Salahaddin University- Erbil

College of Engineering

Architecture Department

Third Year Students

Electrical Installation

Part One

THE BASIC ELEMENTS OF ELECTRICITY

Electricity is the organized flow of electrons a long a conductor, the basic elements of electricity are:

	Voltage (V) :	Current (I):	Resistance (R):	Power (P)
Units;	Volt (V)	Ampere (A)	ohm (**Ω**)	Watt (W)

The Voltage is directly proportional to current and Resistance:

$$V \propto I \quad \& \quad V \propto R \rightarrow\rightarrow \quad V = I \times R \quad \text{(Ohm's law)}$$

1) **Voltage**: defined as electric potential difference between two points of an electric field. Or is electric pressure provided by a Battery (D.C) or other Power source.

   The higher the voltage, the more current that the source can produce.

   Voltage is measured in volts (V). If current and resistance are known, a Voltmeter measures the Voltage between two points. Fig (1.1).

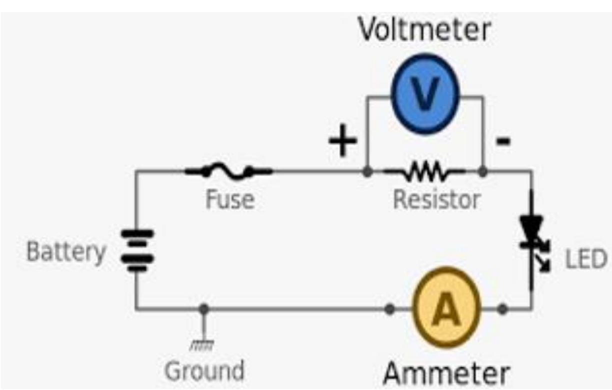


Fig (1.1) Electrical circuit

Fig (1.2) Clump – meter

2) **Current**: is the organized flow of electrons from one point to another on a circuit, current can be calculated using:

$$\mathbf{I = V/ R} \qquad \text{(Ohm's law)} \qquad \ldots\ldots\ldots\ldots\ldots\ (1.1)$$

Current can be increased by raising voltage or lowering resistance. It's measured in Amperes (A), by inserting an ammeter in series with the circuit wiring Fig (1.1), but it is much safer to use a CLAMPMETER, which clamps around the hot wire. Fig (1.2).

3) **Resistance:** is defined as the opposition to electrical current flow through a conductor. The opposition is created by electrons refusing to be stripped from their atoms and sent down to wire. The higher materials resistance, the more energy will take to strip OFF electrons. It's important to point out that conductivity and resistivity (the property that determines final Resistance) are inversely proportional. Fig (1.3).

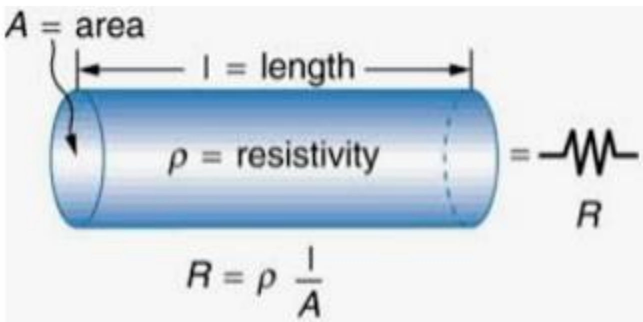


Fig (1.3) Resistance of conductor

The higher Resistance the less current flow. It is measured in ohms (**Ω**), represented by the letter(R); it always followed by the Greek letter Omega (**Ω**).

It can be calculated if the Current and the Voltage are known:

$$\mathbf{R = V / I} \qquad (\Omega)$$

4) **Electrical power** (**P**):

Is mainly classified into two types. They are the DC power and the AC power.

A.C Electrical power

Watts or (active power); is the energy rate per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is (watt, one joule per second). Electric power is usually produced by electric generators, but can also be supplied by sources such as electric batteries for D.C power.

The electric power is divided into two types, the AC power and the DC power. The classification of the electric power depends on the nature of the current.

a) If the Voltage (V) and Current (A) are known use:

Apparent power (VA) = $\mathbf{V \times I}$ (for single phase circuit) ……. (1.2)

b) Power dissipated: if Current and Resistance are known:

$\mathbf{P = I^2 \times R}$ (The dissipation of heat) …… (1.3)

c) If Voltage and resistance are known: $\mathbf{P = V^2 / R}$ …….. (1.4)

The relation between V, I, R, and P are shown in Fig (1.4)

