EE3044D Electrical System Design for Buildings

Domestic Installation

Domestic Installation

- General aspects as per NEC and IS 732 related to the design of domestic dwellings availing single phase supply (LV) and three phase supply (MV) for a connected load less than 15kW
- Load Survey common power ratings of domestic gadgets, connected load, diversity factor, selection of number of sub circuits (lighting and power), selection of MCB distribution boards to provide over load, short circuit and earth leakage protection
  - Principle of operation of MCB, MCB Isolator, ELCB RCCB and RCBO, Selection of CBS for protection and grading between major and minor sections
- Selection of wiring cables, conduits as per NEC and IS 732
- Design of electrical schematic and physical layout drawings for low and medium class domestic installation. Preparation of schedule of works and bill of quantities (cost estimation excluded).
- Pre-commissioning tests: Insulation resistance measurement, continuity test, polarity test, and earth resistance measurement as applicable to domestic installations.

Supply characteristics in residential buildings

In connection with a new building, the following aspects are to be considered to bring an electric supply to premises

- The nearness of supply point
- The position in the building, where the service cable is required to terminate.
- The characteristic of the supply namely, whether AC or DC.
- If AC, number of phases, voltage levels and power rating of equipment and accessories
- If DC, number of wires and voltage.
- Maximum load demand anticipated.
- In the case of large buildings if alternative supply arrangement is available, change over to alternative supply is to be provided in the event of supply failure.

- According to rules, Power supplying authority give 1 phase (240 V, 2 wire) supply for load less than 5 KW domestic dwellings, 3 phase supply (415 V, 4 wire) for load greater than 5 KW

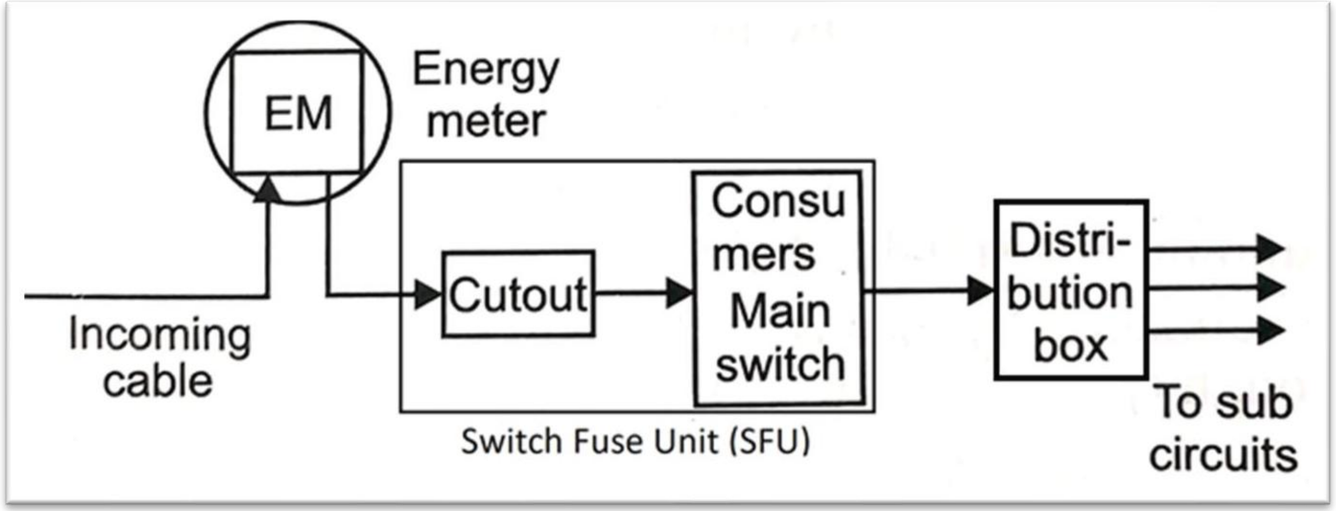
Domestic dwelling : The term 'domestic dwelling' refers to a building that has no more than one family unit resident in it and which is used as a place of permanent or semi-permanent habitation. The most common example of a domestic dwelling is a house.

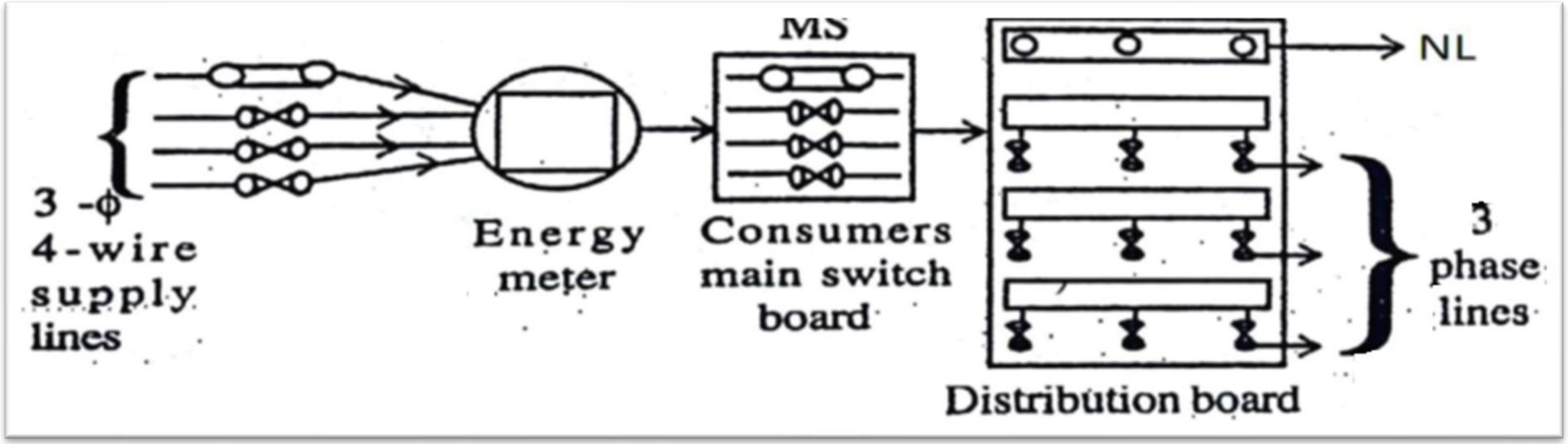
General Rules for Wiring

- The conductor used is to be of such a size that it may carry load current safely
- Every sub circuit is to be connected to a distribution board
- Every phase line is to be protected by a circuit breaker of suitable rating as per requirements
- A switch board is to be installed so that its bottom lies 1.25 meters above the floor
- All plugs and socket outlets are to be 3 pin type, the appropriate pin of socket being connected permanently to the earthing system
- All lamps unless otherwise required, are to be hung at a height of 2.5 meters above the floor level
- Unless otherwise specified, all ceiling fans are to be hung 2.75 meter above the floor level
- No fuse or switch is to be provided in earthed conductor
- Every circuit or apparatus is to be provided with a separate means of isolation such as a switch
- In any building, light and fan wiring and power wiring are to be kept separate
- In 3 phase, 4 wire installation the load is to be distributed equally on all the phases
- Each sub circuit is to be protected against excessive current (that may occur either due to overload or due to short circuit) by fuse or automatic circuit breaker
- After completion of work the installations are to be tested before energization

1 Phase & 3 phase supply schemes

A single phase installation showing energy meter, main switch (SFU) & distribution board

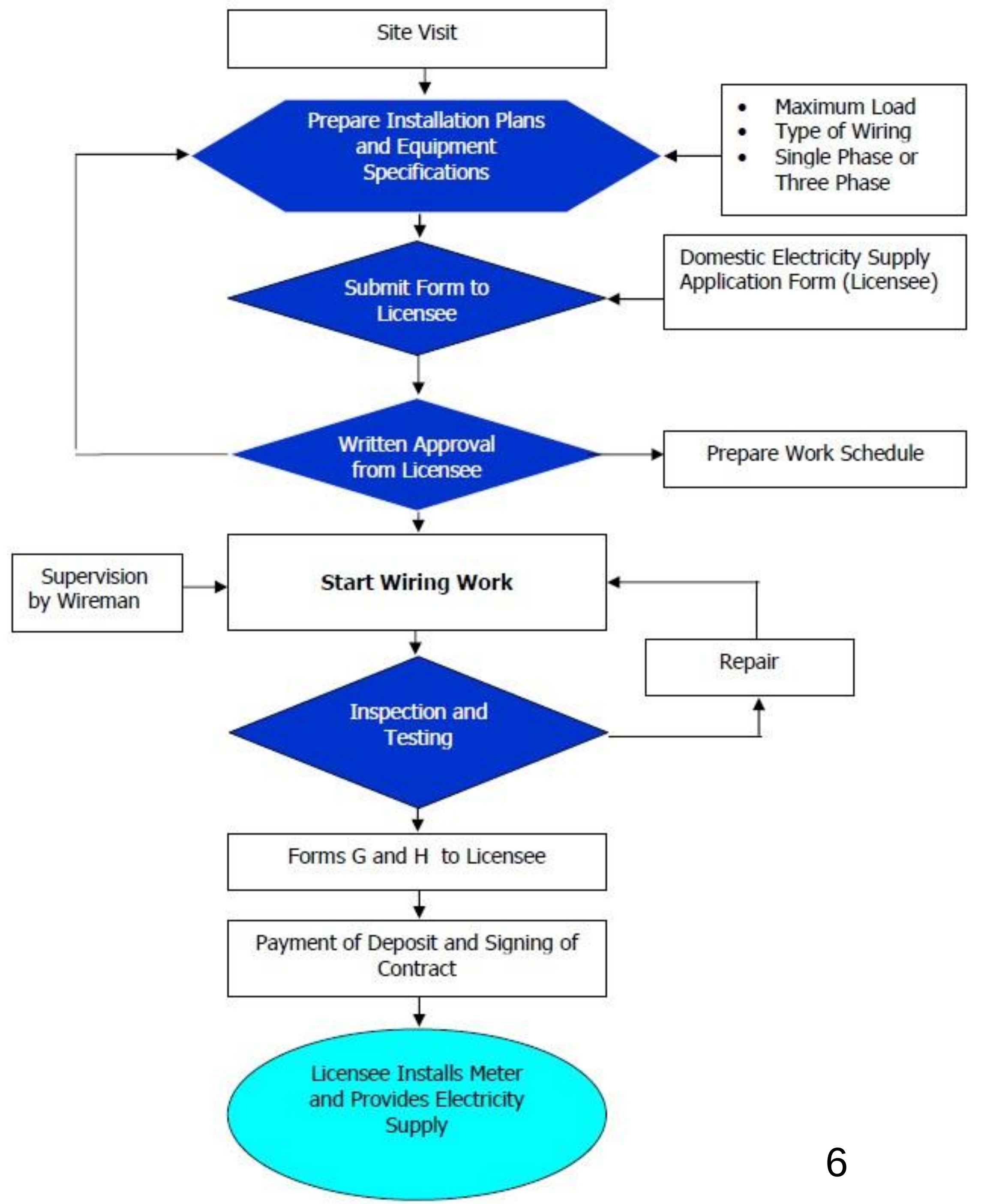




3 phase 4 wire domestic distribution scheme

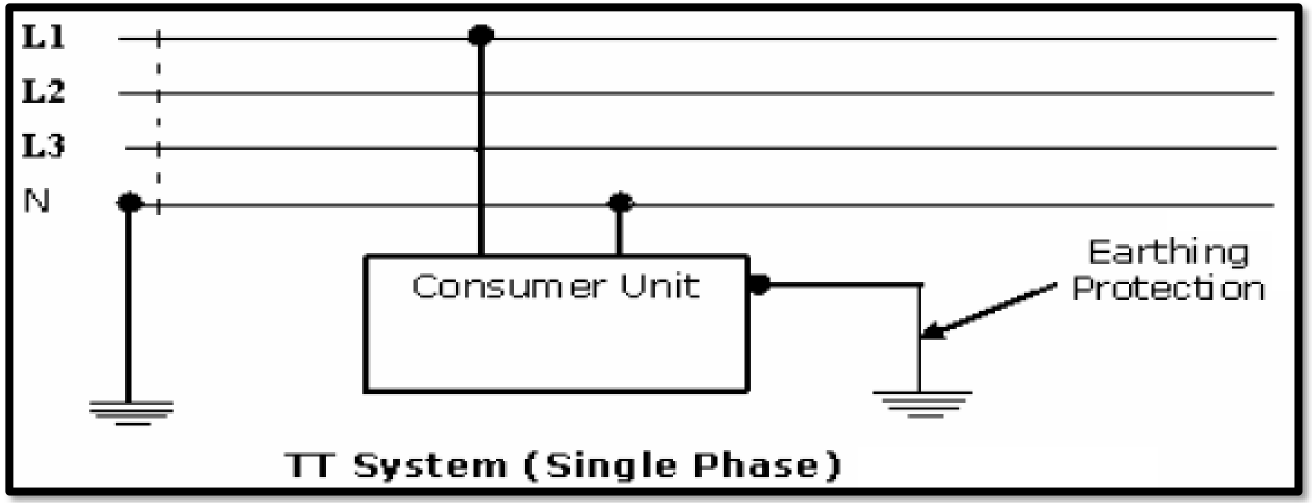
Planning of electrical wiring work

- Prior to carrying out wiring work, the wireman/ contractor should plan and determine the tasks to be undertaken so that the work carried out is tidy, neat and safe to be used.
- The wireman/contractor shall: -
  i. Undertake a site visit
  ii. Determine the consumer load requirements
  iii. Calculate the maximum load demand
  iv. Submit the plans, drawings & specifications.
- The planning flow chart for building wiring installations is as shown in figure

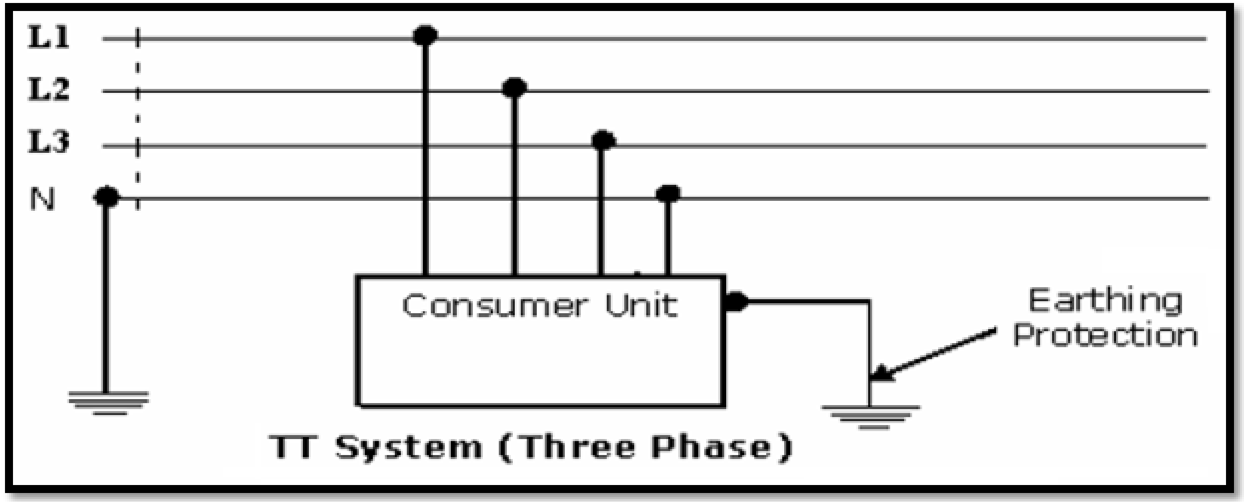


Electricity Supply Specifications

- Electricity supply for domestic consumers, according to IEC 60038 standards, meets the following specifications:
  i. Single phase supply with nominal voltage of 230V, range +10%, -6%
  ii. Three phase supply with nominal voltage of 400V, range +10%, -6%
  iii. Permitted frequency is 50Hz + 1%
  iv. Earthing system type (TT System)



TT System (Single Phase)

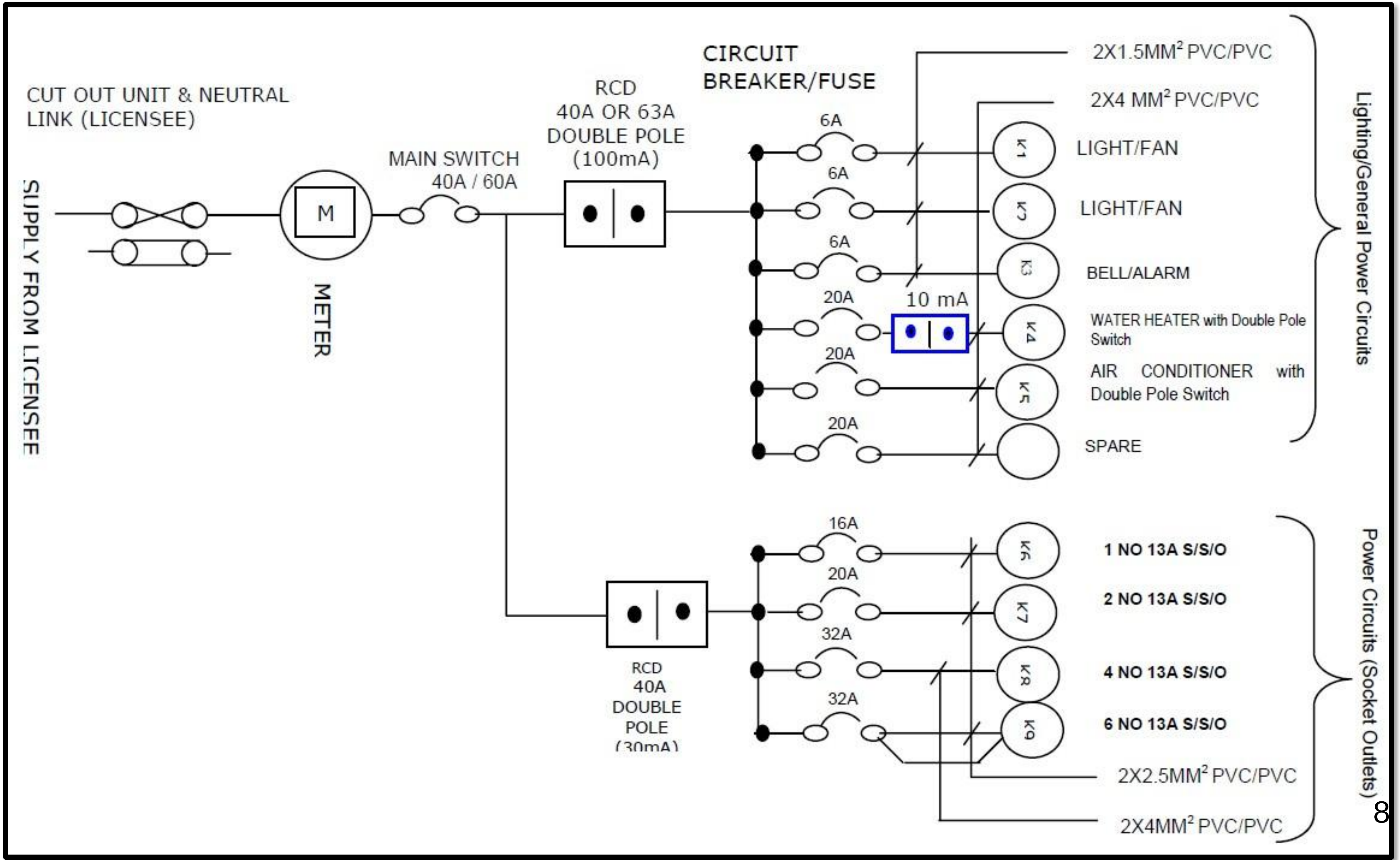


TT System (Three Phase)

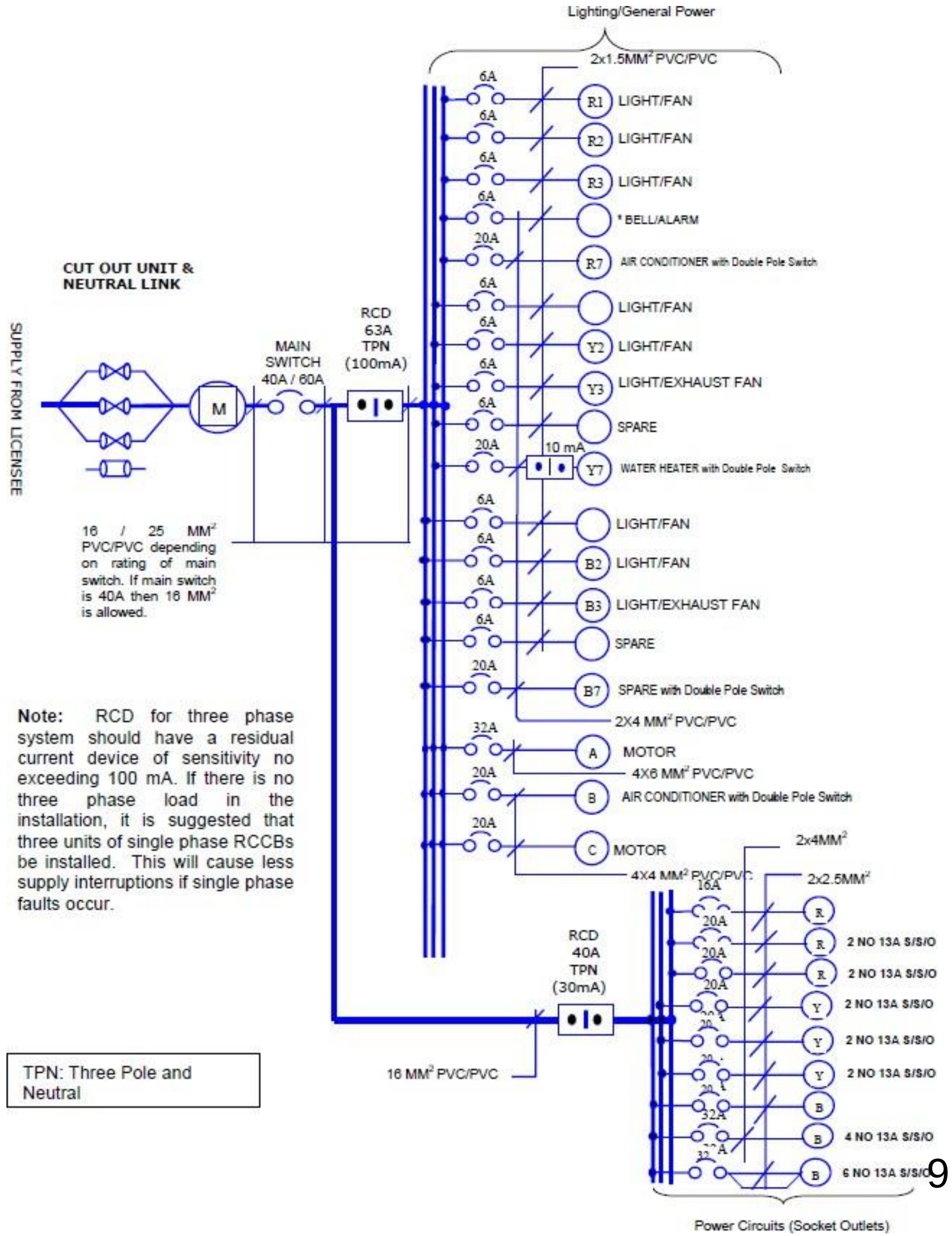
Electrical Wiring

- Electrical wiring composes of electrical equipment such as cables, switch boards, main switches, miniature circuit breakers (MCB) or fuses, residual current devices (RCD), lighting points, power points, lightning arrestors etc.

