single rod in ohms.

  *S: is the distance between rods in meters.

  *ρ: is soil resistivity in ohms meter.

  *λ: is a factor given by below table.

  *n: is number of rods.

Factors for vertical parallel electrodes arranged in a line

Number of electrodes *n*	Factor λ	Number of electrodes *n*	Factor λ
2	1.00	7	3.15
3	1.66	8	3.39
4	2.15	9	3.61
5	2.54	10	3.81
6	2.87		

c) ***Three rods at the vertices of an equilateral triangle***

$$Rn = \frac{1}{3}\left\{2\left[\log\left(\frac{8\,L}{d}\right) - 1\right] - 1 + 2LS\right\}$$

- ***Where:***

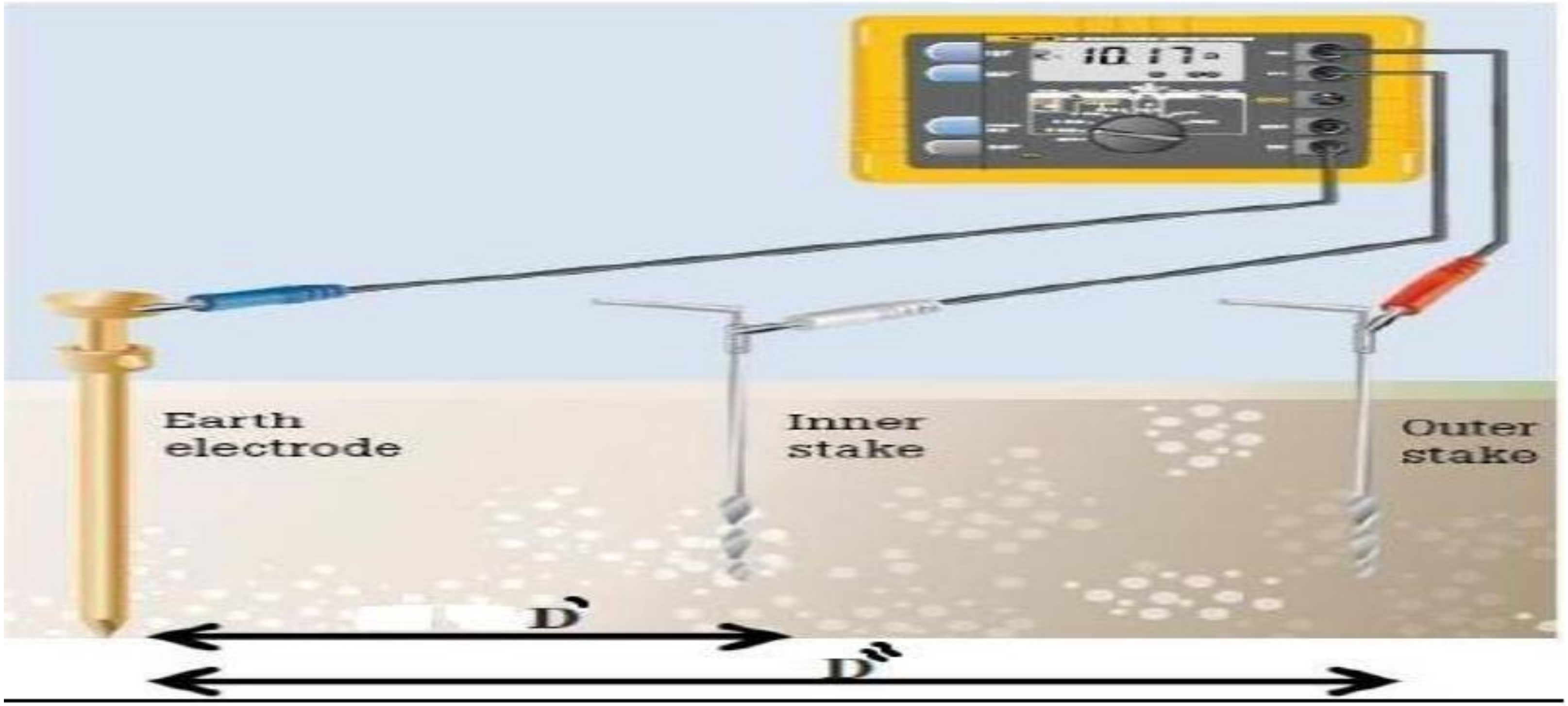
*S: is the distance between rods in meters.

*L: is rod length in meter.

*d: is rod diameter in meter.

Earthing System Measurements

- Connect earth **Megger** as below.
- The distances between rods are according to manufacture of earth **Megger** regulations.



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