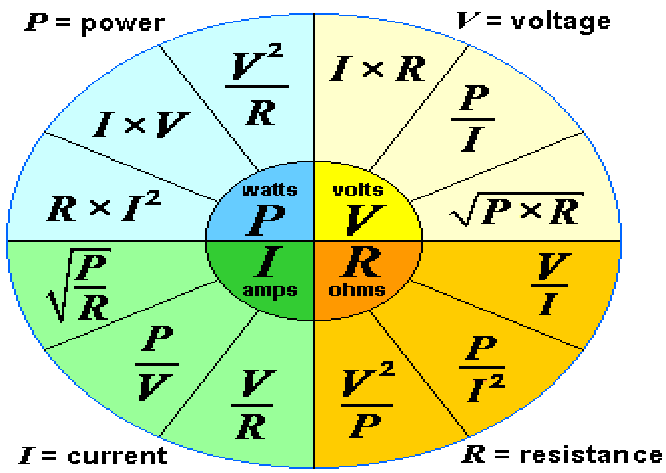


Fig (1,4) relation between V , I , R , and P.

In 3 – phase circuit the Active power can be calculated by;

$$\mathbf{P = \sqrt{3}\, V_L \times I_L \times Cos\ \theta} \qquad ……. (1.5)$$

The relations between active power (**P** Kw), with apparent power (**S** KVA), and Reactive Power (**Q** KVAR) are, as shown Fig (1.5):

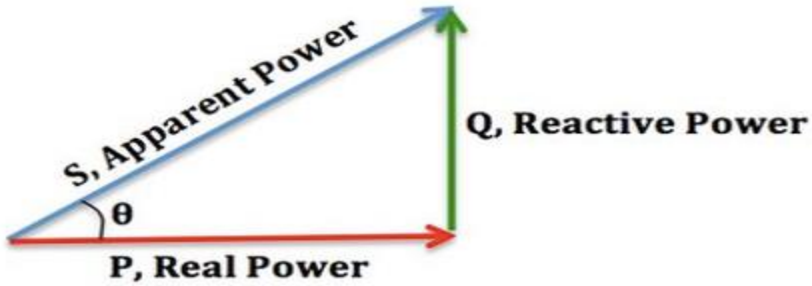


Fig (1.5) **power tringle**

$$S^2 = P^2 + Q^2 \qquad \text{...... (1.6)}$$

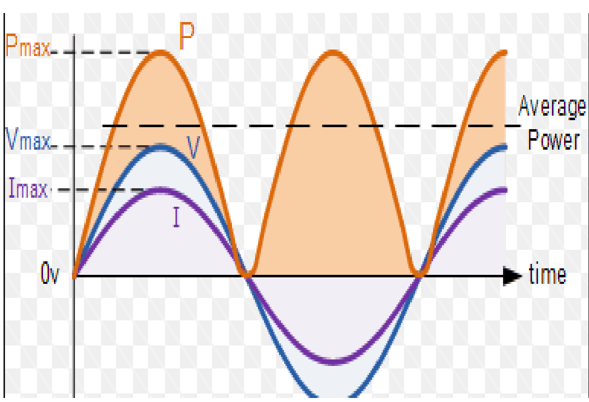
$$S = \sqrt{3} \times V_L \times I_L \qquad \text{....... (1.7)}$$

$$\cos\theta = P / S \qquad \text{.......(1.8)}$$

V_L – Line Voltage. , **I_L** – Line Current

θ power factor angle , such that (P.F): Power factor angle **(P.F) = $\cos^{-1}\theta$**

Also **θ** represent the angle between Voltage and Current. Fig (1.6b)



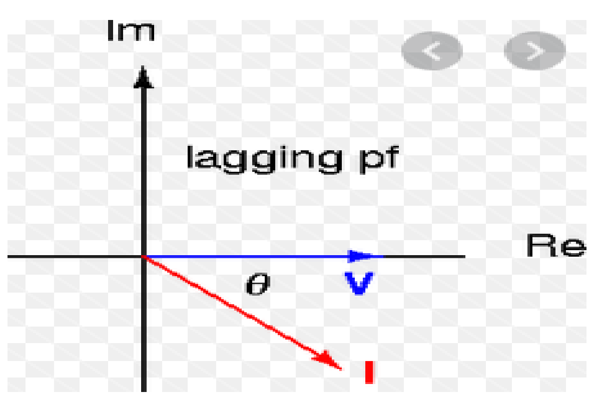


Fig (1.6) (a) Voltage (E), I, &P wave form (b) lagging P.F.