Single phase consumer electrical wiring (Schematic diagram/single line diagram)



Three phase consumer electrical wiring



Cable selection

- All wiring cables must be PVC insulated with copper or aluminium conductor (conductor cross sectional area of $16mm^2$ or less must be of copper)
- Cable size allows it to carry the current without heating the cable
- Voltage drop must not exceed 4% of supply voltage
- Cable insulation must be suitable for the surrounding conditions of the installations such as the ability to provide mechanical protection
- The selected cable must be capable of delivering the electrical energy efficiently
- The minimum cross sectional areas of conductors based on their applications is given in table below

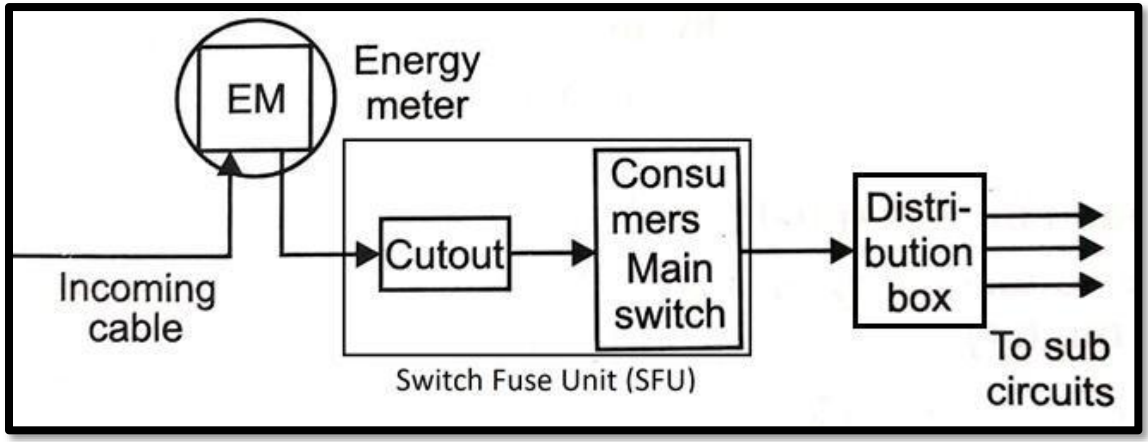
Conductor Cross Sectional Area in mm^2	Material	Application
1.5 mm^2	Copper	Lighting/fan circuit
2.5 mm^2	Copper	Power socket outlet circuit
4.0 mm^2 – 6.0 mm^2	Copper	General Power Circuit (example: water heater, cooker unit, motor/pump)
16.0 mm^2 / 25.0 mm^2	Copper	Main Circuit

Cable selection

- The following points shall be taken into consideration before selecting the cable for a particular application
  - ➢ The power and voltage rating for which the cable are being used
  - ➢ Conditions of installation at the site
  - ➢ Current carrying capacity of the cables
  - ➢ Voltage drop in the cables
  - ➢ Short circuit capacity of the cables
  - ➢ Availability of the selected size of the cable

Classification of domestic circuit

1. **Main circuit** – from pole to main distribution board via meter
2. **Sub circuit**



- The circuit from distribution board to different electrical appliances
- In the figure shown, the main disadvantage is that in case of short circuit in any part of the wiring, the fuse will disconnect supply to whole installation
- Also when the number of load points is large, the voltage available at the farthest end will be low due to voltage drop in the line
- For these reasons, it is the practice to divide the wiring into a number of smaller circuits called sub circuits
- A sub circuit may contain light, fan & power points
- The possibility of faults in power circuits is more & power appliances cause large voltage drop in the sub circuit
- Therefore, sub circuits are divided into 2 groups

a) Light & fan sub circuit

- This sub circuit feeds supply to various light points & fan points
- Each sub circuit should have not more than a total of ***10 points of lights, fan & 5A socket outlets***
- The load on each sub circuit shall be restricted to ***800W***

b) Power sub circuit

- This sub circuit supplies power to appliances like electric iron, induction cooker, small single phase motors of washing machine, refrigerator, mixer etc.
- The load on each power circuit should normally be restricted to ***3000W***
- In no case should there be more than 2 power outlets on each sub circuit

Domestic Electrical installations

- Different steps for electrical installation in domestic buildings are

a) Identifying loads

b) Calculate connected load

c) Deciding number of sub circuits

d) Prepare installation plan

e) Deciding distribution board, main switch, ELCB, MCB etc

f) Deciding size of wire

g) Schematic diagram

h) Prepare estimate

a) Identifying loads – in consultation with the consumer

- ***The National Electrical Code (1985) recommendation on the minimum number of points to be provided in domestic buildings based on the plinth area*** is given in next slide
- The details given are the minimum requirements & the house owner can opt for higher number of points based on the requirement

Description	Area of the residential building (m^2)				
	35	45	55	85	140
Light points	7	8	10	12	17
Ceiling fans*	2-2	3-2	4-3	5-4	7-5
6 A sockets	2	3	4	5	7
16 A sockets	-	1	2	3	4
Call bell	-	-	1	1	1

b) Calculate connected load

- Once all points are decided, the total connected load of the building is calculated
- The total installed kVA is assumed to be the sum of the kVA ratings of individual loads
- The maximum demand kVA is less than installed kVA (Because all individual loads need not necessarily operate at same time)
- Therefore a suitable correction factor is applied to installed kVA to find maximum kVA demand
- The factors are

1. ***Factor of maximum utilization*** – In normal condition, the power consumed by a load is less than the normal rating of load. This factor must be applied to individual loads which are very rarely operated

1. ***Factor of Simultaneity (k_s)*** – The simultaneous operation of all the connected loads of an installation never occurs in practice. In other words, there is always some degree of diversity & this factor is taken into account for estimation purpose. It is applied to a group of loads. The determination of this factor is the responsibility of system designer based on the knowledge of working of installation. For this reason it is not defined precisely. The term diversity factor defined by IEC & Simultaneity factor are one & same. However in India, ***Diversity factor is the reciprocal of Simultaneity factor & its value is greater than 1***. For domestic installations, the diversity factor can be assumed to be ***2 to 2.5*** on the assumption that only 40 to 50% of the connected load will be used simultaneously

- To find the total connected load, if the actual wattage of the appliances & light points are not known, it may be calculated based on the recommended ratings in the table

Specification	Rating (Watts)
Incandescent lamps	60
Fans (ceiling / table)	60
6 A three-pin sockets	100
16 A three-pin sockets	1000
Fluorescent lamp 600 mm	25
Fluorescent lamp 1200 mm	50
Exhaust fan 300 mm	45

c) Deciding the number of sub circuits

- ***No. of light sub circuits = No. of light points/6***

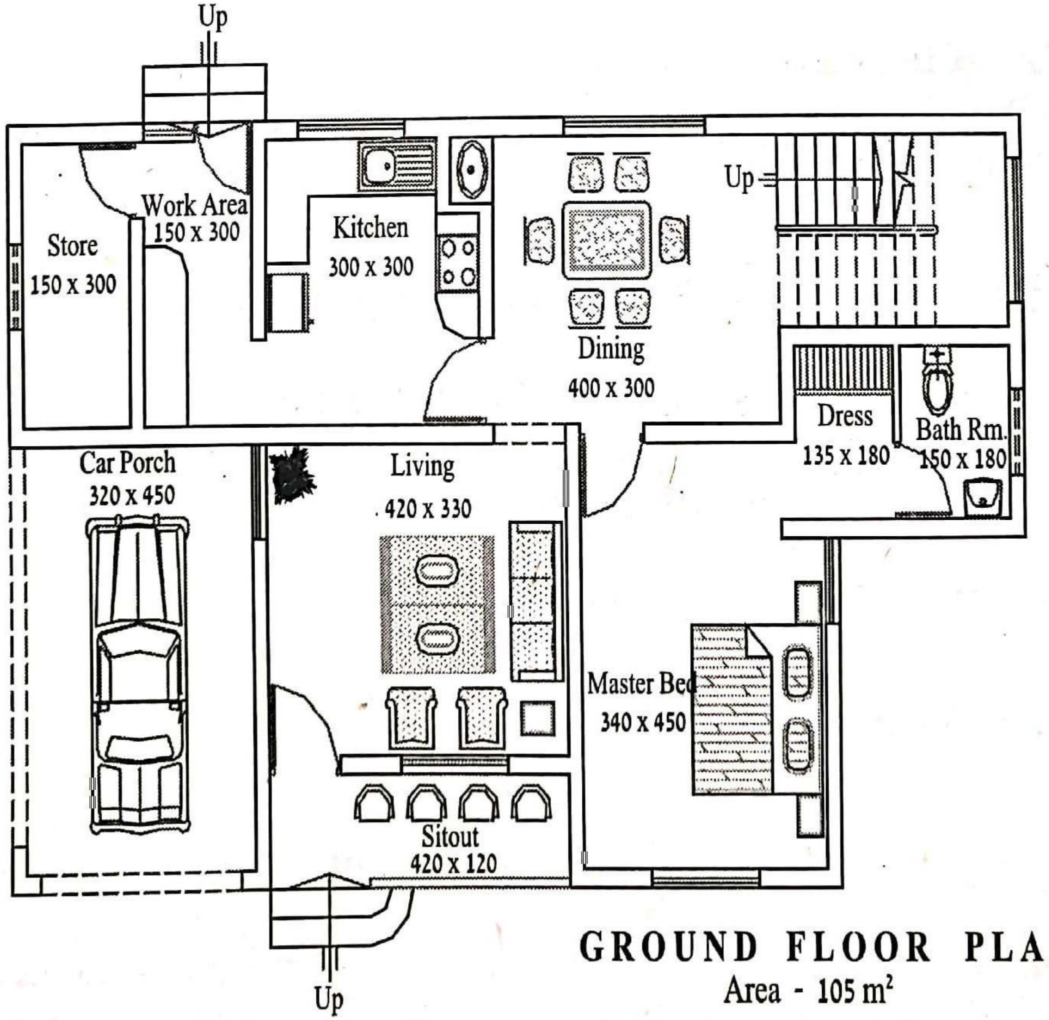
(According to IS 732, max. no. of light points in a light circuit is 10. A good engineering practice is to select the number of light points between 6 & 8)

- ***No. of power sub circuits = No. of power points/2***

Q1. The floor plan of a two storied residential building is shown in figure. Calculate the number of light, fan, socket & exhaust fan points required for the building as per NEC guidelines. Also find out the total connected load, number of sub circuits, size of distribution board, type of supply.

Identifying loads

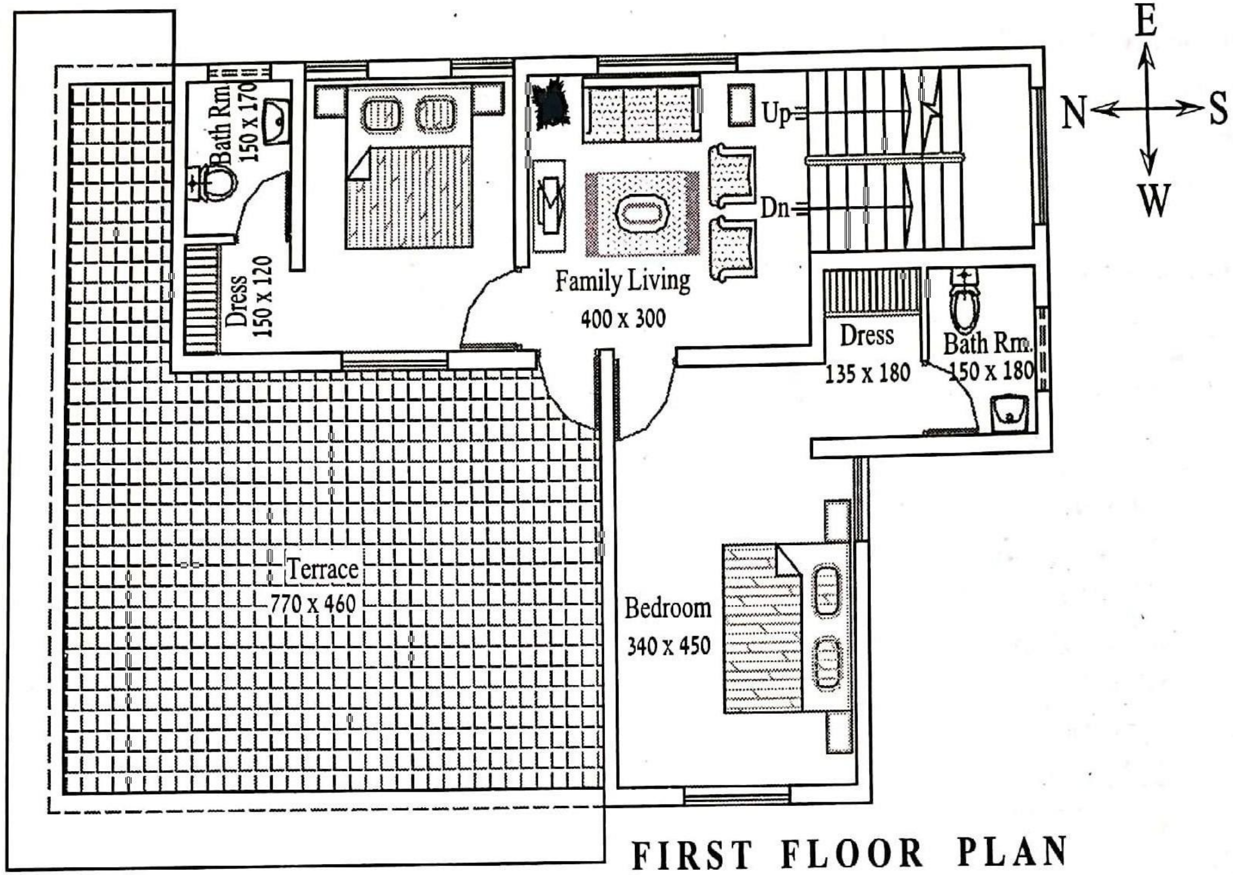
- The number of light, fan & socket points required as per NEC guidelines for each area is tabulated in the table



GROUND FLOOR PLAN

Area - 105 m²

TOTAL AREA - 168 m²



FIRST FLOOR PLAN

Area - 63 m²

SCALE = 1 : 100

Details of light, fan & socket points

Sl. No.	Room space	1x40W	WB	CF	6A	16/6A	EF	Others
1	Bedroom + dressing (3)	1x3	(2+1)3	1x3	3x3	1x3		
2	Living room (2)	1x2	2x2	1x2	3x2	1x2		
3	Dining room	1	1	1	2	1		
4	Kitchen	1	1	1	2	3	1	
5	Verandah/sit out		1					
6	Toilets (3)		1x3		1x3	1	1x3	
7	Store		1					
8	Work area		1			1		
9	Peripheral lights							Bulkhead - 3
10	Car porch		1		1			
	Total points	7	22	7	21	11	4	3

- 1x40W : 40W fluorescent fixtures
- WB : Wall Bracket with 11/15W CFL
- CF : Ceiling fans (1200mm/1500mm)
- 6A : 6A socket points
- 16/6A : 16/6A power socket points
- EF: 220/300mm fresh air fans

Calculate connected load

- Calculate the total connected load by considering the wattage ratings as per NEC

Total connected load = 7 x 50 + 22 x 15 + 7 x 60 +21 x 100 + 11 x 1000 +4 x 60 + 3 x 15

= 14485W

- As per existing norms, a connected load of 14485W will require 3 phase supply from distribution system.
- ***The type of supply corresponding to different ranges of connected load*** is given in table

Supply voltage V	Max. connected load kW/kVA	Max. contract demand kVA
240, 1-phase	5 kW	
415, 3-phase	100 kVA	
11,000		3000
22,000/33000		6000
66,000		8000
1,10,000		20,000
2,20,000		>20,000

- The maximum demand (assuming a diversity factor of 2.5) = 14485/2.5 = 5794W

Deciding the number of sub circuits

- The number of light points = light + fan + 6A socket + exhaust fan + other points

  = 7 + 22 + 7 + 21 + 4 + 3 = 64 points

- The number of light sub circuits = 64/6 = 10.67 ≈ 11
- The number of power points = 11
- The number of power sub circuits = 11/2 = 5.5 ≈ 6
- The total number of sub circuits = 11 + 6 = 17

Distribution board

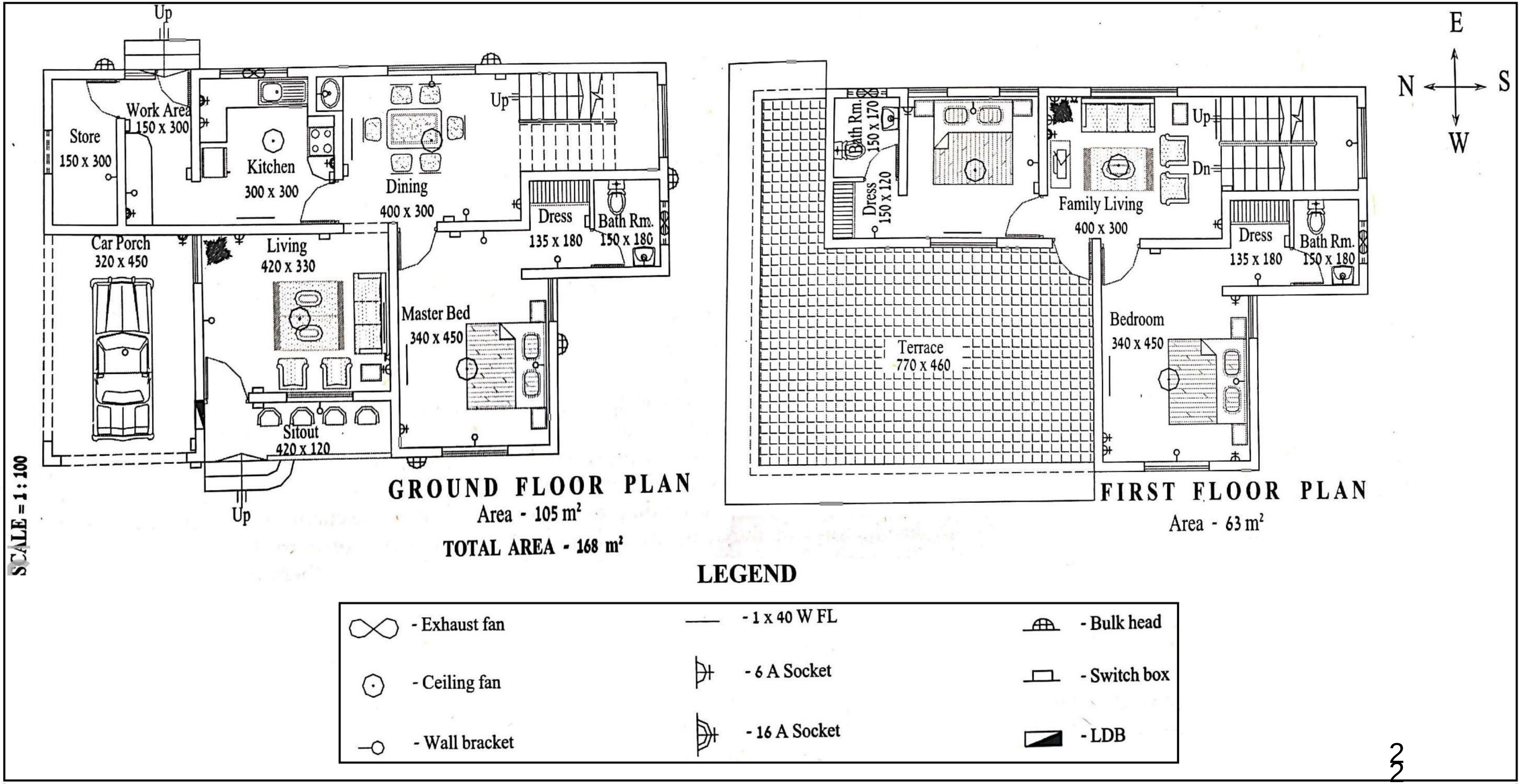
- A 3 phase 8 way MCB distribution board will provide 24 sub circuits of which 17 can be used now & remaining 7 can be used as spare capacity for future extension
- The distribution board may be single door (IP20) or double door (IP42)

MCB/ELCB

- Incomer : 25A, 4 pole, RCBO, 415V with 30mA sensitivity
- Outgoing : 6A, single pole MCB with B curve – 11 Nos (for light sub circuits)

  16A, single pole MCB with C curve- 6 Nos (for power sub circuits)

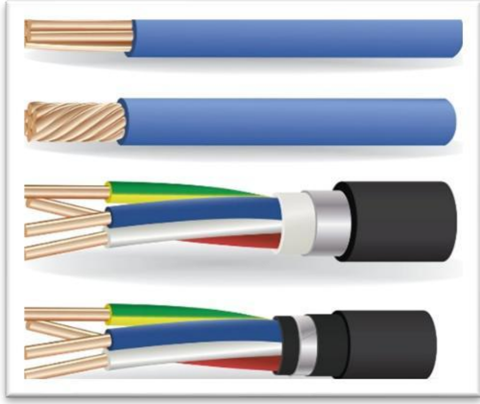
- The plan layout showing location of electrical points is shown below



Differences between a wire & a cable

Wire : Any conductor which is composed of a conducting material & is uniform in diameter & circular in cross section is called a wire

Cable : A length of a single insulated conductor (solid/stranded) or two or more such conductors, each provided with its own insulation which are laid up together is called a cable



- The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering
- In short, any conductor which is provided with insulation is called a cable

Selection of conductor size

- All conductors used for domestic installations shall be PVC insulated copper or aluminium cable
- The conductors used for final sub circuits for ***light & fans*** shall not be less than ***1 mm^2 copper or 1.5 mm^2 aluminium***
- The cross sectional area of ***power sub circuits*** shall not be less than ***2.5 mm^2 copper or 4 mm^2 aluminium***
- The minimum cross section of flexible chord shall not be less than 0.5mm^2 copper

Determination of size of conductor

- There are 3 points which must be taken into account while determining the size of conductor for internal wiring

i) Minimum size of cable (mainly for mechanical reasons)

- According to the regulations in our country, the minimum size of conductor must not be less than 1/1.12mm in copper or 1/1.4mm (1.5mm^2) in aluminium wire

ii) Current carrying capacity

- The wire or cable should be of size sufficient to carry the maximum circuit current continuously without overheating
- Current carrying capacity depends on cross sectional area, resistance of conductor, rate of heat dissipation, type of insulation etc.

iii) Voltage drop

- The maximum voltage drop from supply terminal to any point on the installation is not to exceed the prescribed limit of 2% of supply voltage plus 1V for light load wiring & 5% of supply voltage for power load wiring

Determination of size of conductor for a sub circuit

- The size of conductor to be used in a sub circuit can be ***calculated by knowing the total current in that sub circuit***
- Consider the example of a sub circuit containing 4 light points, 1 fan point & two 6A plug point
- Total connected load in the sub circuit = 4*9 + 1*60 + 2*100 = 296W
- Assuming the voltage = 230V and power factor 0.8, current in the sub circuit = 296/(230*0.8)
- = 1.6 A
- A Copper conductor having a cross sectional area of 1mm^2 can carry a current of 5A safely.
- So for the above sub circuit a conductor having a cross sectional area of 1mm^2 is sufficient

Selection of switches & sockets

- Switches are the most frequently used item in the domestic wiring
- The reliability & useful life are the main features in selecting the switches
- 6A switches are normally used in light, fan and light socket points
- 16A switches are used for power socket points
- Switches with higher ratings may be necessary for controlling room air conditioners, water heaters & cooking ranges with capacity above 2000W
- Switches are generally classified ***as tumbler, flush, plate & modular*** types
- Tumbler type switches are now obsolete & were used in CTS wiring systems
- Flush type switches are cheap & reliable and have good service life. They are mounted on hylam or acrylic sheets
- Plate type switches & sockets are costlier
- Modular switches & sockets are now very popular. Their sizes are standardized in multiples of modules. They are very aesthetic & reliable

Distribution board (DB)

- A distribution board is a panel or enclosure that houses the fuses, circuit breakers, and ground leakage protection units used to distribute electrical power to numerous individual circuits or consumer points.
- In case of large buildings, there is a Main Distribution Board (MDB), Sub Distribution Boards (SDB) & Final Distribution Boards (FDB)
- They are manufactured from high-quality materials and contain the latest safety features.

Main Distribution Board (MDB)

- A MDB is a panel or enclosure that houses the fuses, circuit breakers, and ground leakage protection units used to distribute electrical power to numerous individual circuits or consumer points and to SDBs & FDBs
- This board typically has a single incoming power source and includes a main circuit breaker and a residual current or earth leakage protection device.
- The supply to a building from service provider first comes to main distribution board. From main DB supply goes to different sub circuits & also to sub/final distribution boards

Sub Distribution Boards (SDB)

- Sub-distribution boards are generally installed between the main distribution boards and the final distribution boards.

- A SDB is a panel or enclosure that houses the fuses, circuit breakers, and ground leakage protection units used to distribute electrical power to numerous individual circuits or consumer points and to FDBs
- Sub-distribution boards offer the right low voltage (LV) solution for large buildings by dividing the electrical power feed into subsidiary circuits.

Final Distribution Boards

- From final distribution boards supply goes to different loads through sub circuits.
- FDB receive power from MDB/SDB
- A FDB is a panel or enclosure that houses the fuses, circuit breakers, and ground leakage protection units used to distribute electrical power to numerous individual circuits or consumer points

Determination of ratings of Distribution board

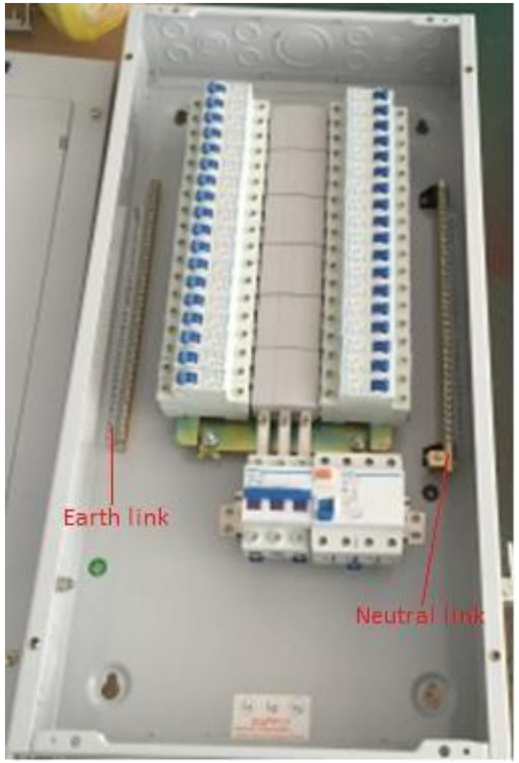
- The single line diagram of the installation will give a clear indication about the number of sub circuits & load on each sub circuit
- By using the above data the current rating of different equipment to be connected in DB & size of DB (number of ways) can be determined

- DBs are sheet metal enclosed & generally available in 32A-63A (single phase) & 63A-250A (3 phase)
- The internal of DB is pre fitted with a clip tray/DIN rail for mounting the MCBs & other devices
- The distribution board may be single door (IP20) or double door (IP42)

Single door DB
1 phase 8 way

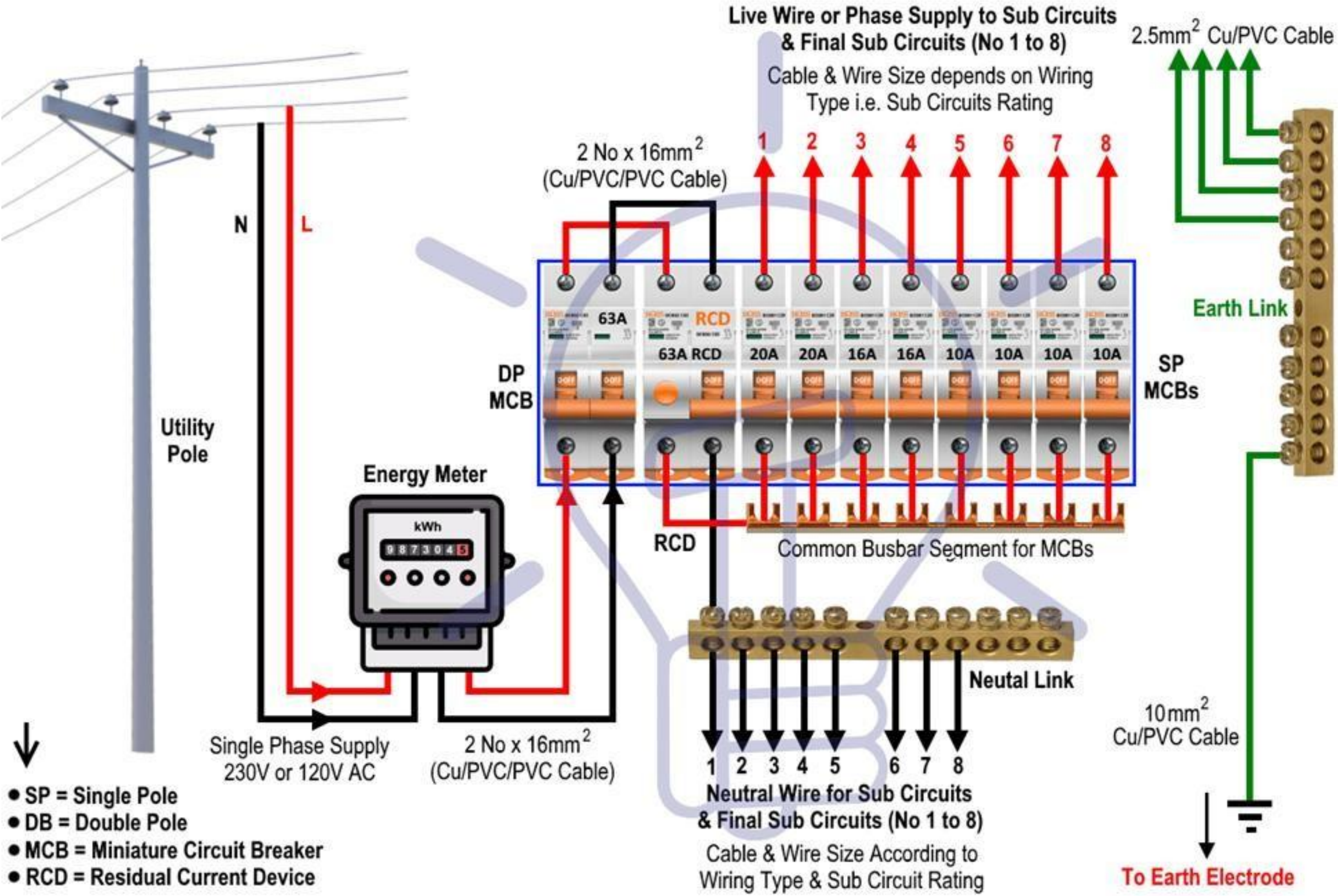
Double door DB
1 phase 8 way

3 phase 8 way TPN Double door (Horizontal)



3 phase 12 way TP DB (Vertical)

Copper bus bar



Wiring of the Distribution Board with RCD (Single Phase Supply)

(From Utility Pole & Energy Meter to the Consumer Unit)

Three Phase Electrical Wiring Installation in a Home

3-Phase Consumer Unit Installation from Utility Pole & 3-Phase Energy Meter to 3 Phase Distribution Board

Multi Distribution System

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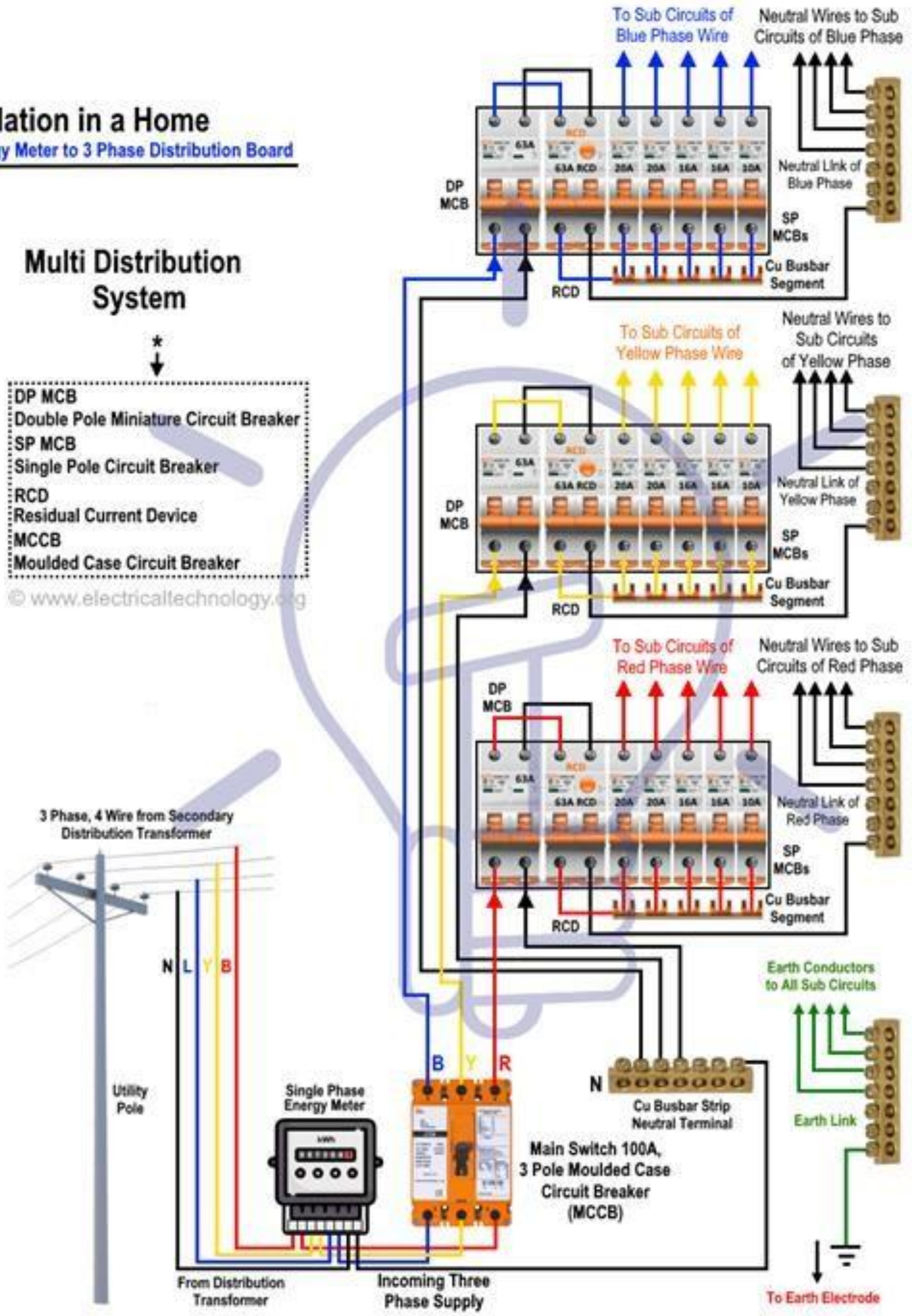
DP MCB
Double Pole Miniature Circuit Breaker
SP MCB
Single Pole Circuit Breaker
RCD
Residual Current Device
MCCB
Moulded Case Circuit Breaker



Isolator

- An isolator performs the function of a main switch
- It connect/disconnect the circuit on which it is connected to the main supply
- It can be manually operated to disconnect supply to the circuit for conducting some maintenance
- It trips automatically under over current
- In domestic installations, the mains supply enters into the DB through an isolator
- Three types of isolators are available : 2 pole (1 phase application), 3 pole & 4 pole (3 phase applications)

Rating

- Number of poles (2P, 3P, 4P)
- Rated current in A
- Rated voltage in Volts
- Protection class (IP20, IP65 etc)

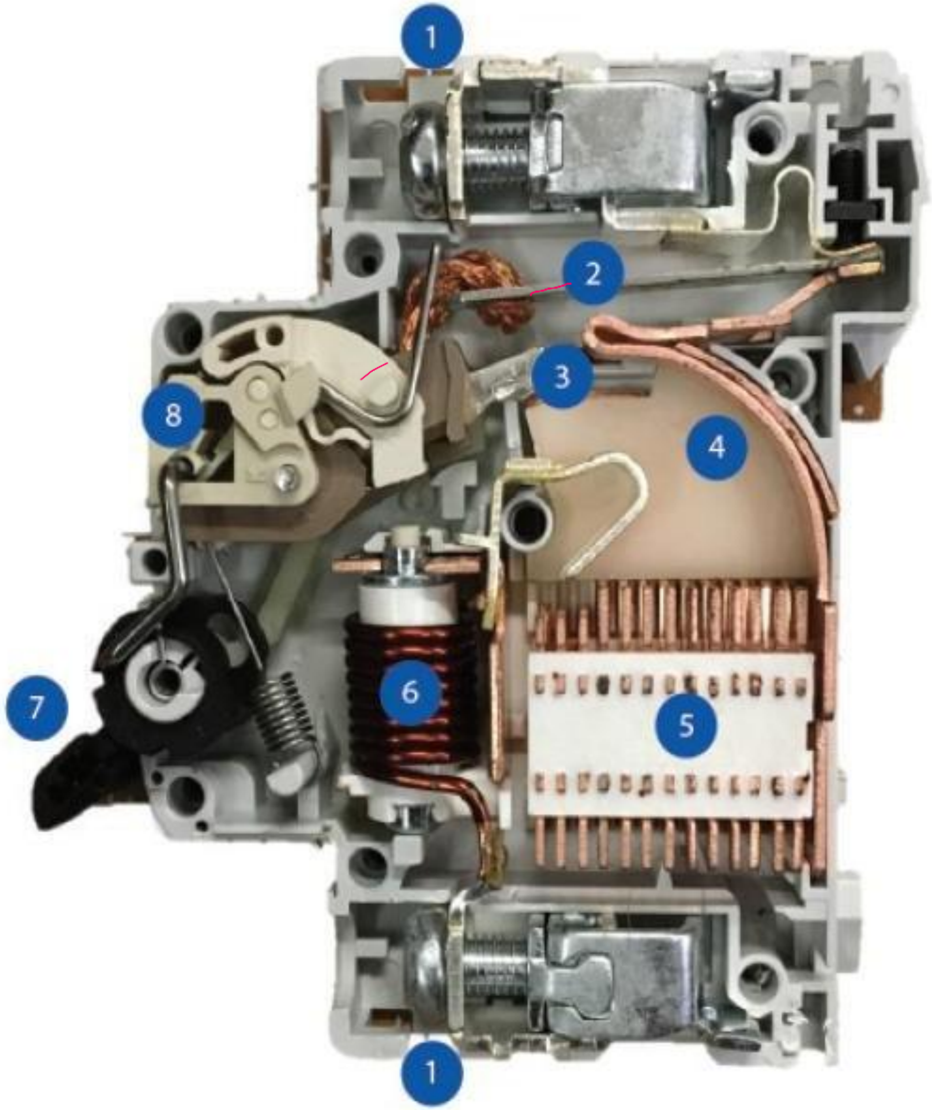
Miniature Circuit Breaker (MCB)

- MCBs are electromechanical circuit protective devices with molded insulating enclosure
- MCB automatically switches OFF electrical circuit during any abnormal condition in the electrical network such as overload & short circuit conditions so as to avoid any kind of fire or electrical hazards.
- A fuse may sense these conditions & provide protection, but it has to be replaced.
- But MCB can be reset very fast & don’t have any maintenance cost
- Handling MCB is quite safer and it quickly restores the supply.
- In domestic installations, MCB is provided in each sub circuit to ensure safety & to isolate each circuit for maintenance purpose

Rating

- ➢ Rated current : It is the current value (in A) above which overload protection is tripped
- ➢ Ultimate short circuit breaking capacity : It is the highest fault current (in kA) that the MCB can trip without being damaged permanently.
- ➢ Rated voltage
- ➢ Number of poles (1P, 2P, 3P, 3PN)
- ➢ Application type : type B/C/D

Internal structure of MCB



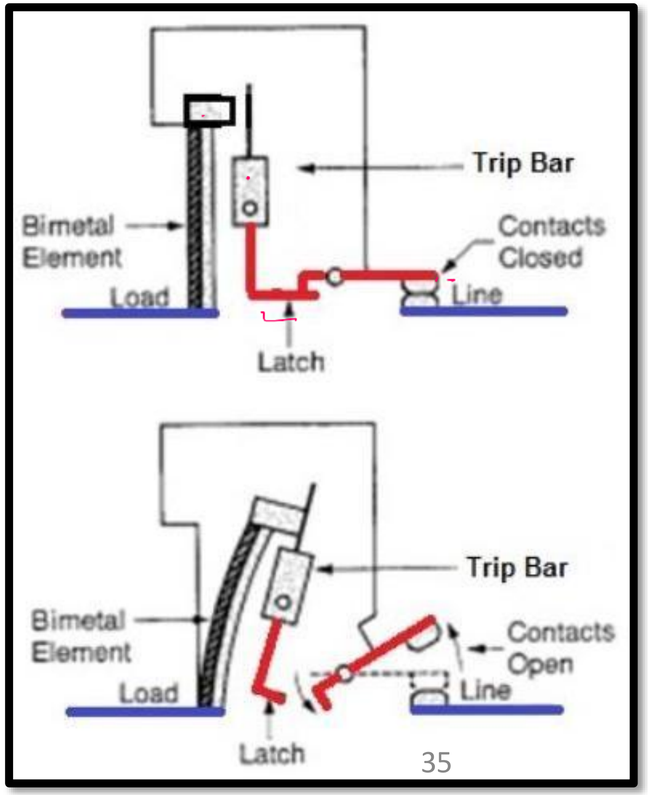
1. Terminal for line/load power.
2. Bi-metallic strip. Bends with heat (current), separates contacts in response to smaller, longer term over currents, tripping breaker.
3. Contacts. Current flows through when closed. Breaks current when separated.
4. Arc Chamber. Channels plasma arcing to arc divider.
5. Arc divider/extinguisher. Breaks main arc into smaller arcs and extinguishes them.
6. Coil/Solenoid. Separates contacts in response to high overcurrents, such as a short circuit.
7. Actuator lever. Manually trips or resets breaker.
8. Actuator mechanism. Forces contacts together or apart.

Working

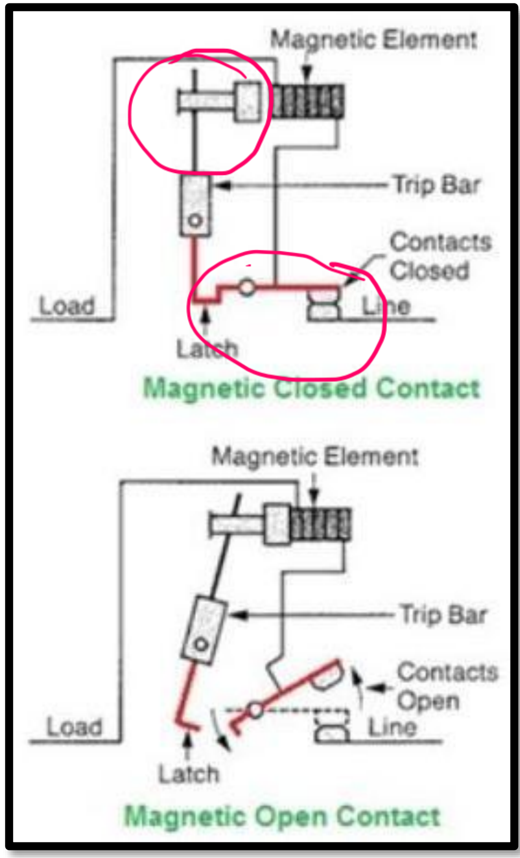
- Under normal operation, MCB operates as a switch (manual one) to make the circuit ON & OFF
- Under overload or short circuit condition, it automatically operates so that the current in the circuit interrupts and the circuit is protected
- The automatic operation of MCB is obtained in two ways : magnetic tripping & thermal tripping

Thermal tripping - using bimetallic strip

- The bi-metallic strip provides overload protection in response to smaller over currents, typically 10X the operating current.
- The metallic strip consists of two strips of different metals, formed together, which expand at different rates as they are heated.
- Under overload/short circuit condition, the current through bimetallic strip causes a raise in temperature in it
- As a result the bimetallic strip bends and this movement actuates a trip mechanism and breaks (opens) the circuit.
- The strip converts a temperature change into mechanical displacement to protect the circuit



Magnetic tripping – using solenoid



- With normal current, the electromagnet will not have enough electromagnetic field to attraction the trip bar for movement and the contacts will remain closed.
- As High current (Short Circuit) current through the coil increases the strength of the magnetic field of the electromagnet. As soon as the current in the circuit becomes large enough, the trip bar is pulled toward the magnetic element (electromagnet), the contacts are opened and the current stops.
- The amount of current needed to trip the MCB depends on the size of the gap between the trip bar and the magnetic element.
- On some MCB this gap (trip current) are fixed and some MCB are adjustable.

- MCBs are available with rated current upto 125A
- The trip characteristics are normally not adjustable
- The operation may be thermal or thermal-magnetic operation

Types of MCBs : Several different MCB types are available – types A, B, C, D, K, and Z. However, the three key versions are type B, type C, and type D

Type B - devices are designed to trip at fault currents of 3-5 times rated current (I_n). These devices are generally suitable for domestic applications.

Type C - devices are designed to trip at 5-10 times rated current. These devices are the normal choice for domestic applications & electromagnetic starting loads with medium starting currents

Type D - devices are designed to trip at 10-20 times rated current. These devices have more limited applications ad suitable for inductive & motor loads with high starting currents

Advantages of MCB

- MCBs act fast against short circuit, overloading compared to fuse
- MCBs are more reliable, tamper proof & modular in design
- With MCB, it is simple to resume the supply
- It has less maintenance & replacement compared to fuse
- It can perform the function of a switch & protective device

Disadvantages of MCB

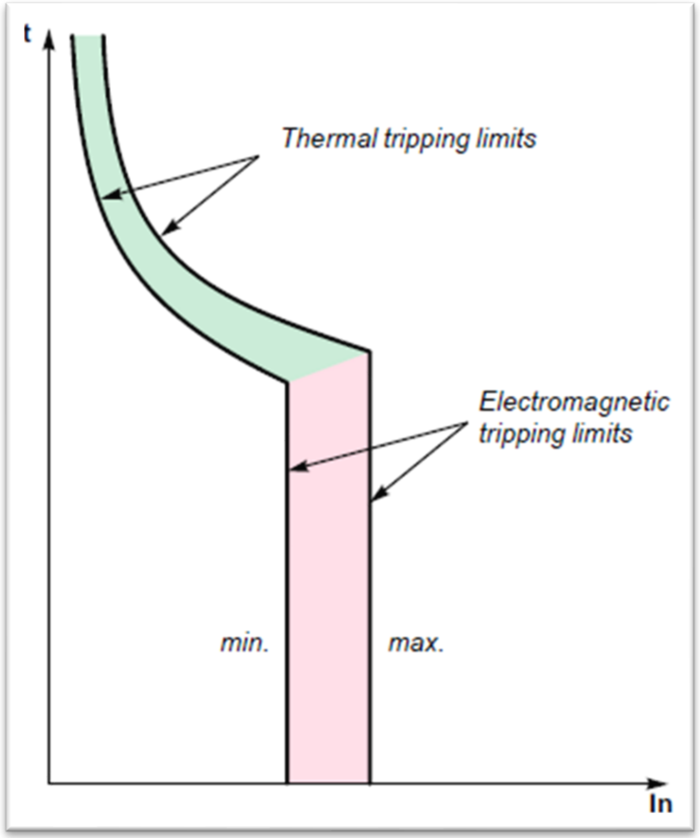
- Cost of MCB is greater than fuse
- Cost of MCB distribution board is greater than rewireable fuse board

MCB trip characteristics

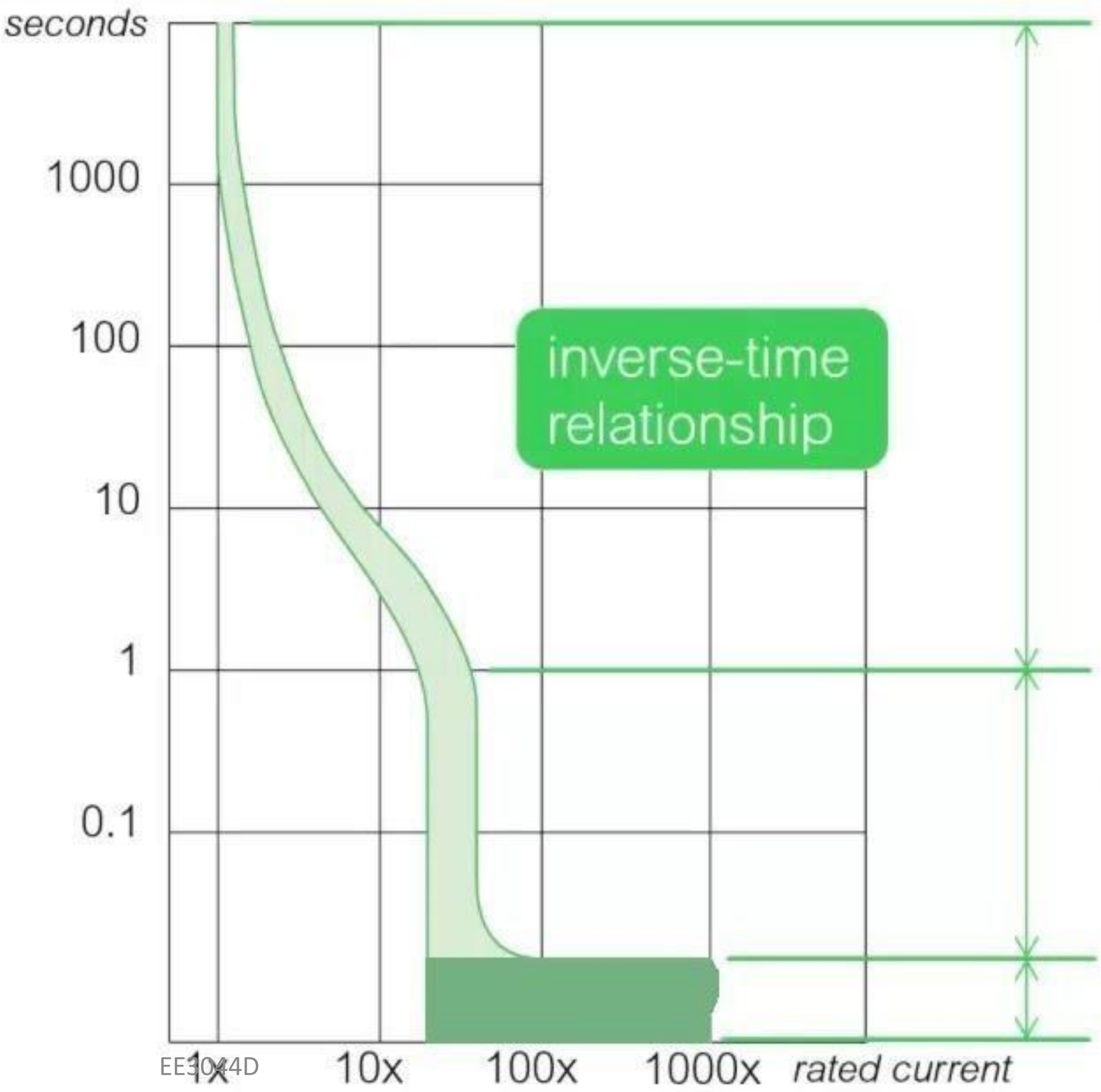
- The MCB trip curves, also known as I-t tripping characteristic consist of two sections viz, overload section and short circuit section.
- Overload section describes the trip time required for various levels of overload currents and the short circuit section describes the instantaneous trip current level of MCB

Importance of MCB trip curves

- It is important to choose an appropriate MCB rating and trip curve in order to safeguard the circuit from damages during faults.
- Hence it is necessary to calculate the short circuit current and inrush current before choosing an appropriate MCB rating.
- If the chosen MCB rating is much higher than required, then it may not trip on the event of a fault.
- Similarly, if the MCB is underrated, then it may cause nuisance trips, for example even the starting currents or inrush currents may trip the MCB.