DC Electrical Power

Is the one directional or unidirectional flow electric charge. An electrochemical cell is a prime example of DC power. The electric current flows in a constant direction, The DC power is defined as the product of the voltage and current. It is produced by the fuel cell, battery and generator .Fig (1.7)

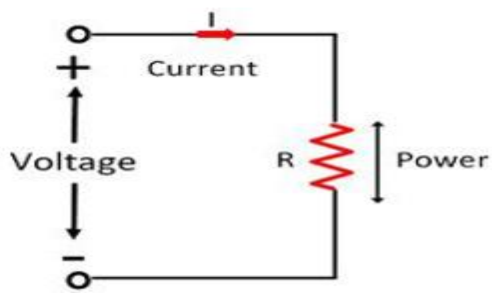


Fig (1.7) **D.C Power**

D .C & A.C Circuits

Electricity that Current flows in one direction is called DIRECT CURRENT (D.C).Although D .C generators do exist d.c, but maybe is normally chemical generated, such as that from a Battery. Fig (1.8)

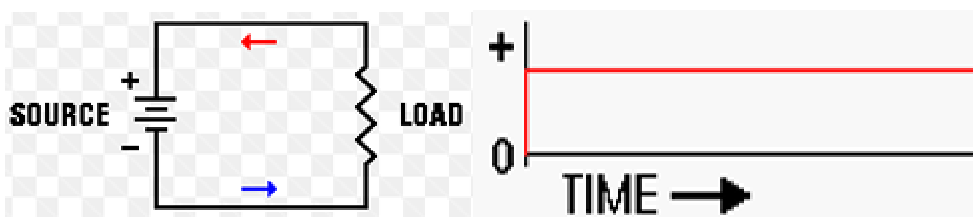


Fig (1.8) D.C circuit

A.C circuit is the work horse of the modern electrical industry, the Voltage alternates back and forth in what is called SINE WAVE ,Fig (1.6a), and unlike D.C circuit, can be easily produced and distributed by generators .Thus, A.C. is that we use throughout our houses to run our plug – in appliances.

Although A.C. originates at power plants and distributed around the country via high Voltage Transmission lines, as far as the house is concerned, electrical Power starts at generation plant and stop at utility transformer (11 KV to 400 V).

For loads such as electric stoves and electric dryers ,we have different load currents simultaneously flowing on both HOT and NEUTRAL conductors ,also the current comes back via the neutral to the transformer ,for 3 – phase of house power ,each phase represents a HOT – BUS in the service panel.

The Neutral Conductor

It is a conductor that normally completes the circuit back to the source. Is connected to earth at two location: The utility transformer and second point at the main panel, that is why sometimes referred to as the neutral conductor. It's designation is BLUE and allowed to be smaller in size (diameter) than the HOT wire. Neutral current is commonly referred to as return current.

Residential Electrical System

Electrical distribution systems for building consist of five divisions Fig (1.9)