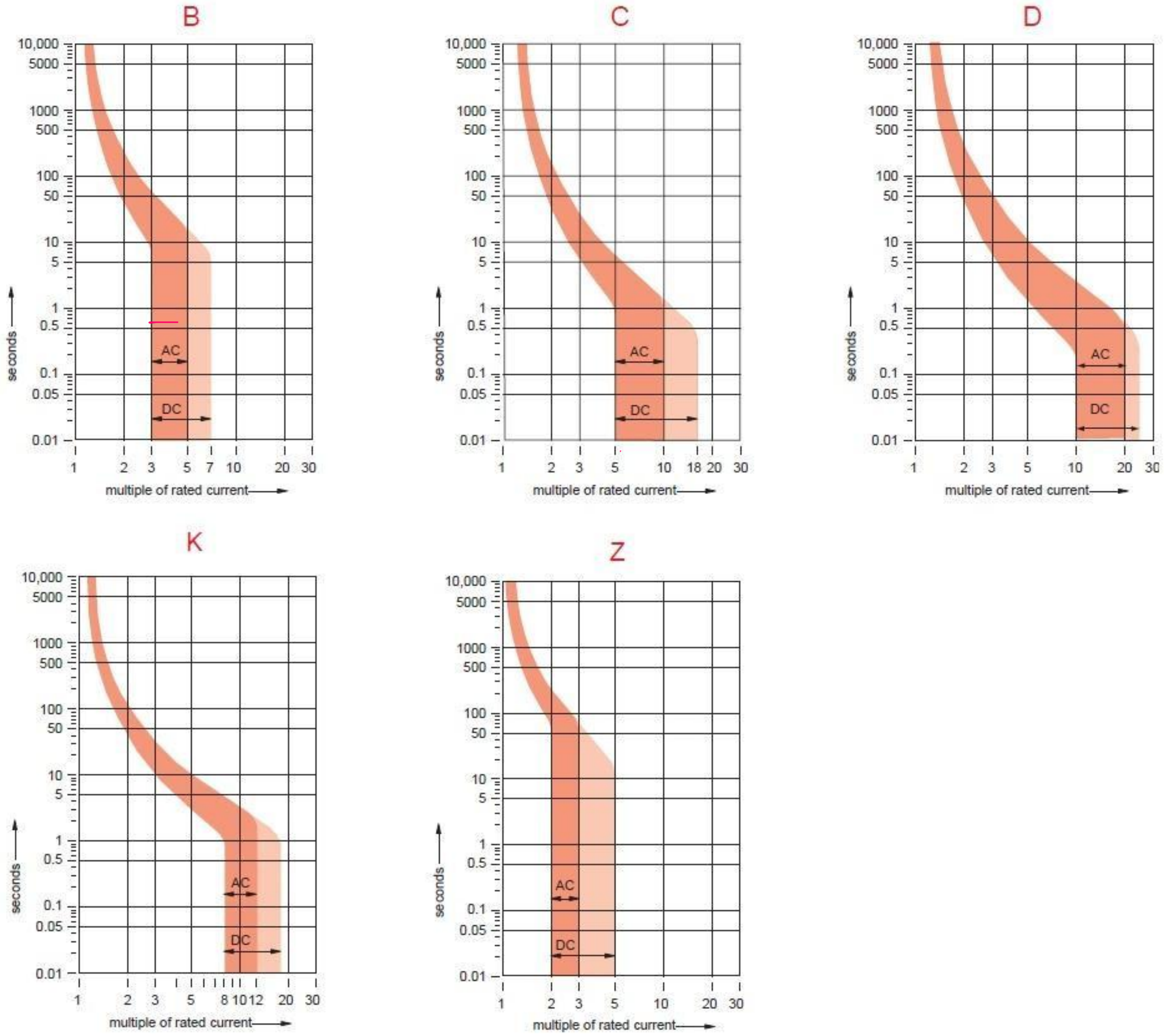
Reading the Time Current Curve



Long Time Trip Values
Response to overload (or over-current)

Short Time Trip Values
Response to short-circuit

Instantaneous Trip Values
Response to short-circuit


B
C
D
K
Z
10,000
5000
1000
500
100
50
10
5
1
0.5
0.1
0.05
0.01
seconds
AC
DC
1 2 3 5 7 10 20 30
1 2 3 5 10 18 20 30
1 2 3 5 10 20 30
1 2 3 5 8 10 12 20 30
multiple of rated current

Moulded Case Circuit Breaker (MCCB)

- MCCB are electromechanical devices which protect a circuit from over current & short circuit
- The MCCB provides protection against overload, short circuit faults and is also used for switching the circuits.
- The wide current ratings and high breaking capacity in MCCB find their use in industrial applications.
- They provide over current & short circuit protection for circuits with current ranging from 32A to 3000A
- MCCB can be used for protection of capacitor bank, generator protection and main electric feeder distribution.
- It is an alternative to fuse to provide protection against over current.
- Also, it can be easily reset after a fault
- MCCBs generally have a thermal element for over current protection & short circuit release which has to operate faster
- MCCBs are manufactured such that end user will not have access to internal workings of device

Operation

- MCCBs are now available with a variety of releases or operating mechanisms. They are

1. Thermal magnetic release MCCB

- These MCCBs use bimetallic strip (thermal element) and electromagnetic assemblies (magnetic element) to provide over current protection
- Working of this type of MCCBs are similar to working of MCBs
- Large MCCBs have adjustable range setting
- The adjustable overload protection is from 70% to 100% of nominal current
- One disadvantage of this type is that the operating characteristics may vary depending on ambient temperature

2. Electronic release MCCB

- This type use power electronic circuitry to provide over current protection
- Here the operating characteristics are independent of ambient temperature
- It has adjustable over load protection from 60% to 100% of nominal current

3. Microprocessor release MCCB

- Here microprocessors are used to provide over current protection

- This system works by monitoring the true rms value of current
- The microprocessor will calculate it from peak values of current
- It has high accuracy & reliability
- System diagnosis is possible as it stores the trip history within the internal memory

Specifications of MCCB

- Current rating (A)
- Short circuit rating (kA)
- Current setting range (A)
- Operating characteristics

Comparison of MCB & MCCB

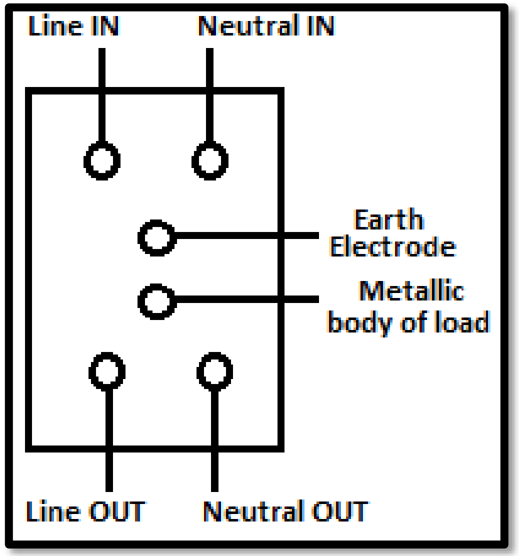
MCB	MCCB
Miniature Circuit Breaker	Molded Case Circuit Breaker
Low voltage circuit breaker	Low voltage circuit breaker
Basic circuit breaker for household applications	Used in commercial & industrial applications
Low current rating (0.5 to 63A)	High current rating (as high as 2500A)
Trip characteristics are not adjustable	Trip characteristics can be adjusted
Provide protection against over current & short circuit	Provide protection against over current, short circuit and additionally it can be designed to respond to earth faults & residual current
Remote control operation is not possible	Remote control operation is possible

Earth Leakage Circuit Breaker (ELCB)

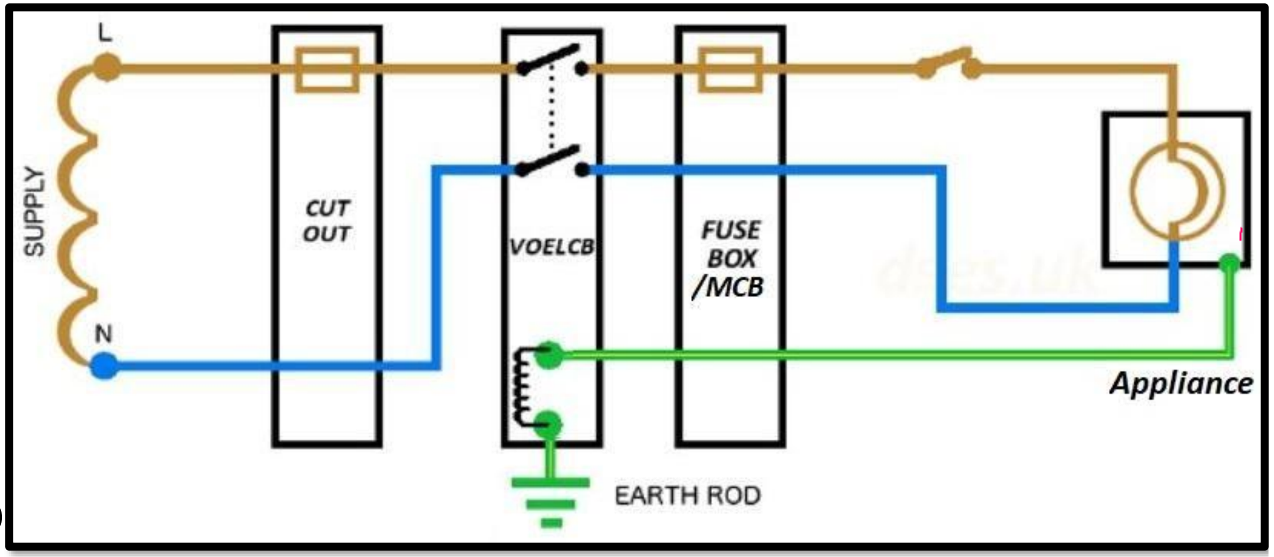
- ELCB detects directly the current leaking to the earth from a load device or installation.
- The main purpose of the device is to prevent damages and injuries due to electric shocks.
- Generally, ELCB works by using the magnetic effect of electric current.
- There are two different types of Earth Leakage Circuit Breakers,
  - ➢ Voltage Operated Earth Leakage Circuit Breaker (Generally known as ELCB)
  - ➢ Current Operated Earth Leakage Circuit Breaker (Generally known as RCD/RCCB)

Voltage Operated Earth Leakage Circuit Breaker (VOELCB)

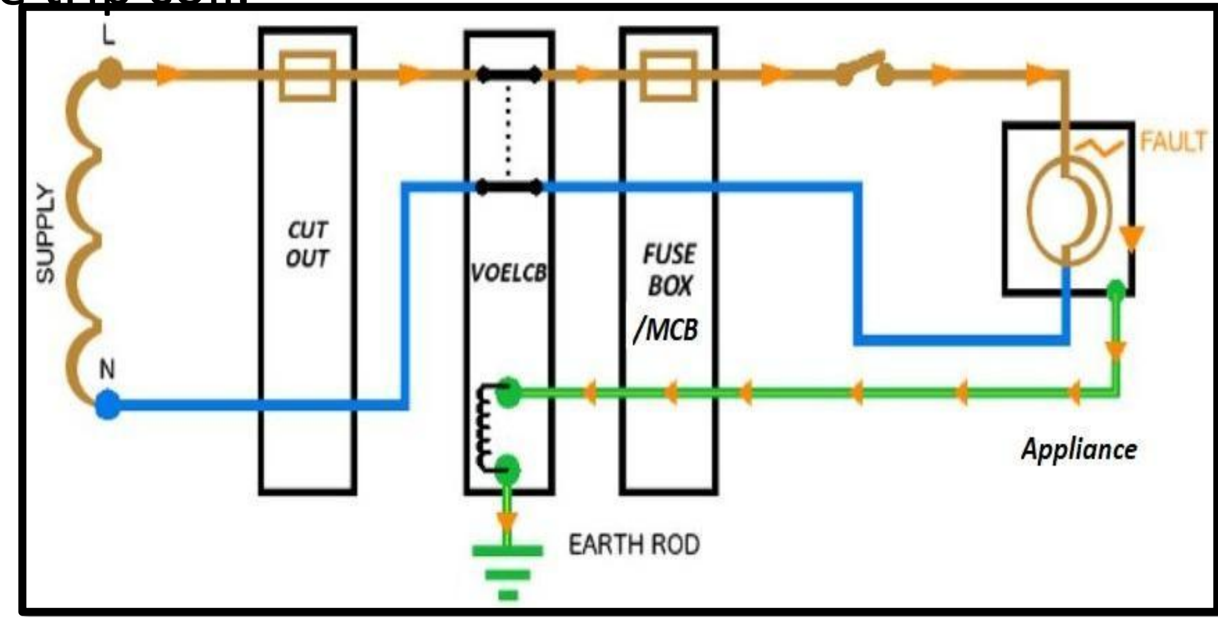
- This device uses detection of a voltage to identify earth leakage
- It has 6 terminals, namely line IN, line OUT, neutral IN, neutral OUT, earth & load (metallic body)
- Voltage Operate ELCB contains a relay coil or ELCB coil.
- One end of the ELCB coil is given connection to the metallic body of load and the other end to the earth electrode.



- The connection of VOELCB is shown in fig.
- Under normal operation, the load's body is isolated from the supply line
- So the current flowing through the ELCB coil is zero
- When an earth fault occur on the load due to interaction of phase wire to metallic body of load, a current will run through the ELCB coil to ground

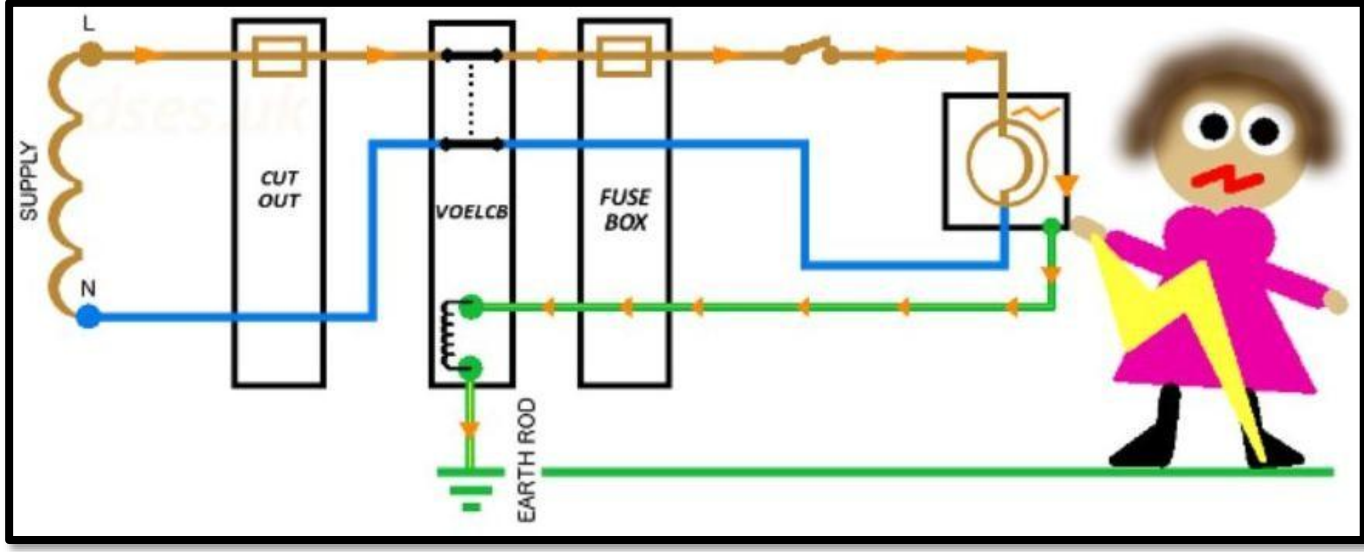


- This flow of current will set up a voltage across the trip coil.
- As ELCB coil gets energized, it will turn ELCB to OFF position & the supply to the appliance is cut off
- Thus it will ensure safety of user & equipment
- The VOELCB will operate when the voltage across ELCB coil increases to around 50 V



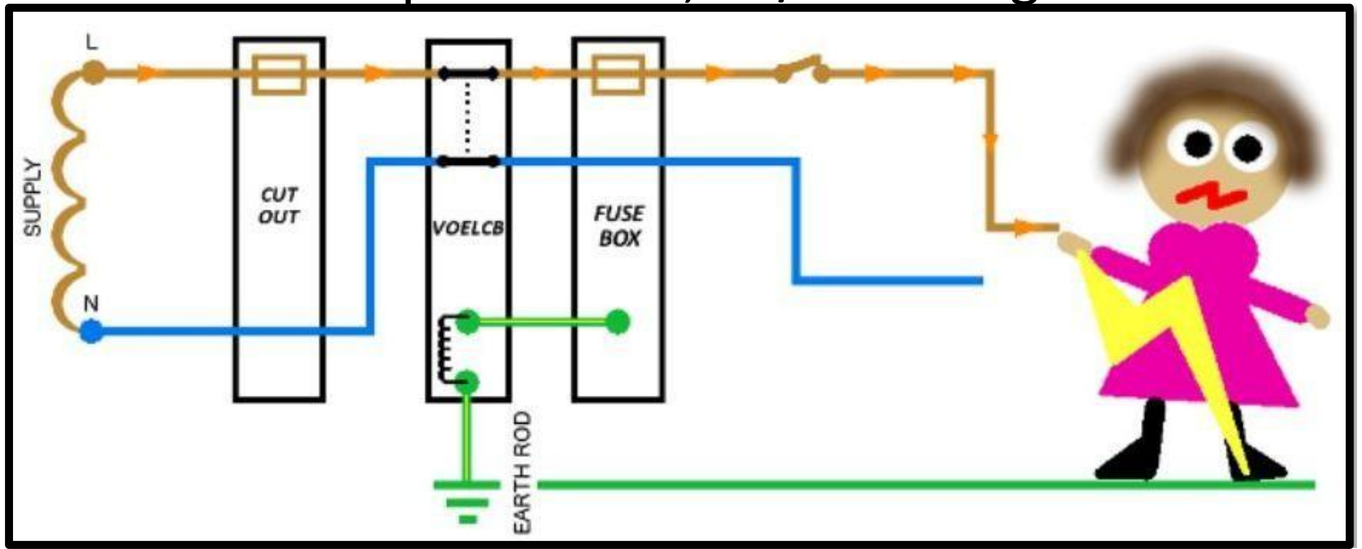
Drawbacks of VOELCB

- The VOELCB is not common in use because it wont give protection under the following cases



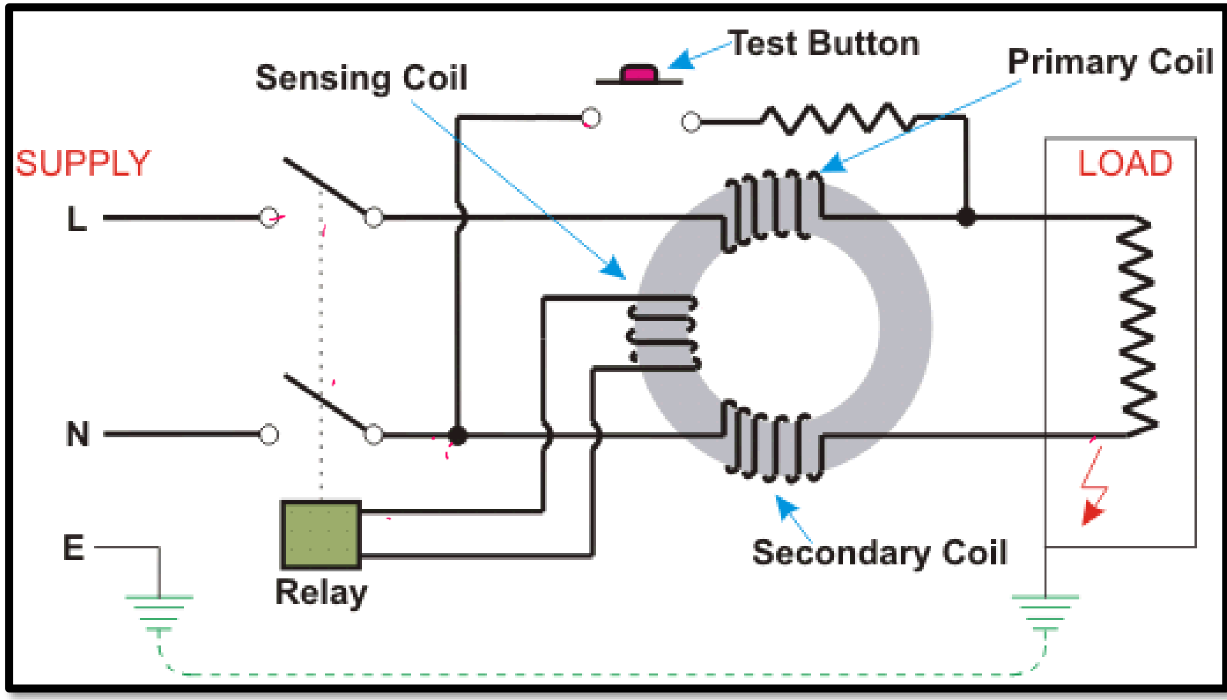
Case 1 : Under faulty condition, if the user touches the device, there are 2 paths for the current to ground. One through earth wire & other through the users body. VOELCB will operate when voltage across coil increase to around 50V. Before that, the user will get a shock and some current will flow through the users body. A current greater than 30mA is harmful for the user & will result in shock

Case 2 : Accidentally if the user come in contact with the live phase wire, he/she will get an electric shock. Under this condition, the VOELCB wont operate as the ELCB coil is not energized. The only protection that will operate in this case is fuse/MCB due to over current



Current Operated Earth Leakage Circuit Breaker

- It is also known as **RCCB** (Residual current Circuit Breaker) or **RCD** (Residual Current Device)
- It consist of a 3 winding transformer that has 2 primary windings & one secondary winding
- Phase & neutral wires work as the two primary windings
- The sensing coil forms the secondary winding
- The circuit diagram is shown in figure



Working

- Under stable operation, the current through the phase & neutral wire are same.
- So the flux produced by them in the core gets cancelled each other & voltage induced in sensing coil is 0
- When a fault occur (i.e, when current flows to earth through the operators body or through earth wire), the phase & neutral current become different & a voltage induces in sensing coil
- The sensing coil is connected to a relay & it operates whenever the sensing coil is energized
- The relay determines the sensitivity of the ELCB. Normally COELCB operates when leakage current increases above 30mA

Test circuit

- Test circuit is provided to test the reliability of RCCB
- The test circuit is always included with the RCD which basically connects the line conductor on the load side and the supply neutral through a test button & resistor
- Whenever the test button is pushed, current starts flowing through the test circuit depending upon the resistance provided in this circuit.
- This current passes through the RCD line side coil & bypasses neutral side coil of RCD
- So there will be an unbalance between the line side and neutral side coil of the device and consequently, the RCCB trips to disconnect the supply even in normal condition.

RCBO (Residual Current Breaker with Overcurrent protection)

- As the name suggests it protects against two types of fault
- It combines the functionality of an MCB and RCD.
- It gives protection against Earth leakage, over current & short circuit

Advantages of ELCB

- Only have phase & neutral connections
- Avoid nuisance trips
- Cheap & efficient
- RCBOs provide better performance
- It protects humans & animals from shock

Comparison between MCB & ELCB

MCB	ELCB
Miniature Circuit Breaker	Earth Leakage Circuit Breaker
Provides protection against over current & short circuit	Provides protection against earth fault (RCBO provides protection against over current, short circuit also)
Replacement of Fuse	Protection for humans & animals from shock
Reliability can't be checked	Reliability can be checked by using test circuit
Trip characteristics are not adjustable	Trip characteristics are not adjustable
Automatic operation	Automatic operation
Can be operated manually as a switch	Normally, not operated manually

Rating of RCD/RCCB

Rated operating voltage : 240V (1 phase), 415V (3 phase)

Rated current : 10 - 100A

Earth leakage sensitivity : 30mA, 100mA, 300mA, 500mA, 1A

Number of poles : 2 pole (1 phase), 4 pole (3 phase)

Pre commissioning tests of Domestic installations

- Pre commissioning tests are necessary pre requisites under statutory provisions
- It ensures that the installation satisfies all the safety regulations & are meticulously followed in the implementation of the installation
- Further it ensures that
  - Good materials & workmanship have gone into the work
  - The installation is in good working condition
  - Faults if any in the installation are located & remedial measures suggested before energizing the installation
- Therefore every wiring installation shall, on completion & before being energized, be inspected & tested in accordance with the provisions of IS732-89 section V, to verify that the provisions have been satisfied

Methods of pre commissioning tests

- The pre commissioning tests in domestic installation is done in following ways

1. Visual inspection

- A visual inspection is necessary to verify that the installation is
  - ➢ In compliance with the applicable Indian standards specification
  - ➢ Correctly erected in accordance with the relevant code
  - ➢ No visual damage is seen outside

2. Testing

- Testing of the installation is to be carried out in the following sequence

i. Continuity of the final circuit conductors, protective conductors, including the main & supplementary equipotential bonding

ii. Continuity of the protective conductors, including the main & supplementary equipotential bonding

iii. Earth electrode resistance

iv. Insulation resistance

v. Polarity

vi. Earth fault loop impedance

vii. Operation of residual current devices (RCDs)

- Continuity test is to be carried out in all final circuits to make sure that there is no discontinuity in the circuit
- Similarly, every protective conductor also is to be tested separately to make sure that they are electrically sound & are correctly connected
- All protective conductors & extraneous conductive parts used for providing equipotential bonding
- The resistance of the earth electrode is to be measured as per the methods specified in the IS 3043 (code of practice of earthing)

Insulation resistance measurements

- The insulation resistance measurement of large installations are to be carried out by dividing the installation into smaller units, each containing not less than 50 outlets
- The test voltage to be applied for the insulation measurement is selected from the following list
  - For voltages up to 250V - 500V
  - 250 to 500V - 1000V
  - For circuits above 500V - 2500V

- The insulation resistance are to be recorded between

i) Live conductors & earth

- The following steps are involved in the measurement of insulation resistance between conductor & earth

  a) The main switch is positioned in the OFF position

  b) All fuses & MCBs beyond the main switch is in place & ON

  c) All lamps & other accessories are in place

  d) The phase conductor & the neutral conductor are connected together near the main switch (on consumer side)

  e) The insulation resistance between the conductors (phase & neutral conductors connected together) & the earth is measured using the Megohm meter of appropriate voltage class

  f) The measured value of the insulation resistance shall not be less than 1MΩ

ii) Insulation resistance between conductors

The steps involved in the measurement are

a) The main switch is placed in the OFF position

b) The phase & neutral conductors are not connected together

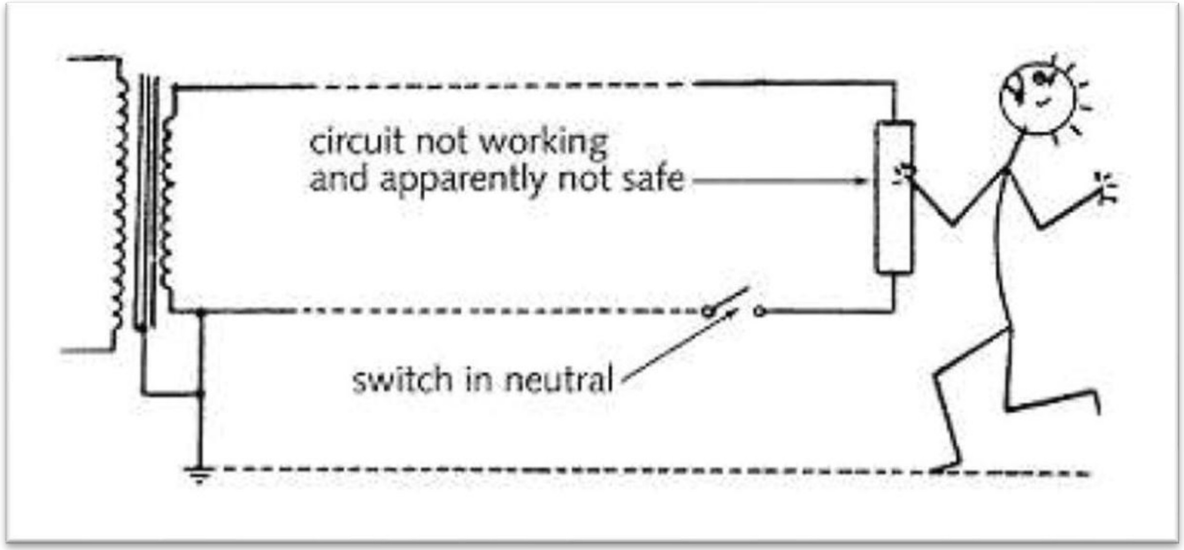
c) All switches are placed in the ON position

d) All lamps & equipment are removed

e) All fuses beyond the main switch on the consumer side are ON

- The insulation resistance is recorded using Megohm meter
- The insulation resistance recorded between any two phase conductors shall not be less than 1MΩ
- If the equipment has exposed conductive parts, the insulation resistance between conductive part & live conductors of equipment shall not be less than 0.5MΩ

Polarity test



- The steps involved in conducting the polarity are
  a) All equipment/apparatus are disconnected
  b) All switch covers are open
  c) Use a test lamp with long leads
  d) Touch one end of the lead to the neutral point
  e) Touch the other lead to the input terminal of switch. If the lamp burns, the polarity is correct. In the case no power supply available for this test, a battery source can also be used

- When protective measures are incorporated in the installation which operates on the principle of leakage currents, the earth fault loop impedance plays an important role in the satisfactory operation of the protective device
- Therefore the earth fault loop impedance shall be measured with the help of standard methods of measuring the loop impedance
- In installations where ***residual current devices*** are mandatory for providing protection against indirect contact, ***the effectiveness of the residual current devices are to be tested by simulating an artificial fault condition on the installation***.
- This testing is independent of any test facility provided on the device by manufacturers

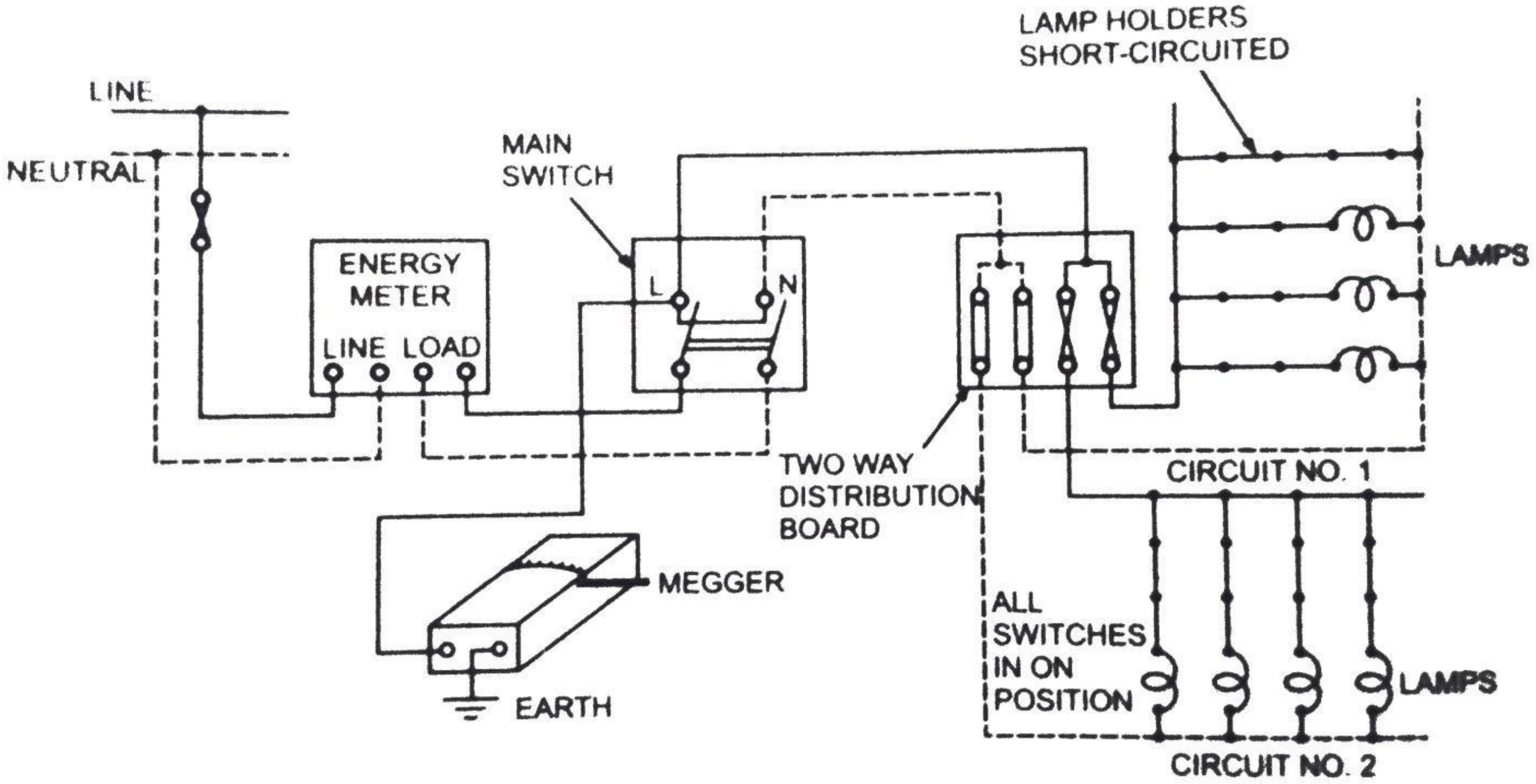
Testing of installations

- Before commencement of supply, a number of tests are to be carried out to ensure the health of the electrical distribution system.
- Testing done as per IS 732(Part III):2019
- Tests to be conducted:
    - Testing of insulation resistance
    - Testing of polarity of single pole switches
    - Test for earth continuity path
    - Testing of earth resistance

Testing of insulation resistance – For wiring installations between earth and conductors

- Aim of test – to know whether the wires/cables used in wiring system are sufficiently insulated to avoid leakage of current.
- Test is performed using DC supply
- Applied voltage should be not less than twice the normal working voltage.
- In MV installations, 500V insulation tester is used
- Before conducting insulation test, one must make sure that:
    - Main switch is in OFF position, energy meter should be disconnected.
    - Main fuse is taken out
    - All other fuses shall be in position
    - All switches are in ON position
    - All lamps are in position or lamp holders are short circuited
    - Line and neutral terminals are shorted on installation side

Testing of insulation resistance – For wiring installations between earth and conductors



Measurement of Insulation Resistance

Testing of insulation resistance – For wiring installations between earth and conductors

- Insulation resistance is measured in mega ohms (MΩ)
- Measured resistance should not be less than 50/(No of outlets).

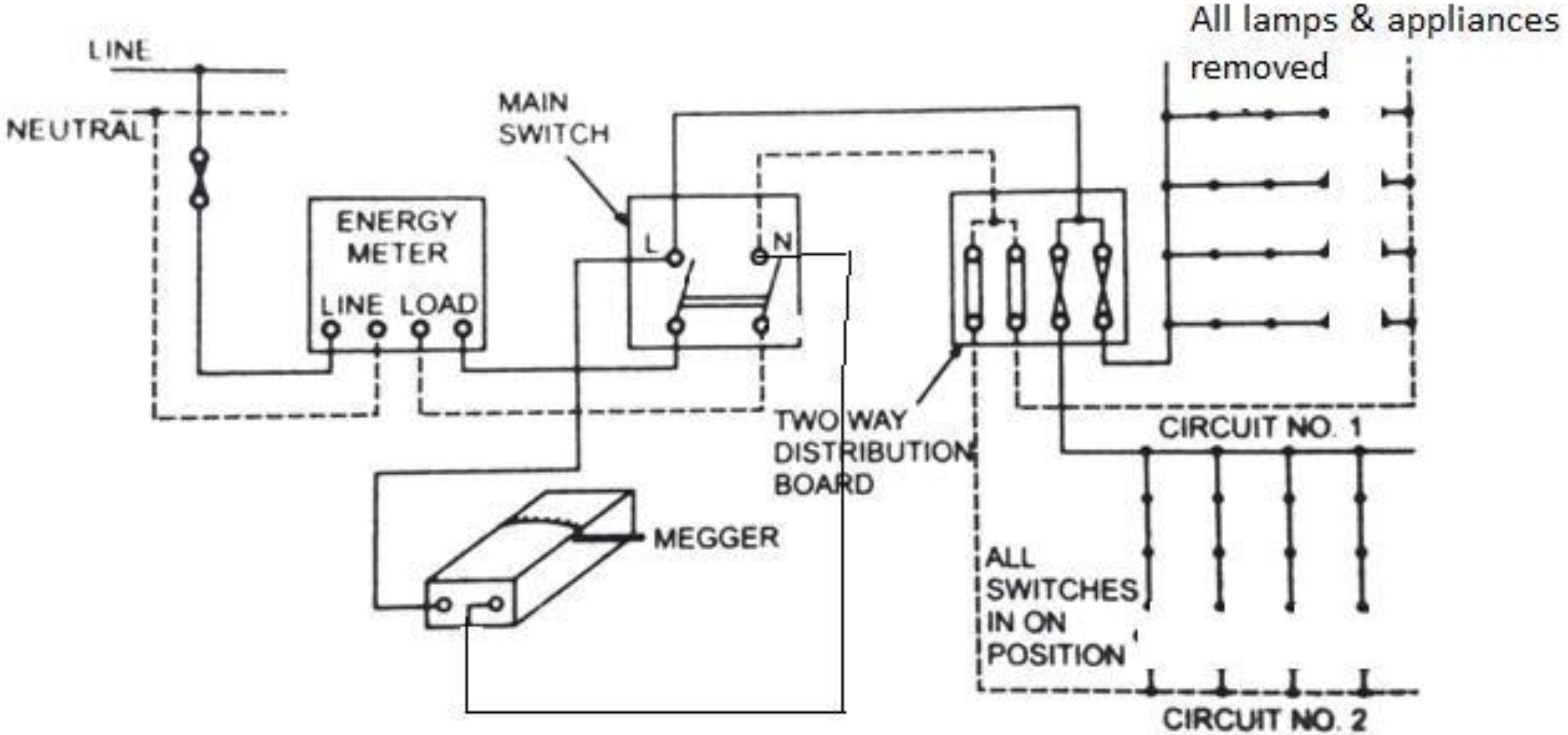
$$Minimum\ IR\ value = \frac{50\ M\Omega}{Number\ of\ outlets}$$

- Insulation resistance value in no case should be less than 0.5MΩ

Testing of insulation resistance – For wiring installations between conductors

- Insulation resistance to be measured
    - Between phases (for polyphase circuits)
    - Between phase and neutral
- Aim of test – to ensure insulation strength between two conductors is sound, thereby avoiding electric leakage
- Conditions to be satisfied is almost similar to previous one, except
    - The looping in the main switch are removed
    - All lamps and all metallic connections between two wires of installations are removed from lamp holders

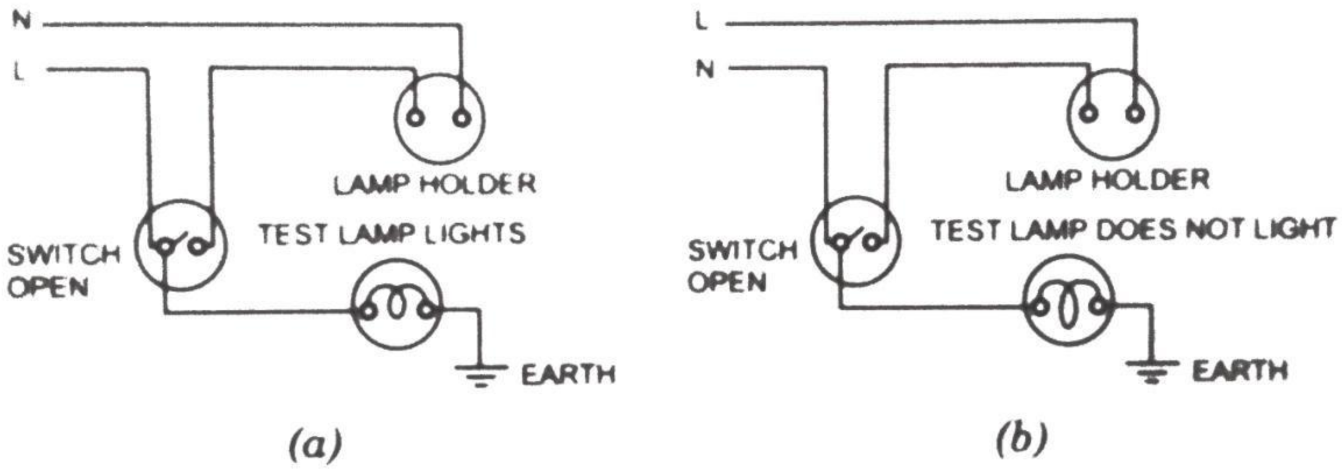
Testing of insulation resistance – For wiring installations between conductors



Measurement of Insulation Resistance

Testing polarity of Single-pole switches

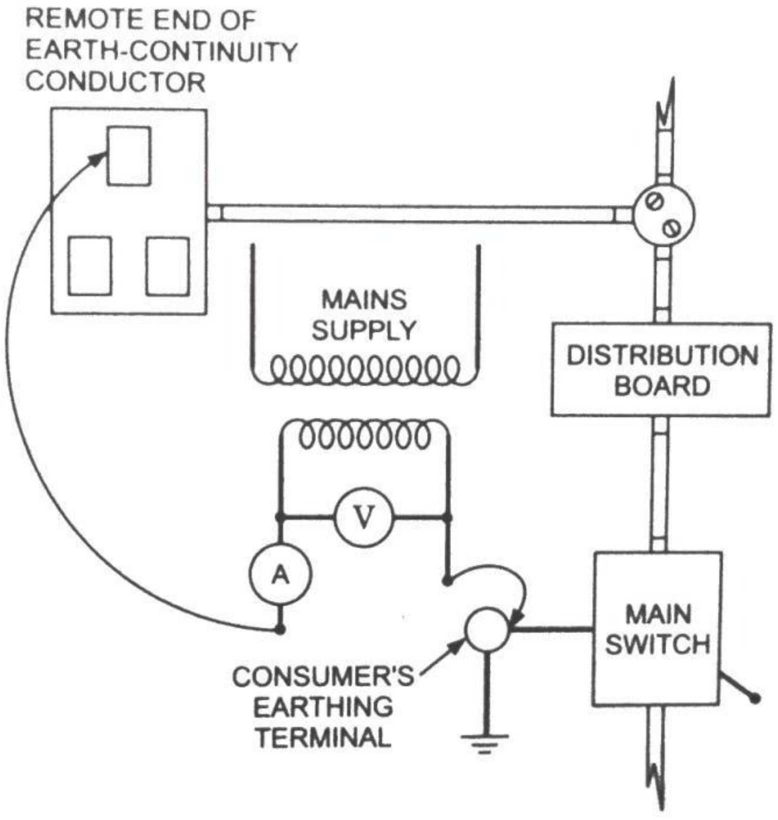
- All switches must be connected to phase wire of circuit.
- Neutral must be continuous and unbroken.
- All apparatus should be disconnected.
- A neon bulb tester can be used for this purpose.



Polarity Test

Testing for Earth Continuity Path

- For safety, all non functional metallic parts, coverings, metal conduits etc. must be solidly connected to earth
- For continuity test
    - Main switch should be opened, main fuse should be withdrawn
    - All switches to be kept in ON position, lamps to be placed in respective holders
    - One end of earth continuity tester connected to independent earth, other end to the extraneous or exposed metallic part
    - Earth resistance shall not be greater than 0.1ohm
    - Higher value shows conduit or switch not properly earthed



Earth-Continuity Conductor Testing

Pre-commissioning tests of domestic installations

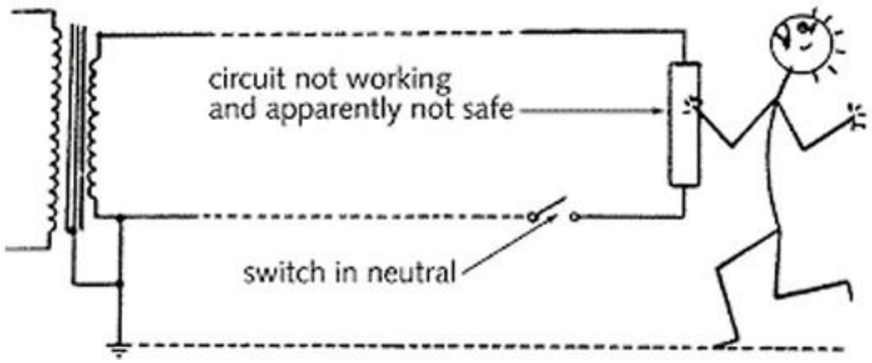
- On completion of installation, the following tests shall be carried out:-
  1. Insulation resistance test.
  2. Polarity test of switch.
  3. Earth continuity test.
  4. Earth electrode resistance test.
- Testing shall be carried out for the completed installations, in the presence of and to the satisfaction of the Engineer-in-charge by the contractor. All test results shall be recorded and submitted to the Department.

1. Insulation resistance test.

- Its objective is to measure the ohmic value of the insulation under a direct voltage of great stability, generally 50, 100, 250, 500, or 1000 VDC.
- A megohmmeter (also called **insulation resistance tester**) is then used to measure the ohmic value of an insulator under a DC voltage of great stability.
- The ohmmic value of the insulation resistance is expressed in megohms (MΩ).
- The insulation resistance in mega ohms measured as above shall not be less than 12.5 mega ohms for the wiring with PVC insulated cables, subject to a minimum of 1 mega ohm.

Pre-commissioning tests of domestic installations

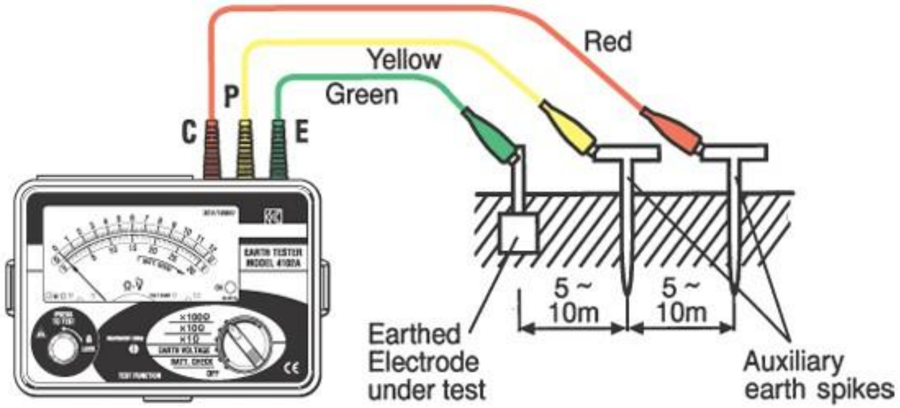
2. **Polarity test of switch.**
   - This test will verify that all the switches installed in the system are connected in current carrying conductor and not in neutral.
   - The terminals of all switches shall be tested by a test lamp, one lead of which is connected to the earth.
   - Glowing of test lamp to its full brightness, when the switch is in “on” position shall indicate that the switch is connected to the right polarity.



Pre-commissioning tests of domestic installations

3. Earth electrode resistance test

- ***Earth electrode*** *– conductive part, which may be embedded in the soil or in a specific conductive medium, e.g. c oncrete or coke, in electrical contact with the Earth.*
- ***Earth electrode resistance*** *– the resistance of an earth electrode to Earth.*
- The purpose of this test is to establish that the resistance of the soil surrounding an earth electrode is suitabl e and that the electrode makes contact with the soil
- Two auxiliary earth electrodes, besides the test electrode, are placed at suitable distance from the test electro de (see Fig)
- A measured current is passed between the electrode 'A' to be tested and an auxiliary current electrode 'C', and the potential difference between the electrode 'A' and auxiliary potential 'B' is measured.
- Measured voltage and current values are used to calculate the electrode resistance



Pre-commissioning tests of domestic installations

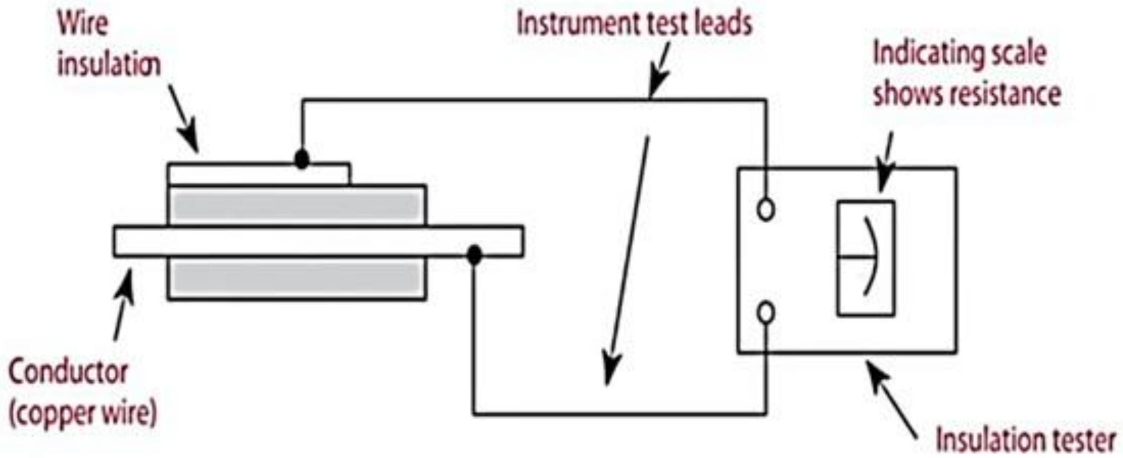
4. Earth continuity test

- The purpose of the test is to check that there is a good connection between the Earth pin on the plug and the case of the appliance.
- A good connection is defined as having a resistance of less than 0.1 ohms (or 100 milli-ohms).
- If the resistance measured is less than 0.1 ohms, then there is a good earth connection and the appliance is co nsidered safe
- The conventional way to carry out this test is to plug the appliance into a **Portable Appliance Tester** (PAT Tester) and clip the Test lead to a suitable earth point.

- Other than the above mentioned tests followings things are also done
  - Analysis of the wiring diagrams to confirm the polarity of connections
  - A general inspection of the equipment, physically verifying all the connections.
  - Checking the operation of the protection tripping and alarm circuits
- **Test Certificate**
  - On completion of an electrical installation (or an extension to an installation), a certificate shall be furnished by the contractor, countersigned by the certified supervisor under whose direct supervision the installation was carried out.
  - This certificate shall be in the prescribed form required by the local Electric Supply Authorities.

1. Insulation resistance test.

- Its objective is to measure the ohmmic value of the insulation under a direct voltage of great stability, generally 50, 100, 250, 500, or 1000 VDC.
- A megohmmeter (also called **insulation resistance tester**) is then used to measure the ohmic value of an insulator under a DC voltage of great stability.
- The ohmmic value of the insulation resistance is expressed in megohms (MΩ).
- The insulation resistance in mega ohms measured as above shall not be less than 12.5 mega ohms for the wiring with PVC insulated cables, subject to a minimum of 1 mega ohm.