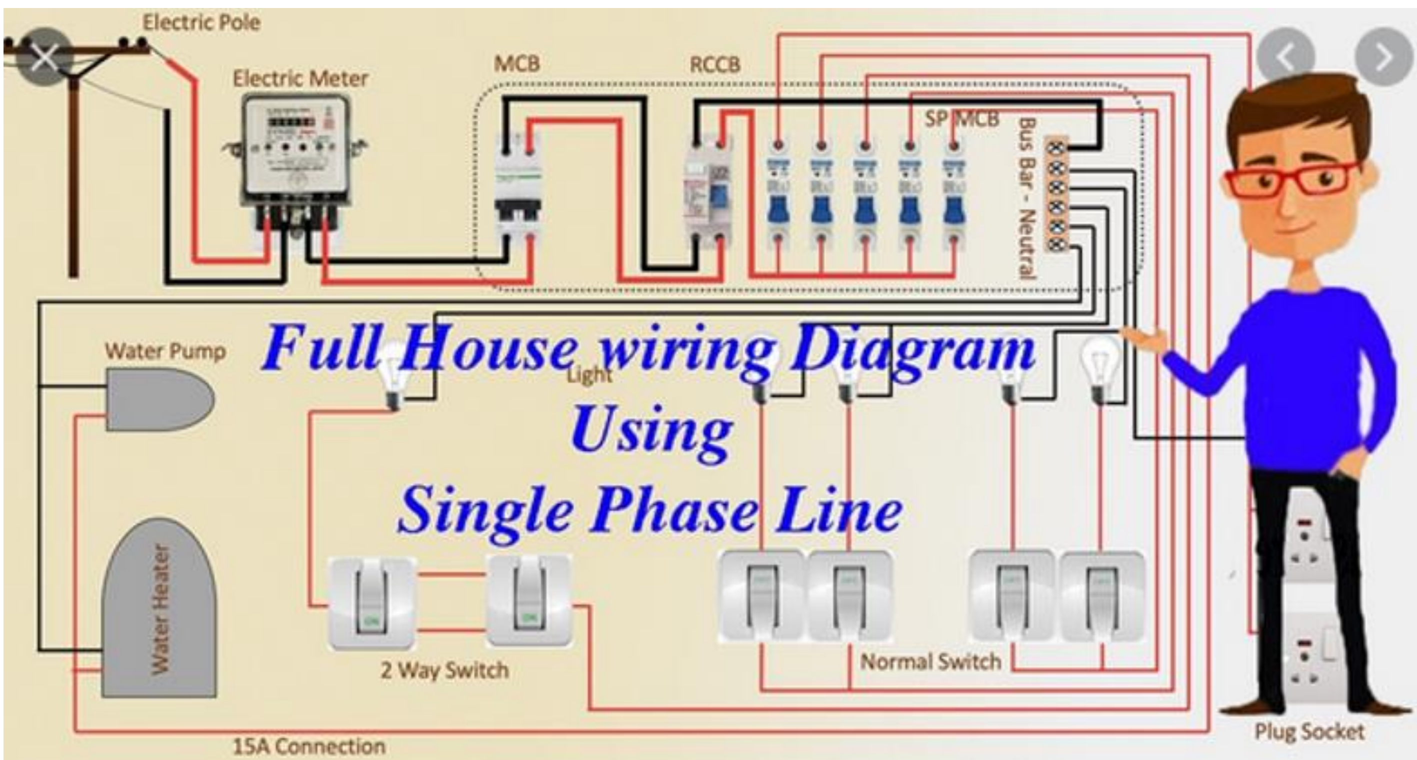


Fig (1.9) House wiring diagram

1) Service entrance :

Including main disconnecting devices, metering equipment (Kw – h), distribution panel boards, and conduit and wiring.

2) Feeder system:

A system of heavy – duty conduits and wiring that carries electric power from the service entrance equipment to the various lighting and power panel – Boards that are strategically located throughout a building.

3) Lighting and Power Panel – Boards :

Metal enclosures which house circuit Breakers (C.B), Fuses, and fused switch connect to all branch circuits which need electrical protection Branch Circuits:

The wiring circuits that receive Power in a controlled manner from the lighting and Power Panel – Boards and carry power to all items of electrical equipment that constitute the electrical load of Building.

Branch circuits usually extend(to/ and) serve all parts of Building .A large Building will have hundreds of Branch circuits running over head, under the floors ,and in walls ,switched and protected as necessary .

4) Electrical load :

Consists of a wide range of electrically operated equipment's, including lighting fixtures , electrical motors ,heaters ,signal system of many types , …etc.

The house wiring begins at the service entrance. A typical house wiring ,drawing (2),once the service wires (cable of size 3 × 16 +10 or 4 ×16 or 3×25+1 6) m.m, enter the masthead (also called weather head), they travel down to steel mast into the meter Base (Kw -h). The service entrance Cable goes directly into main service panel .The panel is where all wiring begins, from there, wires travel to various receptacles, lights, and appliances throughout the house.

The main Panel is where the house electrical system obtains its earth ground via the ground rod.

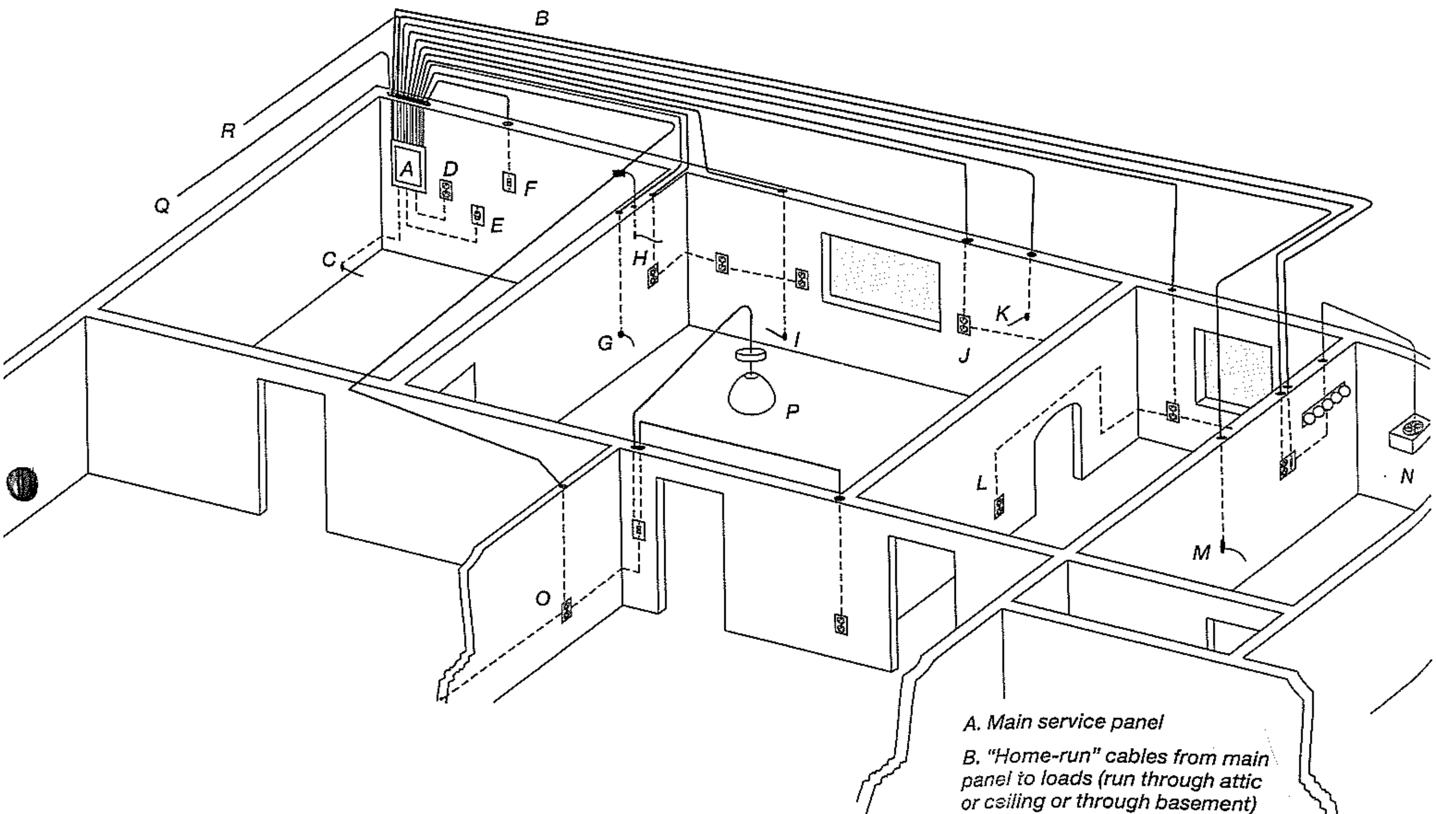
The drawing at left shows some of the main wiring runs, utility room, kitchen, living, and bath room. These rooms are illustrated because each one has its own special requirements. Cables going through walls perform serval different functions, but, all of them can be routed together through same holes in the studs.