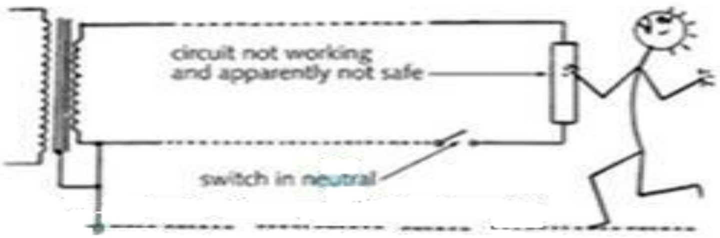


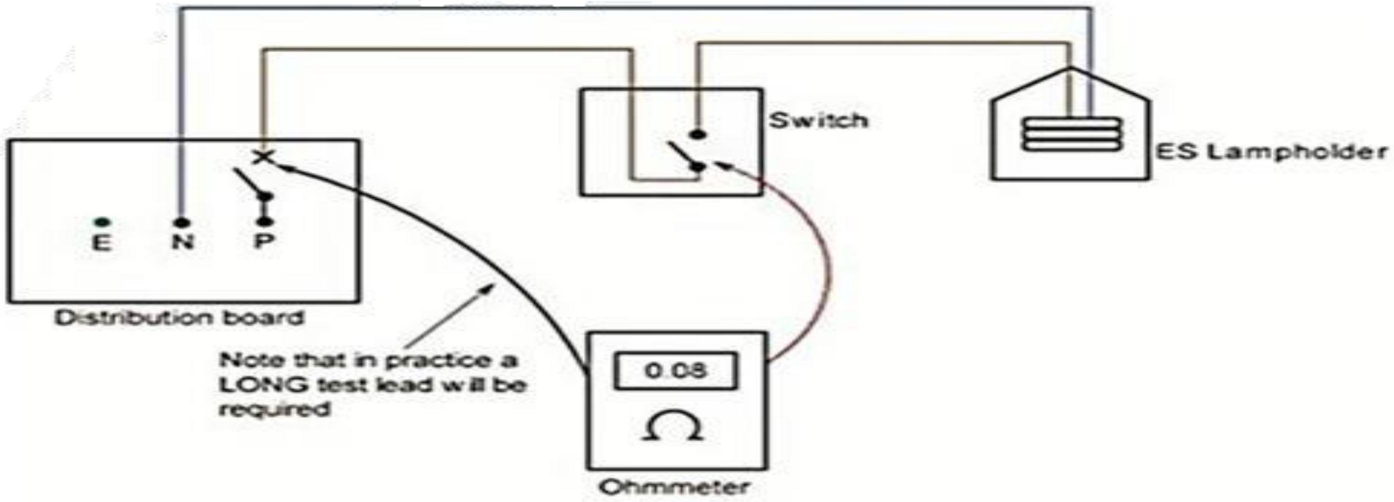
- This test is to ensure that there are no short circuits between live conductors or between live conductors and earth, and that there is no deterioration in insulation resistance caused by damage or dampness.
- A direct voltage is applied, to test insulation resistance as the capacitive current quickly falls to zero so that it has no effect on the measurement. A high voltage is used because this will often break down poor insulation or surface leakage paths. In other words the high voltage may show up insulation weaknesses which would not be noticed at lower voltage levels.
- An insulation resistance tester measures the applied voltage and the resulting leakage current flow. The resistance displayed, is obtained by an internal calculation based on Ohm's Law.

$$\text{Insulation Resistance (M}\Omega\text{)} = \frac{\text{Test voltage (V)}}{\text{Leakage Current (}\mu\text{A)}}$$

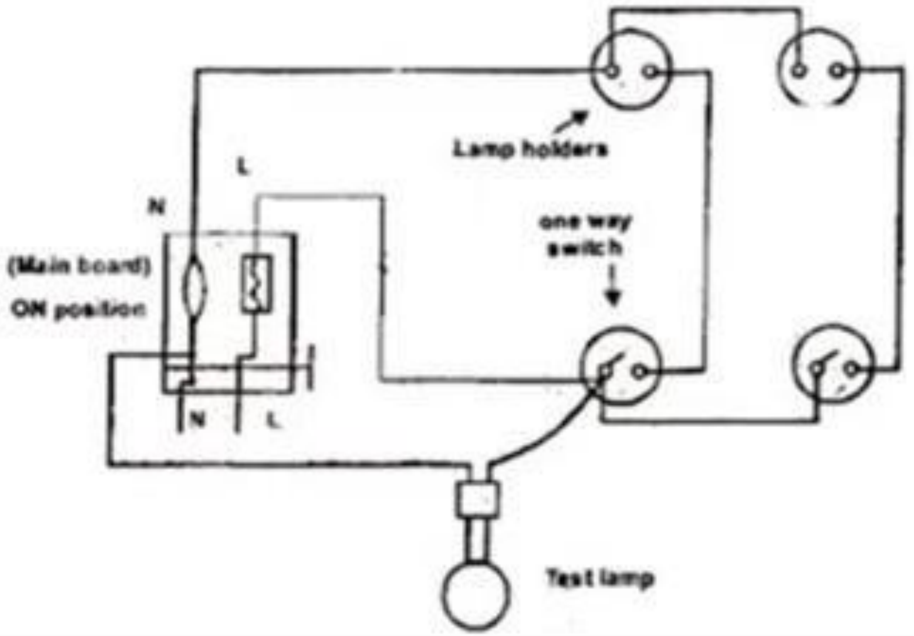
2. Polarity test of switch.

- This test will verify that all the switches installed in the system are connected in current carrying conductor and not in neutral.



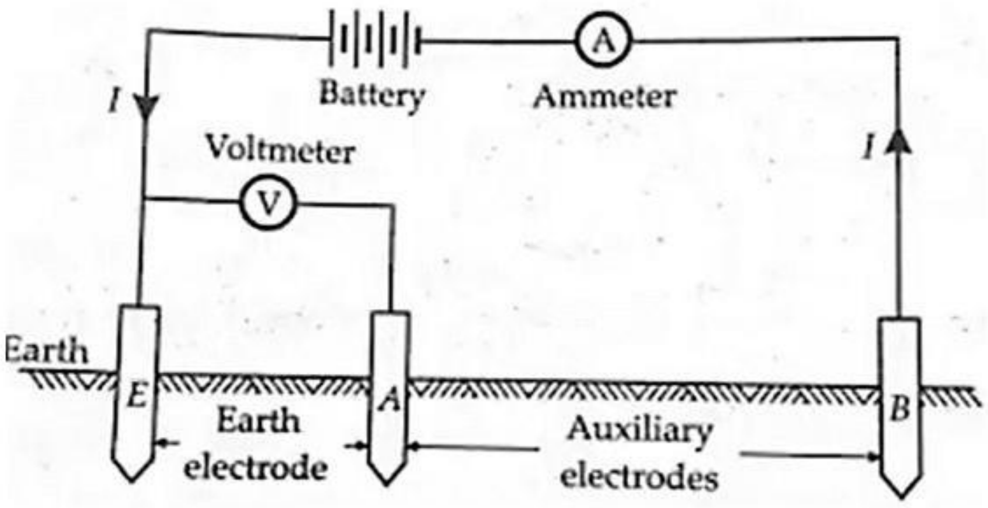


- The terminals of all switches shall be tested by a test lamp, one lead of which is connected to the earth.
- Glowing of test lamp to its full brightness, when the switch is in "on" position shall indicate that the switch is connected to the right polarity

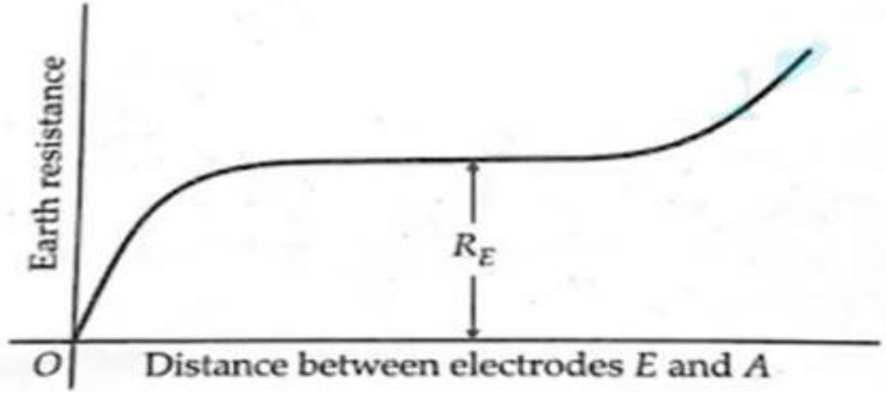


3. Earth electrode resistance test

- ***Earth electrode*** *– conductive part, which may be embedded in the soil or in a specific conductive medium, e.g. c oncrete or coke, in electrical contact with the Earth.*
- ***Earth electrode resistance*** *– the resistance of an earth electrod to Earth.*
- The purpose of this test is to establish that the resistance of the soil surrounding an earth electrode is suitable and that the electrode makes contact with the soil
- Two auxiliary earth electrodes, besides the test electrode, are placed at suitable distance from the test electrode (see Fig)



A graph is plotted between **earth resistance** against the distance between electrode E and A.This graph is shown in the figure below.



- The figure above shows the circuit for **measurement of earth resistance** with fall of potential method.A current is passed through earth electrode an auxiliary electrode B (which is usually an iron spike) inserted in the earth at a distance away from the earth electrode.A second auxiliary electrode A is inserted in the earth between E and B.The potential difference V between E and A is measured for a given current I.The flow of ground currents is shown in the figure below.
- Measured voltage and current values are used to calculate the electrode resistance

4. Earth continuity test

- The purpose of the test is to check that there is a good connection between the Earth pin on the plug and the case of the appliance.
- A good connection is defined as having a resistance of less than 0.1 ohms (or 100 milli-ohms).
- If the resistance measured is less than 0.1 ohms, then there is a good earth connection and the appliance is co nsidered safe
- The conventional way to carry out this test is to plug the appliance into a **Portable Appliance Tester** (PAT Tester) and clip the Test lead to a suitable earth point.

- The main factors on which the resistance *of earth* system depends are:

1. Shape and material of **earth electrode** or electrodes used.
2. Depth in the soil at which the electrodes are hurried.
3. The specific resistance of soil surrounding and in the neighbourhood of electrodes.

The specific resistance of the soil is not constant but varies with one type of soil to another. The amount of moisture present in the soil affects its specific resistance and hence the **resistance of earth** electrode is not a constant factor but suffers seasonal variations.This calls for periodic testing to ensure that the earthing system remains reasonably effective.

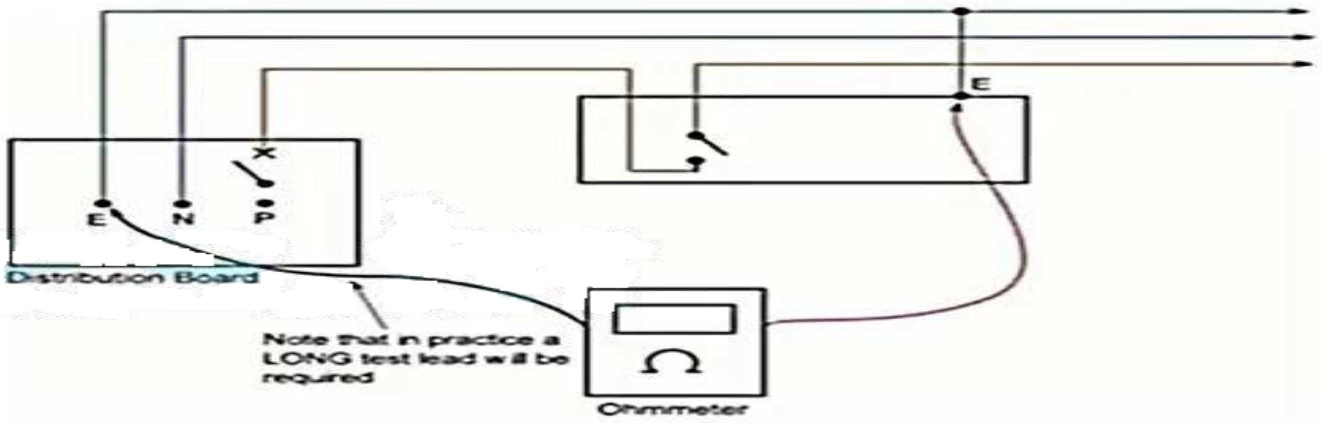


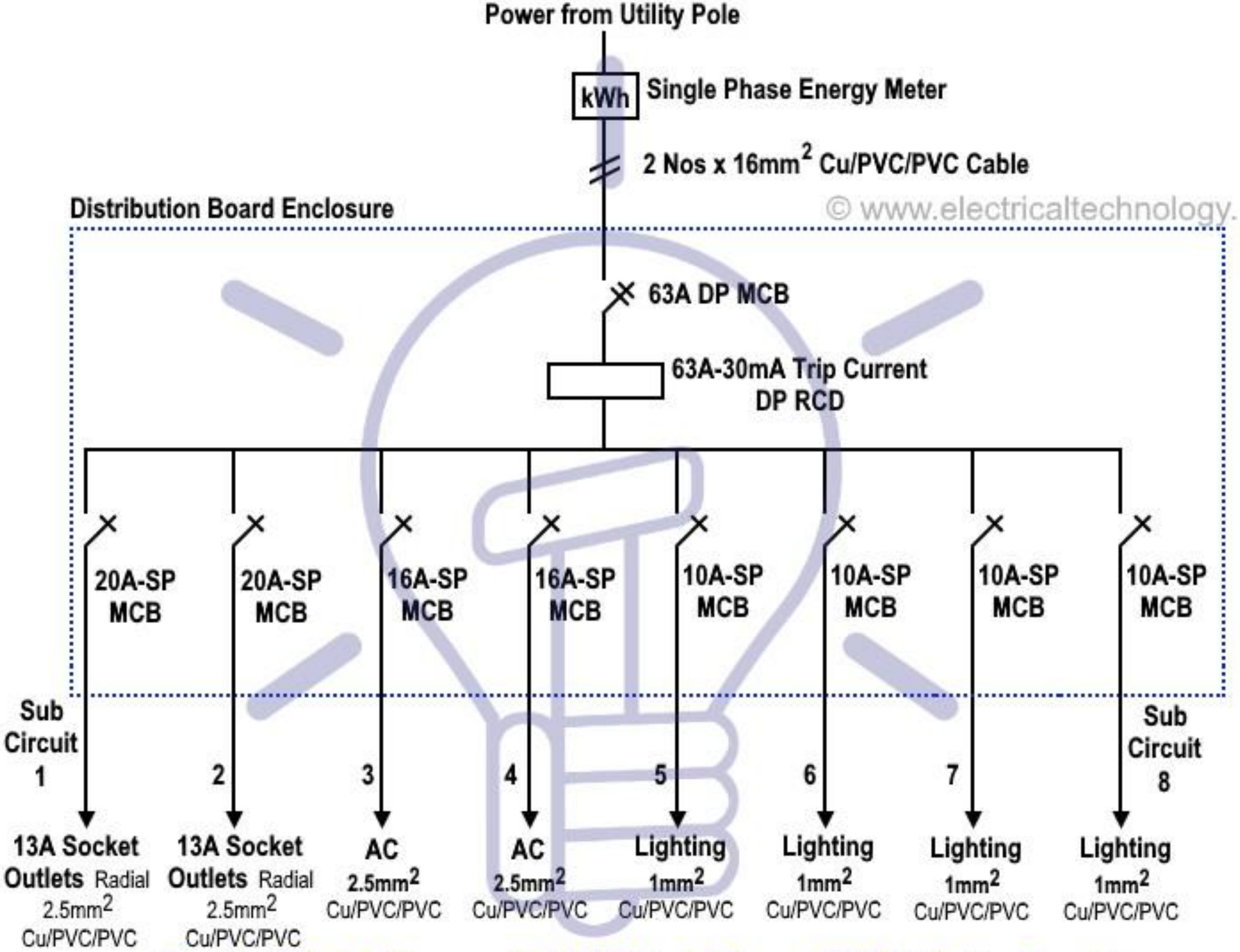
Figure 1

Protective conductor resistance *equals* Meter reading *minus* Test lead resistance

0.35R *equals* **0.66R** *minus* **0.31R**

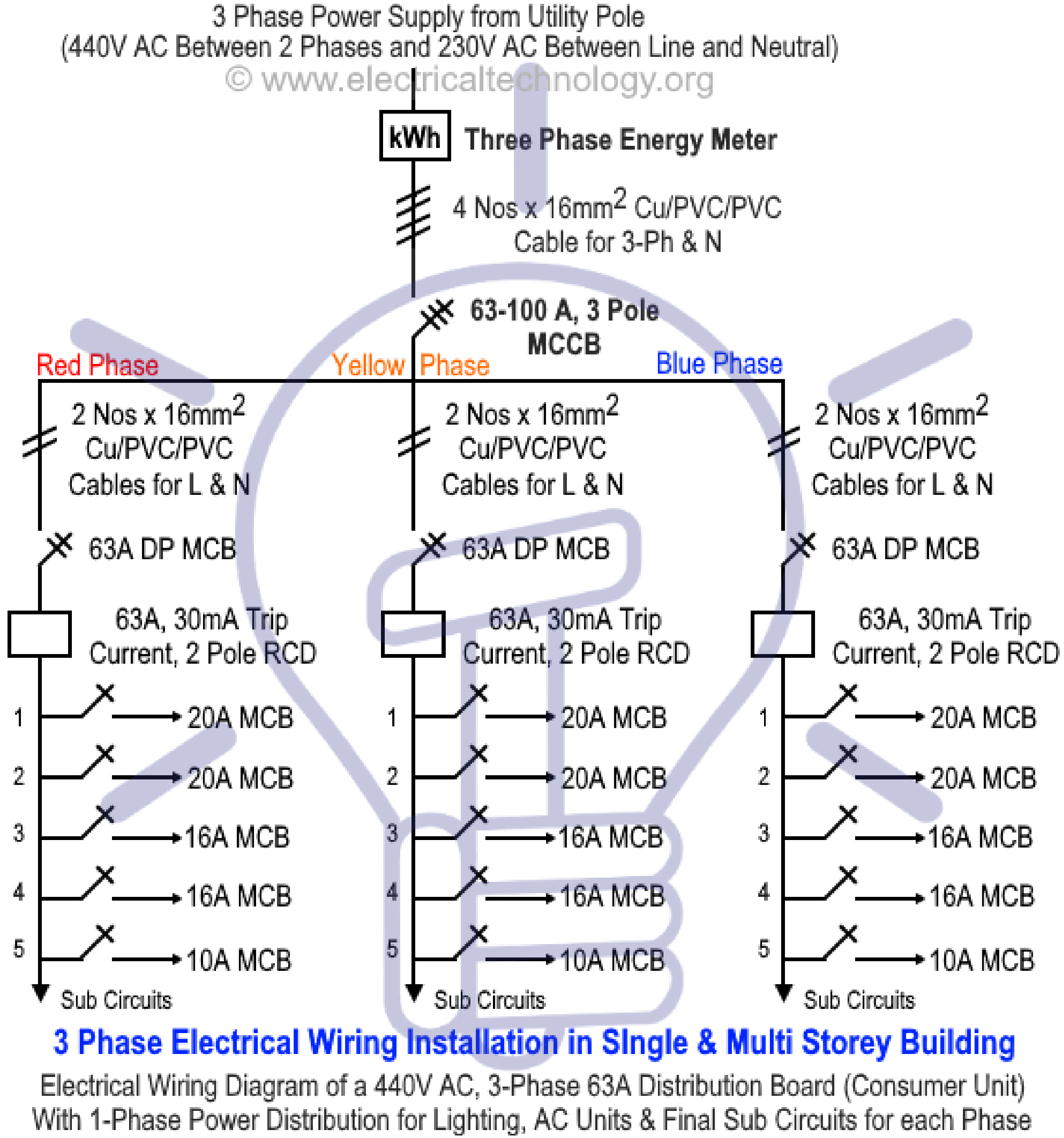
- Other than the above mentioned tests followings things are also done
  - Analysis of the wiring diagrams to confirm the polarity of connections
  - A general inspection of the equipment, physically verifying all the connections.
  - Checking the operation of the protection tripping and alarm circuits
- **Test Certificate**
  - On completion of an electrical installation (or an extension to an installation), a certificate shall be furnished by the contractor, countersigned by the certified supervisor under whose direct supervision the installation was carried out.
  - This certificate shall be in the prescribed form required by the local Electric Supply Authorities.

Schematic single line diagram of 1 phase DB



Electrical Wiring Diagram of a 230V Single Phase, 63A Distribution Board (Consumer Unit) with RCD for AC Units, Lighting, & 13A Radial Circuits

Schematic single line diagram of 3 phase DB



Grading of fuses

- The process of choosing the rating of fuses in an electrical circuit according to the hierarchical order of current rating is known as grading of fuses
- If we consider a domestic installation, the current rating of MCB in subcircuits should be less than the current rating of MCB isolator in main circuit.The protective device in main circuit should not operate before operating the protective device in sub circuit.
- Eg. Consider a domestic installation with 9 nos of 9W lamps, 5 nos of fans, 4 nos of 6A sockets and 2 nos of 16A sockets

Number of light sub circuits = (9+5+4)/6 = 3

Max. power in light sub circuit = (9 x 9 + 5 x 60 + 4 x 100)/3 = 260.3W

Max. Current in light sub circuit = 260.3/(230 x 0.8) = 1.42A

MCB rating in light sub circuit = 6A MCB

Number of power sub circuit = 2/2 = 1

Max. Current in power sub circuit = 2000/(230 x 0.8) = 10.9A

MCB rating in power sub circuit = 16A MCB

Max. Current in main circuit = (781 + 2000)/(230 x 0.8) = 15.1A

MCB isolator rating in main circuit = 20A MCB Isolator

- From above example it is clear that the current rating of MCB in sub circuits should be less than the current rating of MCB in main circuit.

(U)Q2. In a residential building, having 45 nos of light points, 10 fan points, 20 nos of 5A plug socket, 6 nos of 15A power plug socket & 1.5 HP single phase motor pump set (assume DOL starting). Calculate the total connected load, the no. of sub circuits required & select the conductors used for each sub circuits?

Ans:

To calculate Total connected load

Sl. No.	Equipment	Number of equipment	Power rating (W)
1	Light points (Assume 15W CFL lamps)	45	15
2	Fan	10	60
3	5A plug socket	20	100
4	15A plug socket	6	1000
5	1 phase motor pump	1	1102.5 (1.5 * 735)

Total connected load = 45*15 + 10*60 + 20*100 + 6*1000 + 1102.5 = 10377.5W

Type of supply : As per NEC guidelines, a total connected load of 10377.5W require 3 phase supply

Max. connected load (Assuming a diversity factor of 2.5) = 10377.5/2.5 = 4151W

Number of sub circuits

- Number of light points = 45 + 10 + 20 = 75

  Number of light sub circuits = 75/6 = 12.5 ≈ 13 (Assuming 6 light points/sub circuit)
- Number of power points = 6 + 1 = 7

  Number of power sub circuits = 6/2 = 3 (Assuming 2 power points/sub circuit)
- For 1 phase motor pump, provide separate power sub circuit
- Therefore, total number of power sub circuits = 3 + 1 = 4
- Total number of sub circuits = 13 + 4 = 17

Selection of conductors

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = Total power of light points/number of light sub circuits

  = (45 x 15 + 10 x 60 + 20 x 100) / 13 = 251.9 W
- Max. current in a light sub circuit = 251.9/(230 x 0.8) = 1.37A
- Use 1mm^2 PVC insulated Copper cable or 1.5mm^2 Aluminium cable

For power sub circuits:

- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)

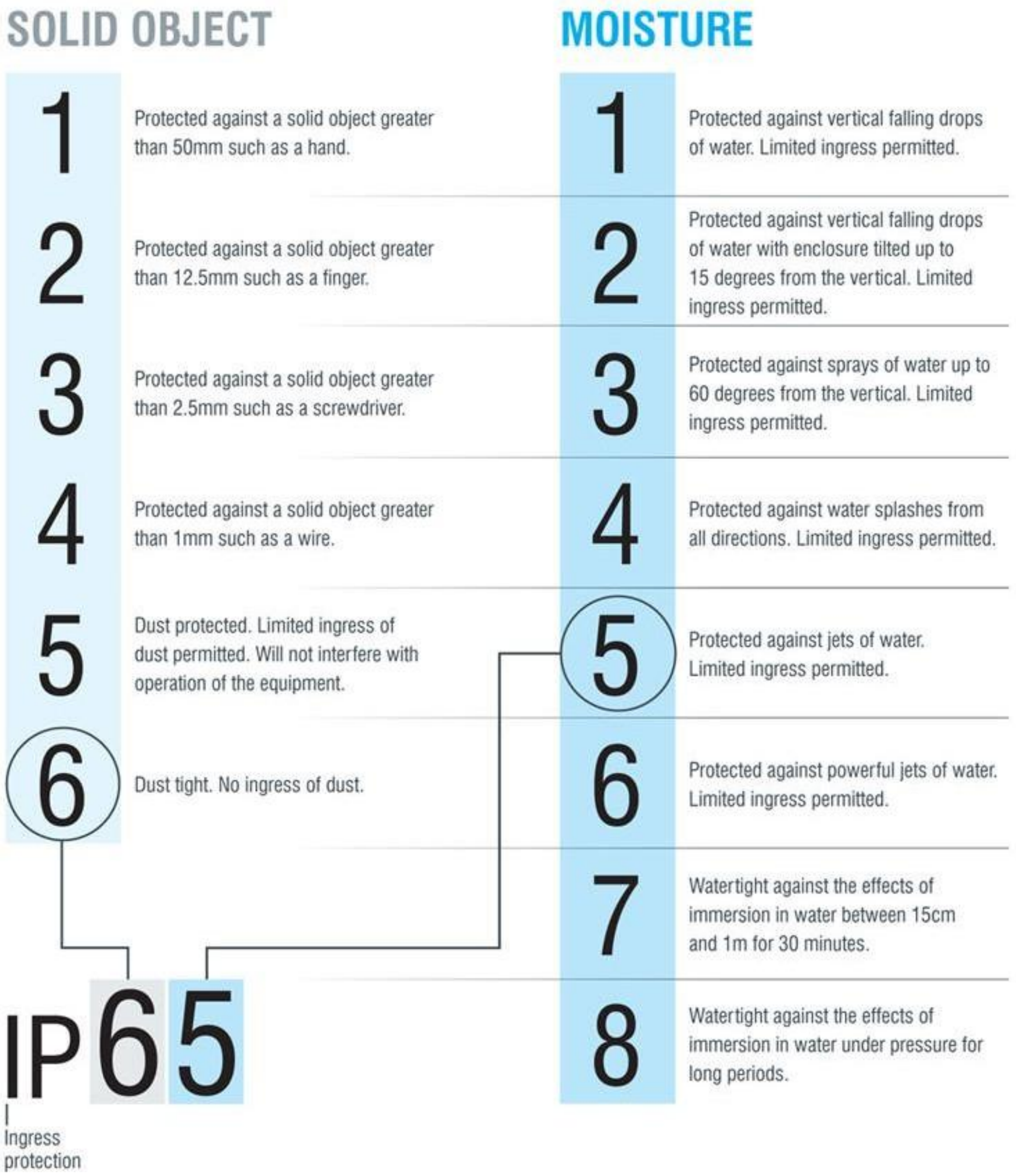
- Max. Power in a power circuit = Total power of power points/number of power sub circuits
  = (6 x 1000) / 3 = 2000 W
- Max. current in a power sub circuit = 2000/(230 x 0.8) = 10.86A
- Use 2.5mm^2 PVC insulated Copper cable or 4mm^2 Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power/phase in main circuit = Total connected load/3 = 10377.5W/3 = 3459 W
- Max. current/phase in main circuit = 3459/(230 x 0.8) = 18.8A
- 4/6 mm^2 PVC insulated copper wire

Selection of Distribution Board

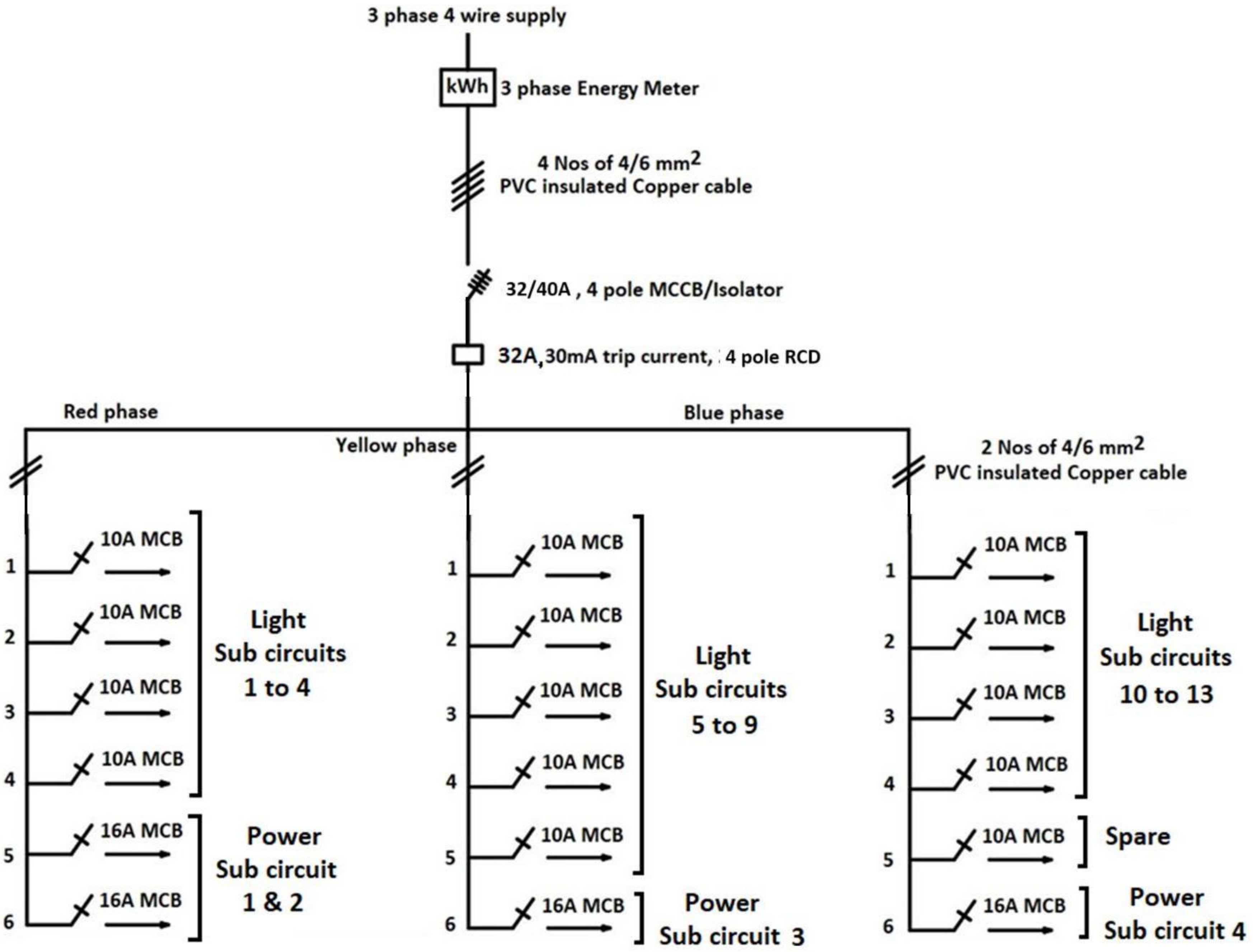
- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 32/40A, 4 pole Isolator *(Considering current in main circuit)*
  32/40A, 4 pole, RCD with 30mA sensitivity *(Considering current in main circuit)*
- Outgoing :
  For light sub circuits : 6/10A, single pole MCB with B curve – 13 Nos *(Considering current in light sub circuit)*
  For power sub circuits : 16/20A, single pole MCB with C curve – 4 Nos *(Considering current in power sub circuit)*
- Number of ways : 8 way TPN


SOLID OBJECT
1 Protected against a solid object greater than 50mm such as a hand.
2 Protected against a solid object greater than 12.5mm such as a finger.
3 Protected against a solid object greater than 2.5mm such as a screwdriver.
4 Protected against a solid object greater than 1mm such as a wire.
5 Dust protected. Limited ingress of dust permitted. Will not interfere with operation of the equipment.
6 Dust tight. No ingress of dust.
MOISTURE
1 Protected against vertical falling drops of water. Limited ingress permitted.
2 Protected against vertical falling drops of water with enclosure tilted up to 15 degrees from the vertical. Limited ingress permitted.
3 Protected against sprays of water up to 60 degrees from the vertical. Limited ingress permitted.
4 Protected against water splashes from all directions. Limited ingress permitted.
5 Protected against jets of water. Limited ingress permitted.
6 Protected against powerful jets of water. Limited ingress permitted.
7 Watertight against the effects of immersion in water between 15cm and 1m for 30 minutes.
8 Watertight against the effects of immersion in water under pressure for long periods.
IP65
Ingress protection

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

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

Schematic diagram of installation



(U)Q3. A 3 occupant building has to be electrified independently from a common energy meter. Design the distribution boards with accessories for each resident having 10 nos of light circuits, 6 nos of power circuits.

Total connected load

- Each resident have 10 light circuits & 6 power circuits
- As per NEC guidelines, each light circuit has a maximum of 800W load & power circuit has maximum of 2 power points (i.e, 1000*2 = 2000W)
- Therefore, connected load of a resident = 800*10 + 6*2000 = 20000W
- Total connected load of the building = 20000*3 = 60000W
- As per NEC guidelines, a total connected load of 60000W require 3 phase supply
- Assuming a diversity factor of 2.5, Max. connected load = 60000/2.5 = 24000W

Distribution board

- Since each residents connected load is 20000W, 3 phase supply is needed to individual residents & can have independent distribution board
  - A 100A, 4 pole MCB isolator is installed between energy meter & DBs

Components of each DB

- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 40/63A, 4 pole Isolator *(Considering current in main circuit)*

  40/63A, 4 pole, RCD with 30mA sensitivity *(Considering current in main circuit)*
- Outgoing :

  For light sub circuits : 6/10A, single pole MCB with B curve – 10 Nos *(Considering current in light sub circuit)*

  For power sub circuits : 16/20A, single pole MCB with C curve – 6 Nos *(Considering current in power sub circuit)*
- Number of ways : 8 way TPN

Conductor size

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = 800W
- Max. current in a light sub circuit = 800/(230 x 0.8) = 4.4A
- Use 1mm^2 PVC insulated Copper cable or 1.5mm^2 Aluminium cable

For power sub circuits:

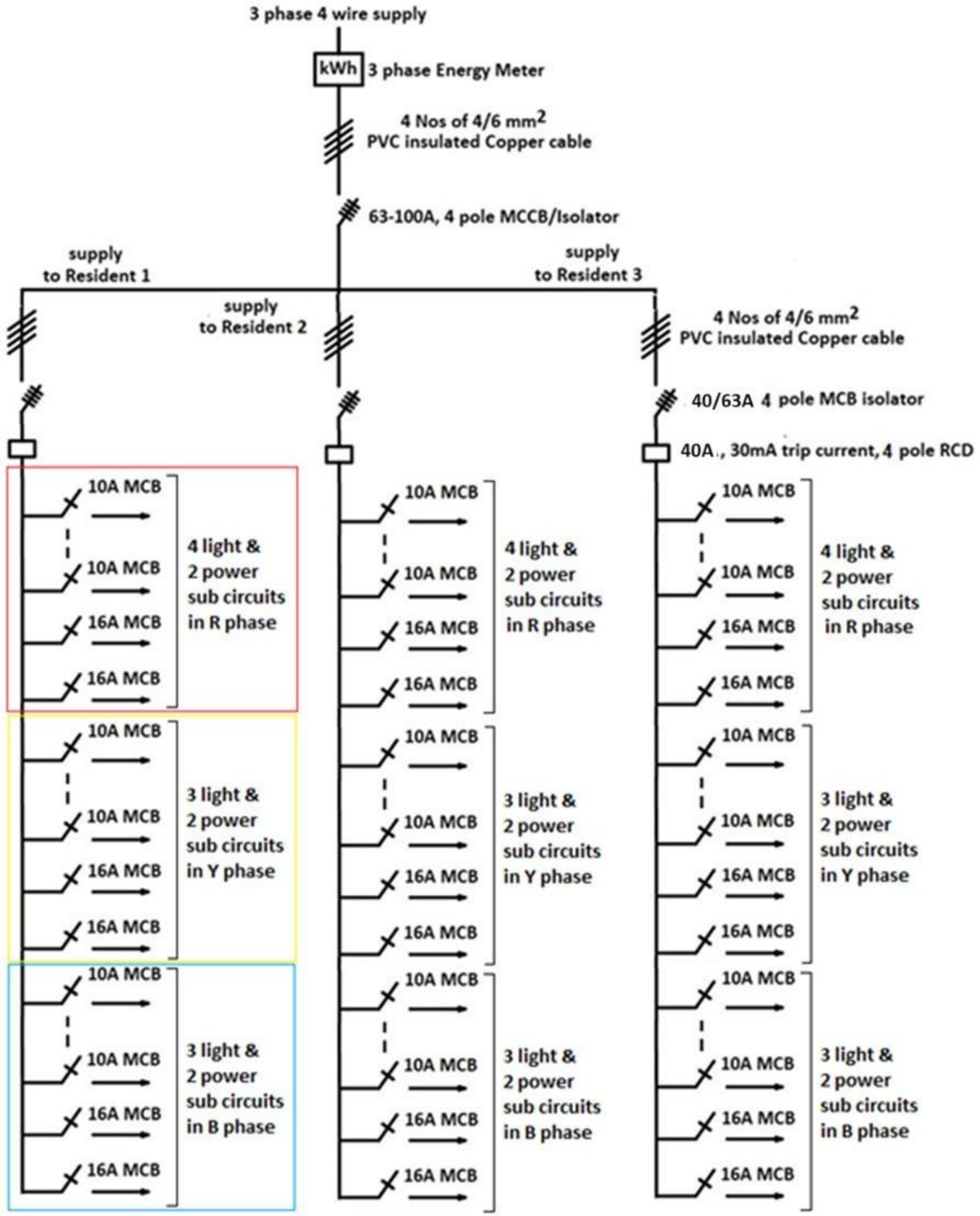
- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)
- Max. Power in a power circuit = 2000 W
- Max. current in a power sub circuit = 2000/(230 x 0.8) = 10.86A
- Use 2.5mm^2 PVC insulated Copper cable or 4mm^2 Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power/phase in main circuit = Total connected load/3 = 20000W/3 = 6666.67 W
- Max. current/phase in main circuit = 6666.67/(230 x 0.8) = 36.3A
- 10 mm^2 PVC insulated copper wire

Single line diagram of the installation

- The single line diagram of the installation is shown in next slide


3 phase 4 wire supply
kWh
3 phase Energy Meter
4 Nos of 4/6 mm2
PVC insulated Copper cable
63-100A, 4 pole MCCB/Isolator
supply
to Resident 1
supply
to Resident 2
supply
to Resident 3
4 Nos of 4/6 mm2
PVC insulated Copper cable
40/63A 4 pole MCB isolator
40A , 30mA trip current, 4 pole RCD
10A MCB
10A MCB
16A MCB
16A MCB
4 light &
2 power
sub circuits
in R phase
10A MCB
10A MCB
16A MCB
16A MCB
3 light &
2 power
sub circuits
in Y phase
10A MCB
10A MCB
16A MCB
16A MCB
3 light &
2 power
sub circuits
in B phase

Q4. A residential building has the following loads. Number of light points - 42, Number of power points - 6, Ceiling fans - 7, 6A sockets - 10. Design the electrical system for the building and draw the single line schematic diagram. Also, determine Connected load of the building and Maximum demand, Number of Light and Power circuits, Type of power supply required, Specification of the distribution board.

Calculation of Total connected load

Sl. No.	Equipment	Number of equipment	Power rating (W)
1	Light points (Assume 9W LED lamps)	42	9
2	Ceiling Fan	7	60
3	6A plug socket	10	100
4	Power points	6	1000

Total connected load = 42*9 + 7*60 + 10*100 + 6*1000 = 7798W

Type of supply : As per NEC guidelines, a total connected load of 7798W require 3 phase supply

Max. connected load (Assuming a diversity factor of 2.5) = 7798/2.5 = 3119.2W

Number of sub circuits

- Number of light points = 42 + 7 + 10 = 59
- Number of light sub circuits = 59/6 = 9.8 ≈ 10 (Assuming 6 light points/sub circuit)
- Number of power points = 6
- Number of power sub circuits = 6/2 = 3 (Assuming 2 power points/sub circuit)
- Total number of sub circuits = 10 + 3 = 13

Selection of conductors

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = Total power of light points/number of light sub circuits

  = (42 x 9 + 7 x 60 + 10 x 100) / 10 = 179.8 W
- Max. current in a light sub circuit = 179.8/(230 x 0.8) = 0.98A
- Use 1mm^2 PVC insulated Copper cable or 1.5mm^2 Aluminium cable

For power sub circuits:

- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)

- Max. Power in a power circuit = Total power of power points/number of power sub circuits

  = (6 x 1000) / 3 = 2000 W

- Max. current in a power sub circuit = 2000/(230 x 0.8) = 10.86A
- Use 2.5mm^2 PVC insulated Copper cable or 4mm^2 Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power/phase in main circuit = Total connected load/3 = 7798W/3 = 2599 W
- Max. current/phase in main circuit = 2599/(230 x 0.8) = 14.1A
- 2.5/4 mm^2 PVC insulated copper wire

Selection of Distribution Board

- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 32A, 4 pole Isolator *(Considering current in main circuit)*

  32A, 4 pole, RCD with 30mA sensitivity (in each phase) *(Considering current in main circuit)*

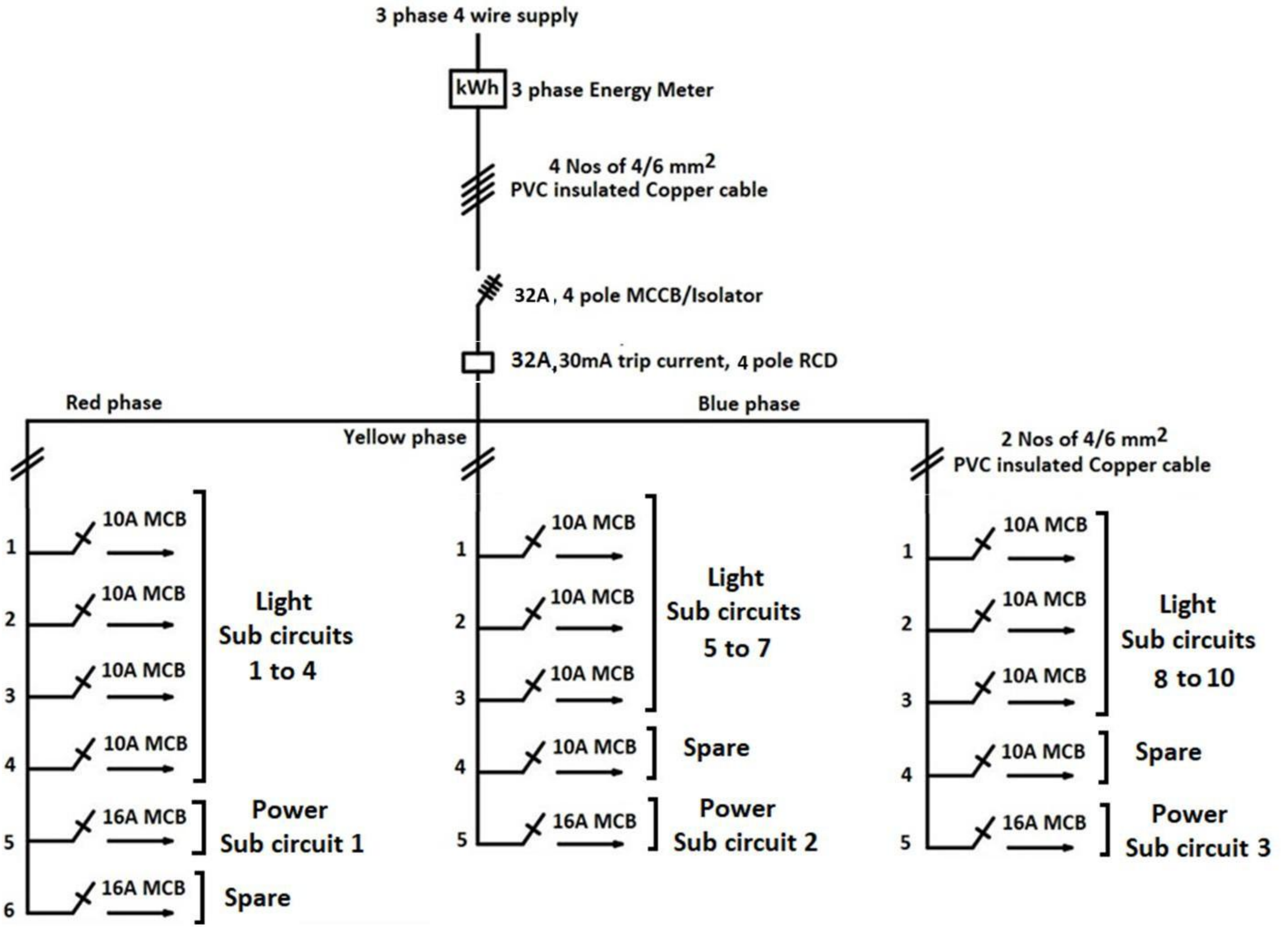
- Outgoing :

  For light sub circuits : 6A, single pole MCB with B curve – 10 Nos *(Considering current in light sub circuit)*

  For power sub circuits : 16A, single pole MCB with C curve – 3 Nos *(Considering current in power sub circuit)*

- Number of ways : 8 way TPN

Schematic diagram of installation



Q5. A 25m x 10m room is to be provided with electrical connections. It has 8 light points, two 5A socket & one 15A socket. Decide the number of sub circuits. Draw the installation plan, calculate the size and length of wiring required for the wiring installation & estimate the quantity of materials required.

Total connected load = 8*9 + 2*100+ 1*1000 = 1272W (Assuming 9W LED lights)

Type of supply : Since total connected load is less than 5000W, as per NEC guidelines a 1 phase supply is needed

Maximum demand (assuming a diversity factor of 2.5) = 1272/2.5 = 508.8W

Number of sub circuits

- Number of light points = 8 + 2 = 10
- Number of light sub circuits = 10/6 = 1.67 ≈ 2 (Assuming 6 light points/sub circuit)
- Number of power points = 1
- Number of power sub circuits = 1 (Assuming 2 power points/sub circuit)
- Total number of sub circuits = 2 + 1 = 3

Selection of conductors

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = Total power of light points/number of light sub circuits

  = (8*9 + 2*100) / 2 = 136 W
- Max. current in a light sub circuit = 136/(230 x 0.8) = 0.74A
- Use 1mm^2 PVC insulated Copper cable or 1.5mm^2 Aluminium cable

For power sub circuits:

- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)
- Max. Power in a power circuit = Total power of power points/number of power sub circuits

  = (1 x 1000) / 1 = 1000 W
- Max. current in a power sub circuit = 1000/(230 x 0.8) = 5.43A
- Use 2.5mm^2 PVC insulated Copper cable or 4mm^2 Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power in main circuit = Total connected load = 1272W
- Max. current in main circuit = 1272/(230 x 0.8) = 6.91A
- 2.5mm^2 PVC insulated copper wire

Details of DB

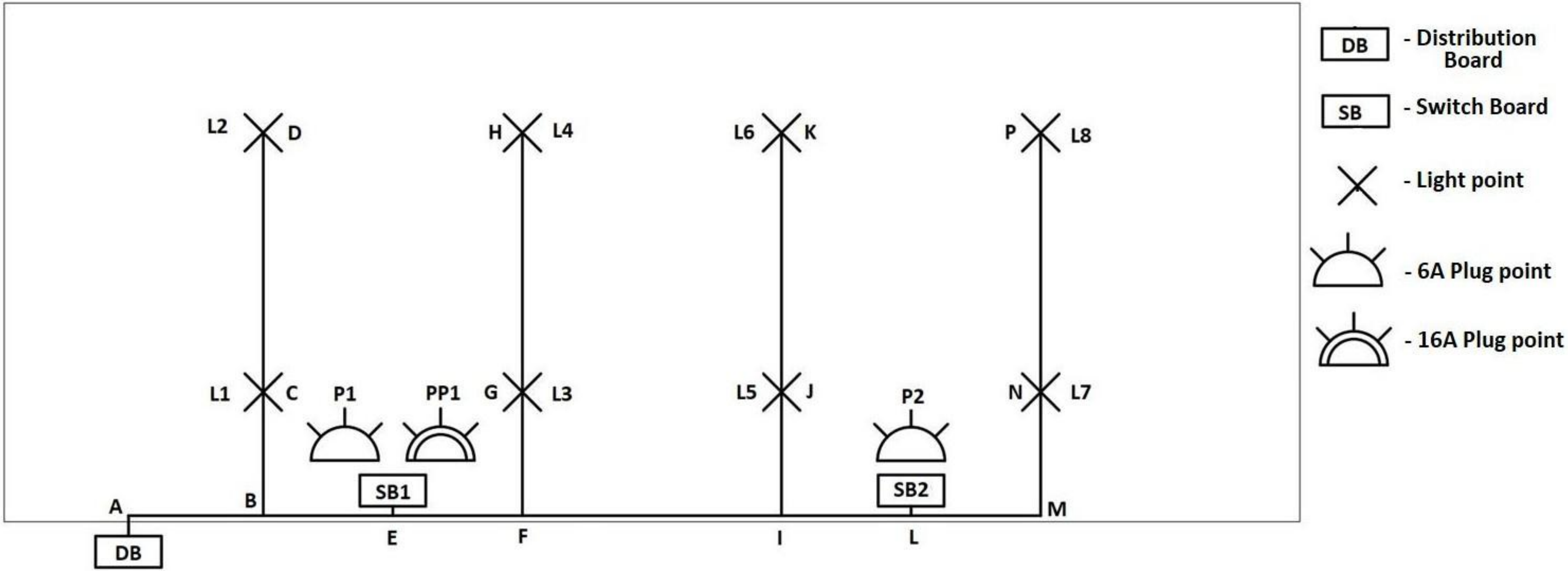
- A 1 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 20A, 2 pole MCB Isolator *(Considering current in main circuit)*

  20A, 2 pole, RCD with 30mA sensitivity *(Considering current in main circuit)*
- Outgoing :

  For light sub circuits : 6A, single pole MCB with B curve – 2 Nos *(Considering current in light sub circuit)*

  For power sub circuits : 16A, single pole MCB with C curve – 1 Nos *(Considering current in power sub circuit)*
- Number of ways : 8 way SP

Installation plan



Length of wire

Length of phase wire ($1mm^2$ Cu wire) = AE+AL+EC+ED+EG+EH+LJ+LK+LN+LP+ vertical run

= 5 + 15 + 5 + 10 + 5 + 10 + 5 + 10 + 5 + 10 + 12 = 92m

Length of phase wire ($2.5mm^2$ Cu wire) = AE + vertical run = 5 + 2 = 7m

Length of neutral wire ($1mm^2$ Cu wire) = AE + ED + EH + EL + LK + LP + vertical run

= 5 + 10 + 10 + 10 + 10 + 10 + 3 = 59M

Length of neutral wire ($2.5mm^2$ Cu wire) = AE + vertical run = 5 + 2 = 7m

Length of earth wire ($1.5 mm^2$ Cu wire) = AE + EL + vertical run = 5 + 10 + 3 = 18m

Considering an allowance of 20% for connections & wastage,

Length of $1 mm^2$ Cu wire = (92+ 59)*1.2 = 181.2m

Length of $2.5 mm^2$ Cu wire = (7+7)*1.2 = 16.8m

Length of $1.5mm^2$ Cu wire = 18 * 1.2 = 21.6m

Estimate

Quantity of material & cost

Sl. No.	Material	Quantity	Rate/unit	Total cost	Remarks
1	250V, 32A, 8 way SP Distribution board	1	1300/unit	1300	
2	20A, 2 pole MCB isolator	1	350/unit	350	
3	20A, 2 pole RCD, 30mA sensitivity	1	2000/unit	2000	
4	6A, single pole MCB with B curve	2	120/unit	240	
5	16A, single pole MCB with C curve	1	250/unit	250	
6	$1mm^2$ Cu wire	181m	11/m	1991	
7	$1.5mm^2$ Cu wire	17m	16/m	272	
8	$2.5mm^2$ Cu wire	21m	22/m	462	
9	flush metal GI box, 6 module	2	120/unit	240	
10	flush metal GI box, 8 module	1	150/unit	150	
11	6A, 240V 1 way switch	10	20/unit	200	
12	16A, 240V 1 way switch	1	70/unit	70	
13	6A, 240V socket	2	120/unit	240	

Sl. No.	Material	Qauntity	Rate/unit	Total cost	Remarks
14	16A, 240V power socket	1	200/unit	200	
15	25mm PVC conduit pipe	50m	15/m	750	
16	Other expenses			2000	
	Total			10574	

Labour cost

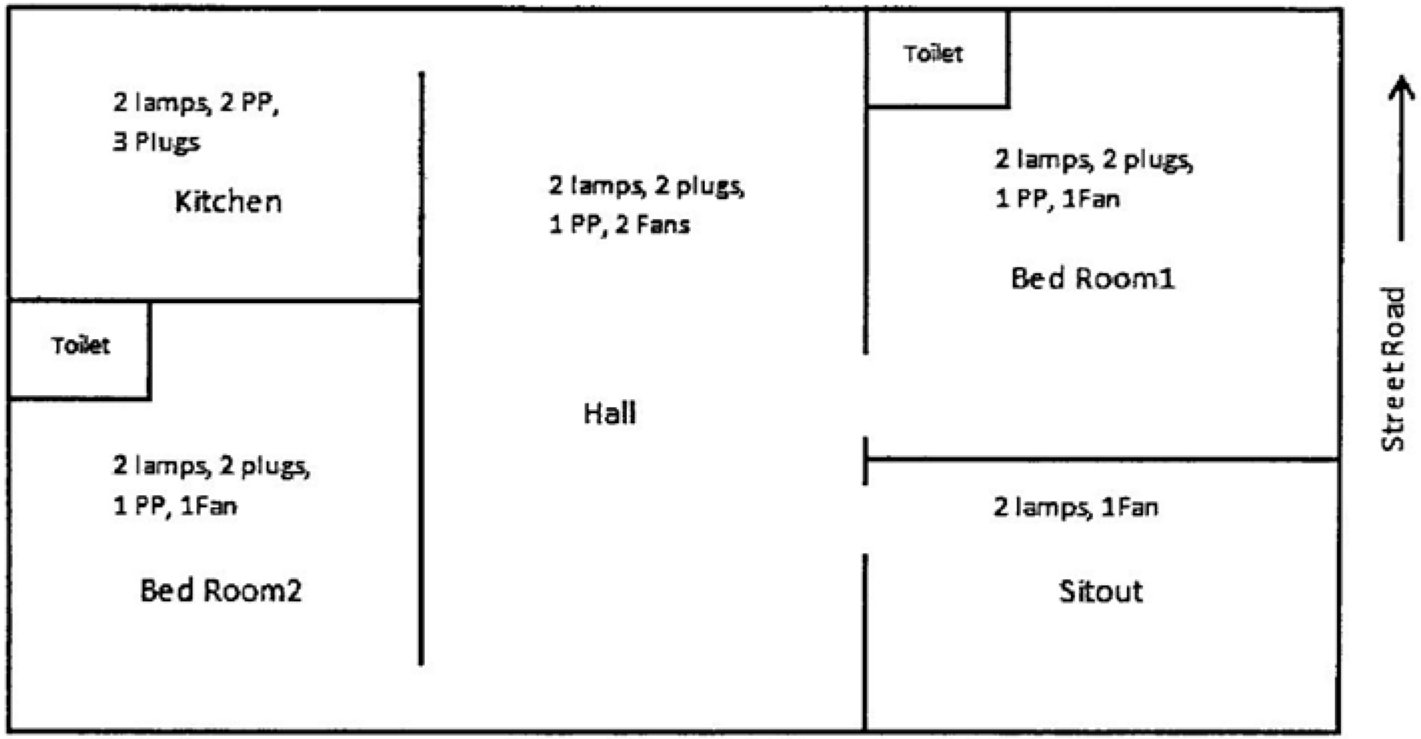
Total number of points to be wired : 11

The number of points that can be installed/day by a wireman & helper = 3

No. of days required = 11/3 ≈ 4

Cost of labour = 4 * (1000 + 800) = Rs. 7200/-

(U)Q6. Design an electrical schematic for residential building with following details. Locate the positions of meter board, main switch board, DB & switch boards.