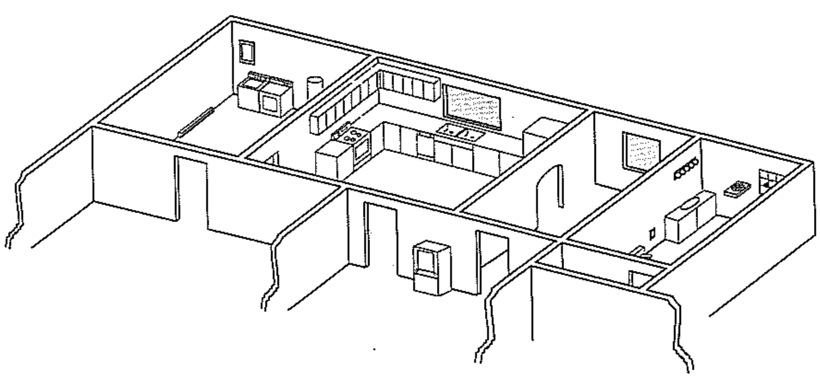
All habitable rooms must have switched lighting at the point of entry.

The Cable enters through the ceiling and connect to a receptacle, which feed other receptacles and Switches in the room. The Smoke – alarm circuit, the Arc – fault circuit are not shown on the drawing. See Fig (1.10).

The Main Wiring Runs in a Residence

Drawing 2





A. Main service panel

B. "Home-run" cables from main panel to loads (run through attic or ceiling or through basement)

C. Cable for baseboard heater (dedicated circuit)

D. Utility-room receptacle (dedicated circuit)

E. Dedicated circuit for dryer receptacle

F. Cutoff switch (optional when in sight of panel) for water heater (dedicated circuit)

G. Range cable (dedicated circuit)

H. Range fan fed off living room circuit

I. Dishwasher cable (dedicated circuit)

J. GFCI-protected receptacles on countertop

K. Refrigerator cable (dedicated circuit optional)

L. Cable for dining-room receptacles

M. Cable for in-wall heater (dedicated circuit)

N. GFCI-protected receptacle and fan

O. Living room circuit

P. Kitchen overhead light powered off living room circuit

Q. Cable for smoke alarms and 3-way light switching

R. AFCI cable for bedrooms and bedroom smoke alarms

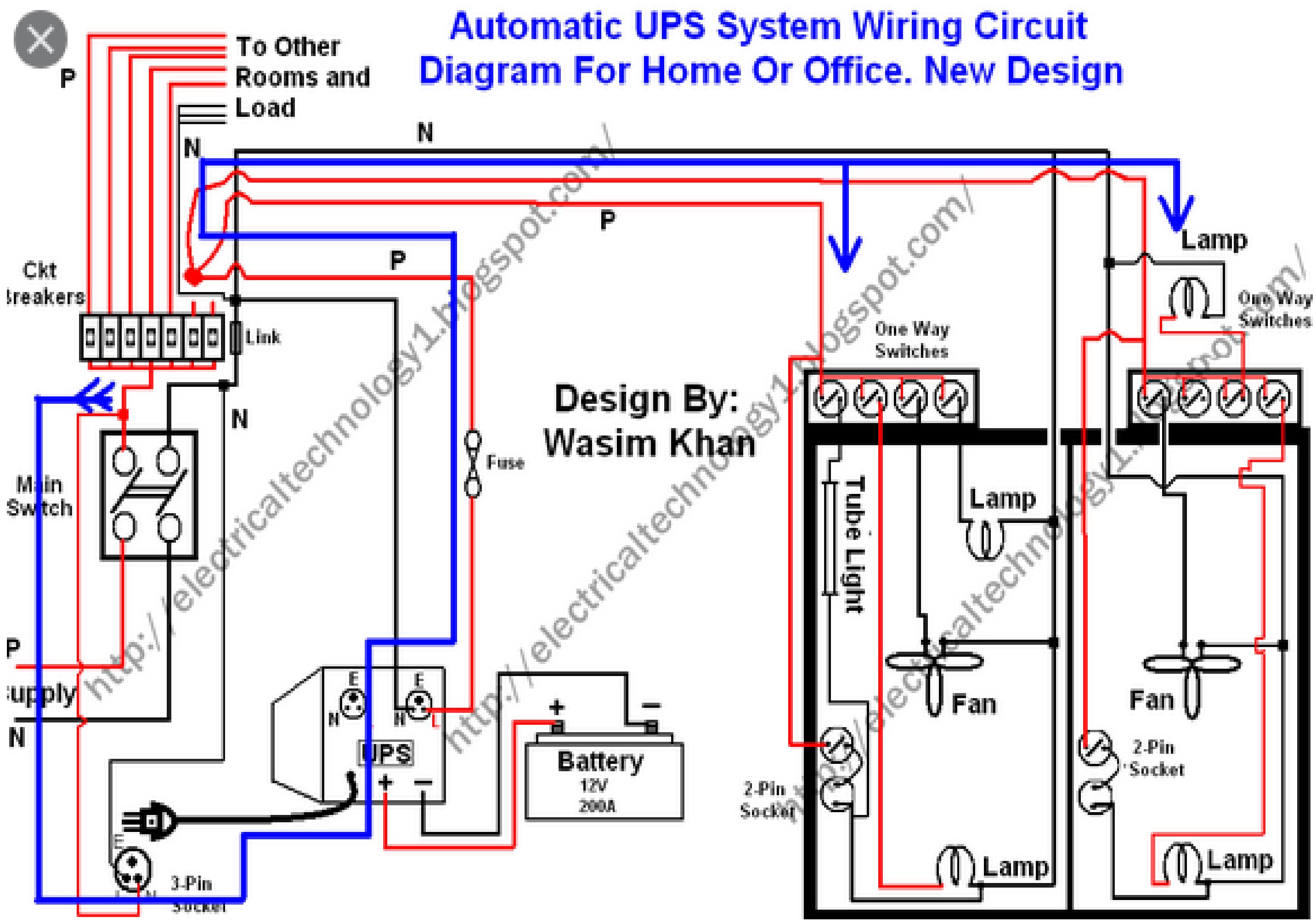


Fig (1.10) wiring circuit diagram .

Separation of power and lighting circuits

Power circuits are separated from lighting circuits due to the following reasons:

i)Faults such as over loading , short – circuits (S.C), …etc , commonly occur on power circuits which can cause unwanted disturbances to lighting circuits if they are connected on the same supply mains. The logic here is if an appliance trips an outlet, the user will not be suddenly in the dark.

ii) Power circuits are designed for more voltage drop than lighting circuits, which reduces illumination output of the lamp.

iii) Life of the lamp decrease with much fluctuation of the line Voltage.

iv) Ground fault circuit interrupters are required for outlets in wet areas, but not for lights.

Comparison of various wiring system

The types of internal wiring are:

1) Cleat wiring Type. 2) Casing and capping wiring. 3) Lead Sheathed Wiring.

4) C.T.S or T.R.S or PVC cover wiring. 5) Conduit Pipe wiring.

Cleat wiring Type

This system consists of ordinary VIR or PVC insulated wires (occasionally, sheaths and weather proof cables) and is gripped and compacted on walls or ceilings by porcelain cleats, plastic or wood. Cleat wiring is a temporary system so it is not suitable for home premises. Use of cleat system is over nowadays. Fig (1.11) .