Calculation of Total connected load

Sl. No.	Equipment	Number of equipment	Power rating (W)
1	Light points (Assume 9W LED lamps)	12	9
2	Ceiling Fan	5	60
3	6A plug socket	9	100
4	Power points	5	1000

Total connected load = 12*9 + 5*60 + 9*100 + 5*1000 = 6308W

Type of supply = Since total connected load is >5000 w as per NEC guide lines a 3 phase supply needed

Number of sub circuits

Number of light points = 26

Number of light sub circuits = 26/6 = 4.33 ≈ 5 (Assuming 6 light points/sub circuit)

Number of power points = 5

Number of power sub circuits = 5/2 = 2.5 ≈ 3 (Assuming 2 points/sub circuit)

Selection of conductors

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = Total power of light points/number of light sub circuits

  = (12*9 + 5*60 + 9*100) / 5 = 261.6 W
- Max. current in a light sub circuit = 261.6/(230 x 0.8) = 1.42A
- Use 1mm^2 PVC insulated Copper cable or 1.5mm^2 Aluminium cable

For power sub circuits:

- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)
- Max. Power in a power circuit = Total power of power points/number of power sub circuits

  = (5 x 1000) / 3 = 1666.7W
- Max. current in a power sub circuit = 1666.7/(230 x 0.8) = 9.1A
- Use 2.5mm^2 PVC insulated Copper cable or 4mm^2 Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power/phase in main circuit = Total connected load/3 = 2102.7W
- Max. current/phase in main circuit = 2102.7/(230 x 0.8) = 11.4A
- 2.5mm^2 PVC insulated copper wire

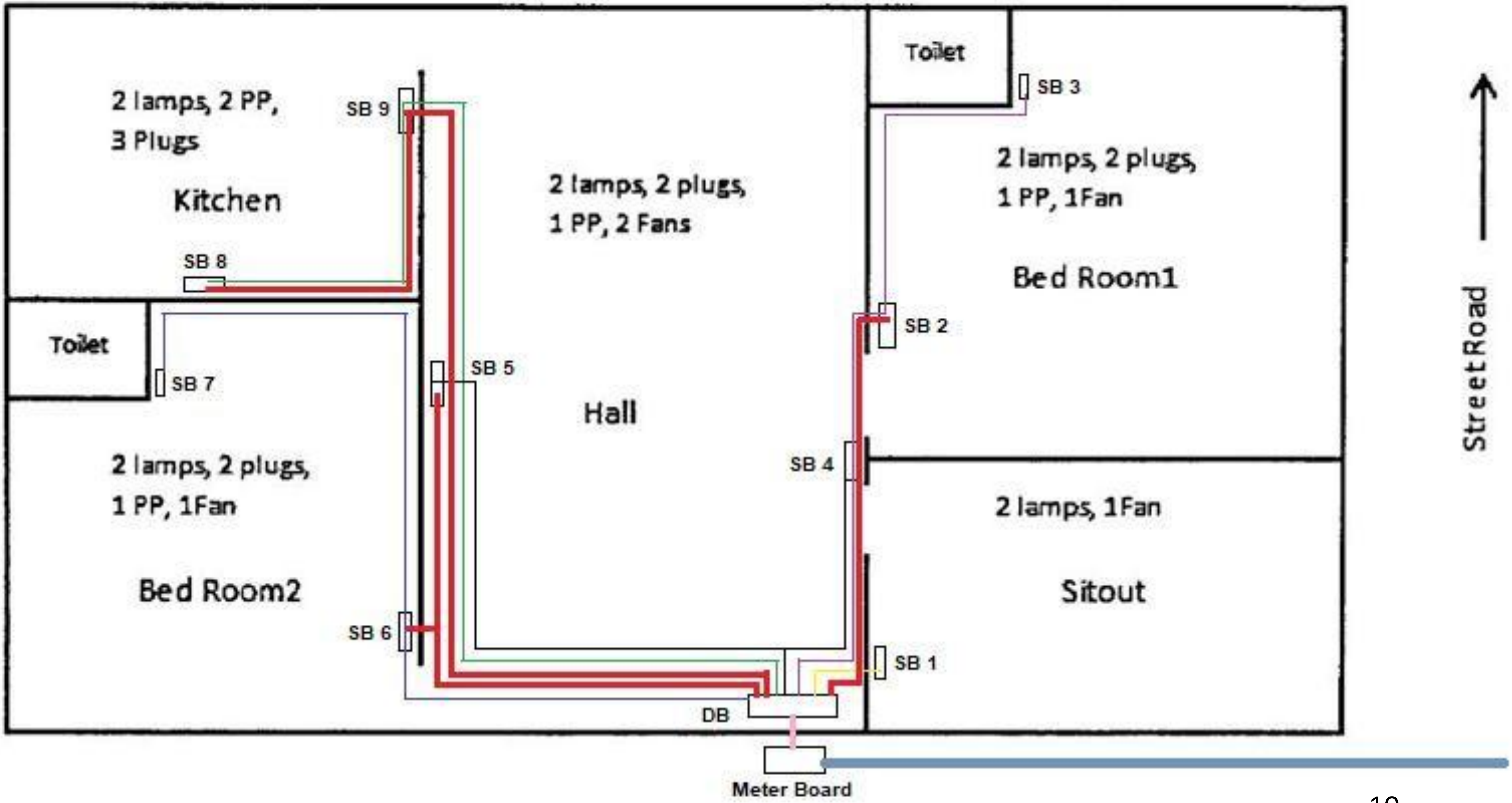
Selection of Distribution Board

- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 20A, 4 pole MCCB/Isolator *(Considering current in main circuit)*

  20A, 4 pole, RCD with 30mA sensitivity *(Considering current in main circuit)*
- Outgoing :

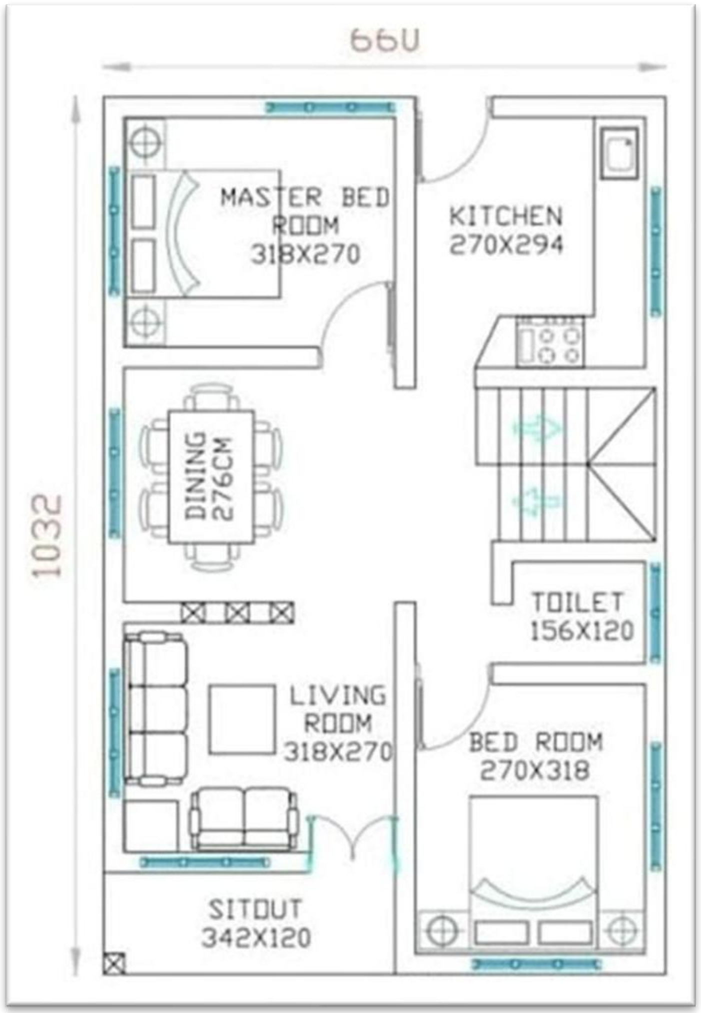
  For light sub circuits : 6A, single pole MCB with B curve – 5 Nos *(Considering current in light circuit)*

  For power sub circuits : 16A, single pole MCB with C curve – 3 Nos *(Considering current in power circuit)*
- Number of ways : 4 way TPN


Toilet
SB 3
2 lamps, 2 PP,
3 Plugs
SB 9
Kitchen
2 lamps, 2 plugs,
1 PP, 2 Fans
2 lamps, 2 plugs,
1 PP, 1Fan
Bed Room1
SB 8
Toilet
SB 7
SB 5
SB 2
Hall
SB 4
2 lamps, 2 plugs,
1 PP, 1Fan
2 lamps, 1Fan
Bed Room2
Sitout
SB 6
SB 1
DB
Meter Board
Street Road

Q7. The plan layout of a two bed room domestic building is shown in figure. Prepare the electrical installation plan showing the positions of light, fan, socket points etc. and compute the following:

1. Connected load of the building
2. Maximum demand in kW
3. Type of supply required
4. Number of light and power circuits
5. The details of the distribution board.



Calculation of Total connected load

Sl. No.	Room space	9W LED lamp	18W led tube	Ceiling fan 60W	6A socket	16/6A socket	Exhaust fan
1	Bedroom (2)	2 x 2	1 x 2	1 x 2	2 x 2	1 x 2	
2	Living room	2	1	1	3	1	
3	Dining room	2	1	1	2	1	
4	Kitchen	1	1	1	2	2	1
5	Sit out	1	1				
6	Toilet	1			1	1	1
9	Peripheral lights	4					
	Total points	15	6	5	12	7	2

Total connected load = 15*9 + 6*18 + 5*60 + 12*100 + 7*1000 + 2*40 = 8823W

Type of supply = Since total connected load is greater than 5000W, as per NEC guidelines a 3 phase supply is needed

Max. demand = 8823/2.5 = 3529.2W = 3.53kW (Assuming a diversity factor of 2.50)

Number of light sub circuits = Number of light points/6

= (15+6+5+12+2)/6 = 40/6 = 6.67 ≈ 7

Number of power sub circuits = Number of power points/2 = 7/2 = 3.5 ≈ 4

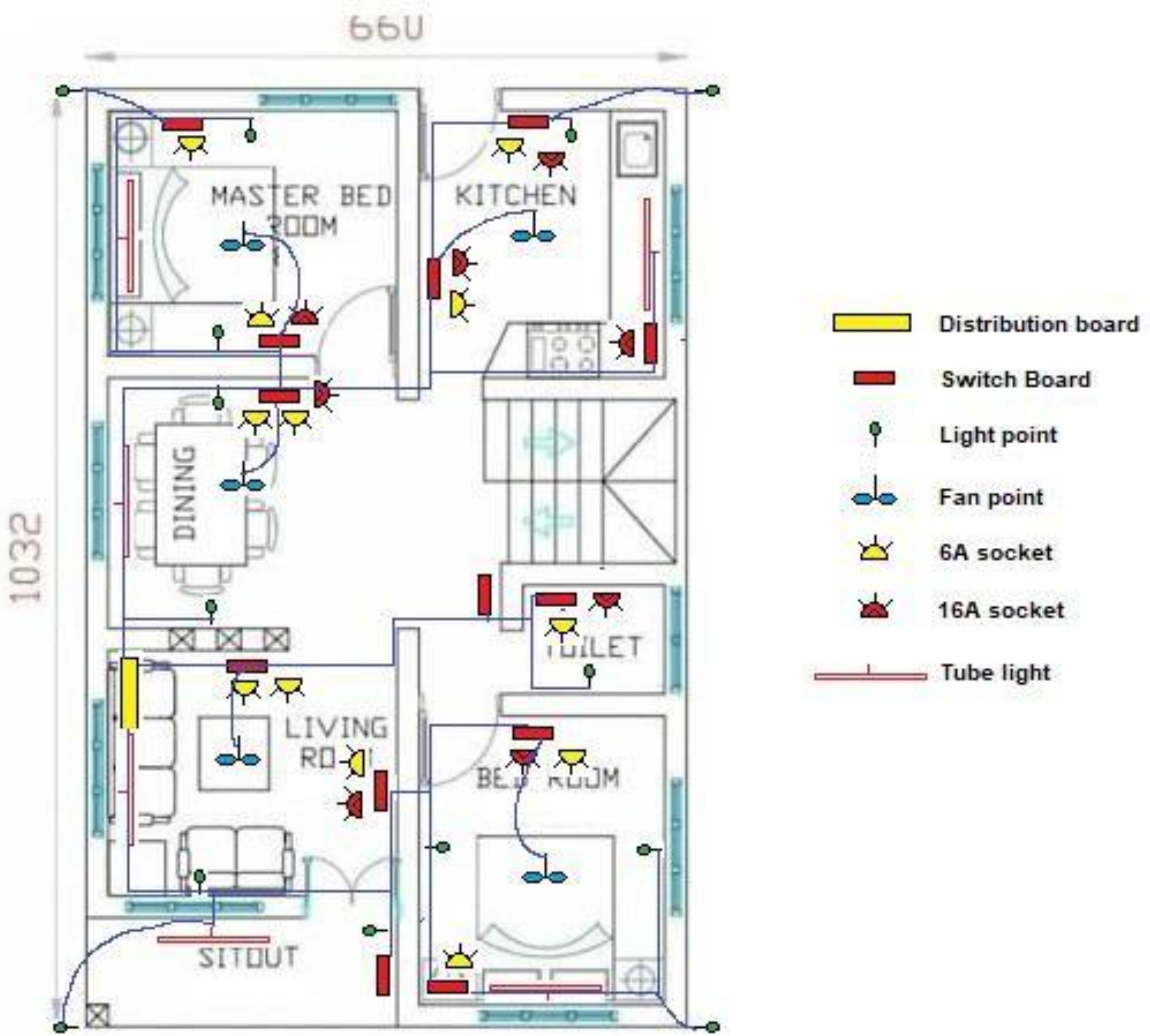
Details of DB

- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 63A, 4 pole MCCB/Isolator

  32A, 2 pole, RCD with 30mA sensitivity (in each phase)
- Outgoing :

  For light sub circuits : 6/10A, single pole MCB with B curve – 7 Nos

  For power sub circuits : 16/20A, single pole MCB with C curve – 4 Nos
- Number of ways : 6 way TPN



660
1032
MASTER BED ROOM
KITCHEN
DINING
TOILET
LIVING ROOM
BED ROOM
SITOUT
Distribution board
Switch Board
Light point
Fan point
6A socket
16A socket
Tube light

Q8. Determine the total connected load, number of sub circuits and type of supply for a domestic building with the following rooms: one bedroom with attached toilet, hall, and kitchen (1 BHK). Draw the schematic diagram showing the ratings of MCBs and sub circuits. Design shall be based on the NEC guidelines. Assume all required data.

Ans:

Room	Lamp	Fan	6A socket	16A socket	Exhaust fan
Bed room	2	1	1	1	-
Toilet	1	-	-	1	1
Hall	2	2	2	1	-
Kitchen	2	1	1	2	-

Total connected load = 7 x 9W + 4 x 60W + 4 x 100W + 5 x 1000W + 1 x 60W = 5763W

Type of supply = 3 phase supply since total connected load > 5000W

Max. demand = 5763/2.5 =2305.2W

No. of light sub circuits = no. of light points/6 = 16/6 ≈ 3

No. of power sub circuits = no. of power points/2 = 5/2 ≈ 3

Selection of conductors

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = Total power of light points/number of light sub circuits

  = (7 x 9W + 4 x 60W + 4 x 100W + 1 x 60W) / 3 = 254.3 W
- Max. current in a light sub circuit = 254.3/(230 x 0.8) = 1.38A
- Use $1mm^2$ PVC insulated Copper cable or $1.5mm^2$ Aluminium cable

For power sub circuits:

- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)
- Max. Power in a power circuit = Total power of power points/number of power sub circuits

  = (5 x 1000) / 3 = 1666.7W
- Max. current in a power sub circuit = 1666.7/(230 x 0.8) = 9.1A
- Use $2.5mm^2$ PVC insulated Copper cable or $4mm^2$ Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power/phase in main circuit = Total connected load/3 = 1921W
- Max. current/phase in main circuit = 1921/(230 x 0.8) = 10.4A
- $2.5mm^2$ PVC insulated copper wire

Details of DB

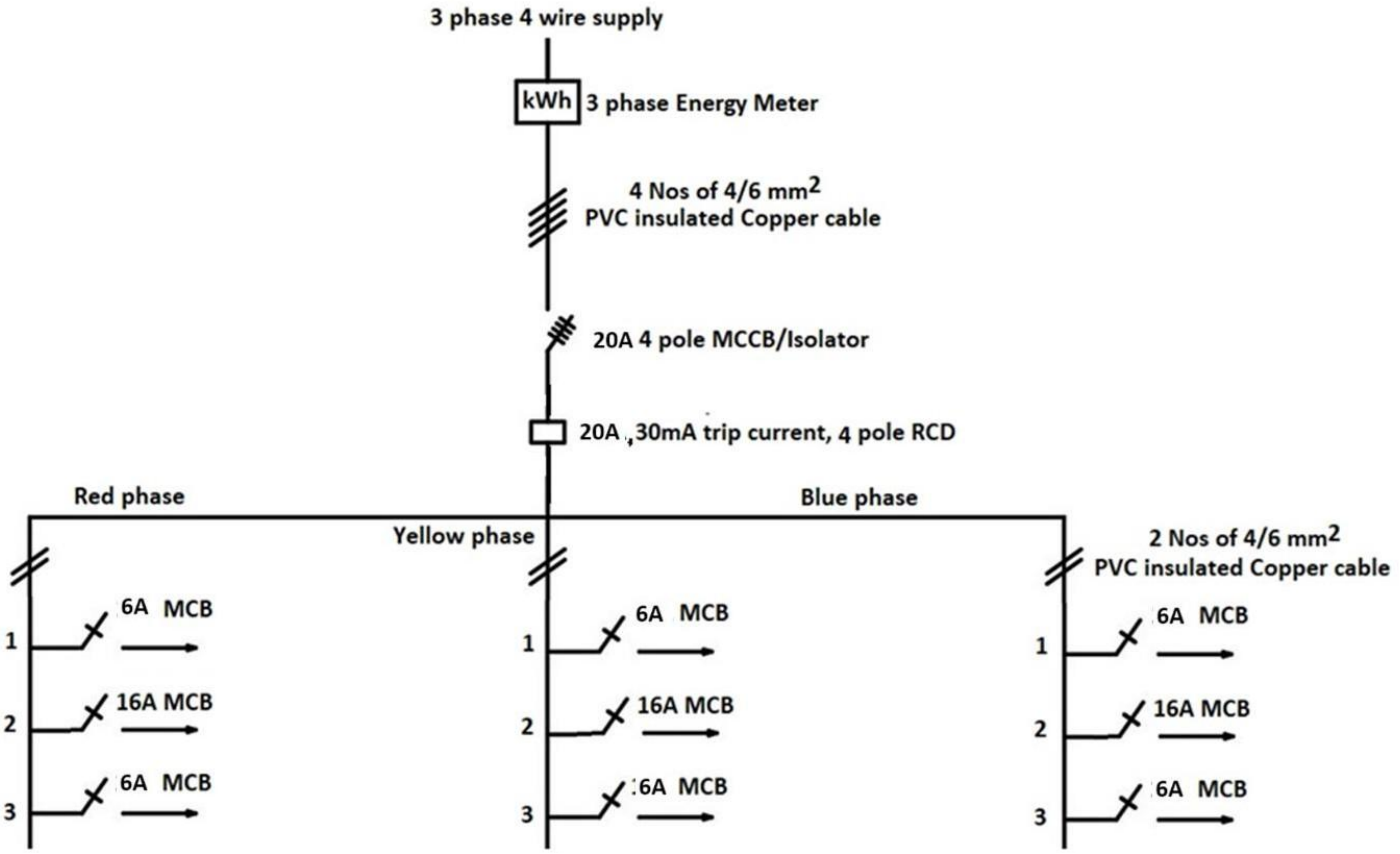
- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 20A, 4 pole MCB Isolator *(Considering current in main circuit)*

  20A, 4 pole, RCD with 30mA sensitivity *(Considering current in main circuit)*
- Outgoing :

  For light sub circuits : 6A, single pole MCB with B curve – 3 Nos *(Considering current in light circuit)*

  For power sub circuits : 16/20A, single pole MCB with C curve – 3 Nos *(Considering current in power circuit)*
- Number of ways : 3 way TPN

Schematic diagram



Q9. A rest house has four air conditioned bed rooms with attached toilets, dining hall and kitchen. Prepare the room wise list of electrical materials for the installation. Draw the schematic diagram showing the ratings of MCBs and sub circuits. Design is based on the NEC guide lines. Assume all required data.

Ans:

Room	Lamp	Fan	6A socket	16A socket	Exhaust fan
Bed room (4)	2 x 4	1 x 4	1 x 4	1 x 4	-
Toilet (4)	1 x 4	-	-	1 x 4	1 x 4
Dining Hall	2	2	2	1	-
Kitchen	2	1	2	3	-

Total connected load = 16 x 9W + 7 x 60W + 8 x 100W + 12 x 1000W + 4 x 60W = 13604W

Type of supply = 3 phase supply since total connected load > 5000W

Max. demand = 13604/2.5 =5441.6W

No. of light sub circuits = no. of light points/6 = 35/6 ≈ 6

No. of power sub circuits = 4 power sub circuits for AC + (remaining no. of power points/2)

= 4 + (8/2) = 8

Selection of conductors

For light sub circuits:

- Max. current in a light sub circuit = Max. Power in a light circuit/(voltage x pf)
- Max. Power in a light sub circuit = Total power of light points/number of light sub circuits

  = (16 x 9W + 7 x 60W + 8 x 100W + 4 x 60W) / 6 = 267.3 W
- Max. current in a light sub circuit = 267.3/(230 x 0.8) = 1.38A
- Use 1mm^2 PVC insulated Copper cable or 1.5mm^2 Aluminium cable

For power sub circuits:

- Max. current in a power sub circuit = Max. Power in a power circuit/(voltage x pf)
- Max. Power in a power circuit = Total power of power points/number of power sub circuits

  = (12 x 1000) / 6 = 2000W
- Max. current in a power sub circuit = 2000/(230 x 0.8) = 10.9A
- Use 2.5mm^2 PVC insulated Copper cable or 4mm^2 Aluminium cable

For main circuit (from energy meter to DB) :

- Max. Power/phase in main circuit = Total connected load/3 = 4534W
- Max. current/phase in main circuit = 4534/(230 x 0.8) = 24.6A
- 6mm^2 PVC insulated copper wire

Details of DB

- A 3 phase Distribution board conforming to IS 8623 with 100A copper bus bar, neutral link & earth link
- Protection class : IP20 or IP42
- Incomer : 32/40A, 4 pole MCB Isolator *(Considering current in main circuit)*

  32/40A, 4 pole, RCD with 30mA sensitivity *(Considering current in main circuit)*
- Outgoing :

  For light sub circuits : 6A, single pole MCB with B curve – 6 Nos *(Considering current in light sub circuit)*

  For power sub circuits : 16/20A, single pole MCB with C curve – 8 Nos *(Considering current in power sub circuit)*
- Number of ways : 6 way TPN

Schematic diagram