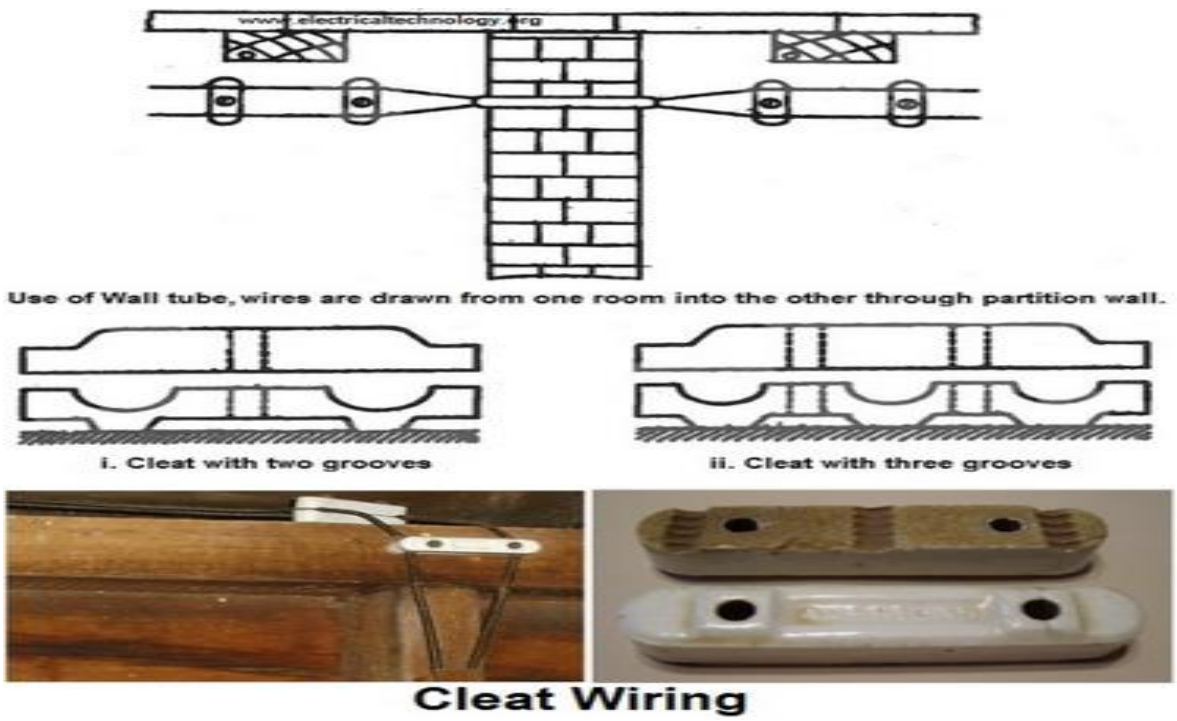


Fig (1.11) Cleat wiring type

Advantages of cleat wiring:

- It is a simple, cheap wiring system. and installation is easy
- Most suitable for temporary use, i.e under construction building or army camping.
- As the cables and wires of the cleat wiring system are in the open air, therefore fault in cables can be seen and repair easily.
- Customization can be easily done in cleat type e.g. alteration and addition.
- Inspection is simple and easy.

Disadvantages of cleat wiring:

- Appearance is not so good.
- Not be used for permanent use, Sag may be occur after sometime of the usage.
- In this wiring system, cables and wiring are in the open air, therefore, oil, steam, moisture, smoke, rain, chemical and acidic effects damage the cable and wires.
- Cleat wiring is not stable due to the risk of weather effects, fire and wear.
- It can be only used on 250/440 Volts on low temperature.
- There is always a risk of fire and electric shock.
- It can’t be used in important and sensitive location and places.
- It is not a stable, reliable and durable wiring system.

Casing and capping wiring

Casing and capping system was a popular wiring in the past, but it is not considered in our days because exist of Pipe and sheathed wiring system. Cables used in this wiring type were either VIR or PVC or other approved insulated cable .Fig (1.12).

The cables were carried through wooden casing enclosures. The casing is made up of a wood strip with parallel grooves cut length wise so as to accommodate VIR cables. The grooves were made to separate opposite polarity. The capping (also wood made) used to cover wires and cables installed and fitted in the casing.

Fig (1 .12) Casing and Capping type

Advantages of casing capping wiring:

- It is cheap wiring system as compared to sheathed and conduit wiring systems
- It is a strong and long lasting - wiring system.
- If the phase and neutral wire are installed in separate slots, then repairing is easy.
- Stay for long time in the field due to strong insulation of capping and casing.
- No risk of electric shock due to covered wires and cables in casing & capping

Disadvantages Casing Capping Wiring:

- There is a high risk of fire in casing & capping wiring system.
- Not suitable in the acidic, alkalis and humidity conditions
- Costly repairing and need more material.

Lead Sheathed Wiring

This wiring type employs conductors insulated with VIR and covered with an outer sheath of lead-aluminum alloy containing about 95% lead. This metal sheath cable protection from mechanical injury, dampness and atmospheric.

The entire electrical current is insulated and connected to earth at the entry point to protect against electrolytic action due to the leakage of the flow and to provide protection if the cover is alive. The cable is operated on a wooden bat and is fixed by link clips just like the TRS wiring.

Fig (1.13) Lead – sheathed wiring type

Batten Wiring (C.T.S or TRS) system

Group of Single or double or three core cables are used to be laid on straight teak wooden batten .Cables are hold with help of tinned brass link clip or buckle clip. Brass pins are used to fix the buckle clips on the wooden batten. Fig (1.14).

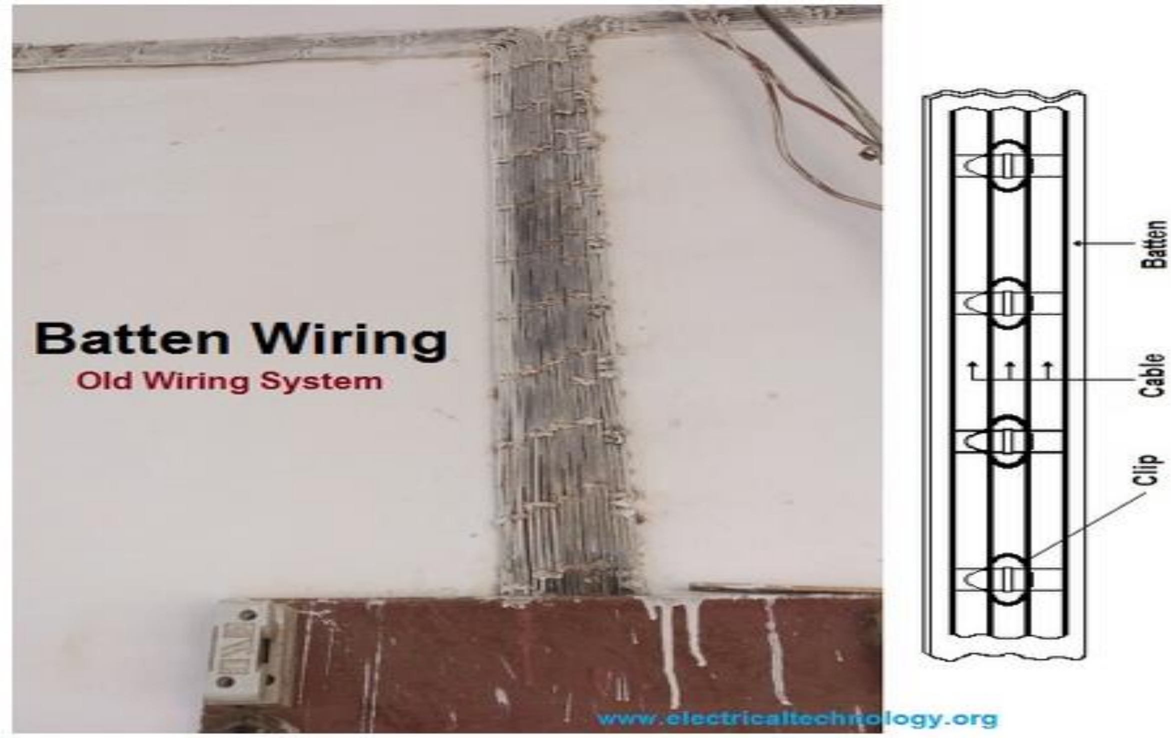


Fig (1.14) Batten Wiring (C.T.S or TRS) system

Batten Wiring Advantages

1 –The current leakage is very rare.

2– It is installed very quickly.

3 – The fault is found easy.

4 – This is simple wiring system.

5–Alternations are possible.

Batten Wiring Disadvantages

1 – The weather effects are directly attack on this wiring system.

2 –Risk of fire and mechanical injury is possible.

3 –Is installed only up to 220V.

Pipe wiring system

This conduit wiring type used a pipe to protect and route electrical wiring in a building or structure. Conduit pipe may be made of metal, plastic, fiber, or fired clay. Most conduit is rigid, but flexible conduit is used for some purposes. Fig(1.15).

Fig (1.15) Pipe Conducting type

Advantages

- Allows adding new wiring to an existing building without removing or cutting holes into the drywall, lath and plaster, concrete, or other wall finish.
- Allows circuits to be easily locatable and accessible for future changes, thus enabling minimum effort upgrades.

Disadvantages

- Appearance may not be acceptable to all observers.

Pipe Conducting Type is one of the most popular, beautiful, robust and common electrical wiring systems of today.

Table (1.3) Comparison of different Wiring System

S. No.	Particulars	Cleat Wiring	Casing and Wiring	Lead sheated Wiring	C.T.S. /T.R.S. Wiring	Conduit pipe Wiring
1.	Protection from mechanical damage	None	Fair	Fair	Good	Very good
2.	Protection from fire	No protection	Bad	Good	Fair resistance	Very good
3.	Protection from dampness	No protection	Little	Good	Excellent	Fair
4.	Cost	Cheap	Fairly expensive	Expensive	Cheap	Very expensive
5.	Life	Short	Fairly long	Long	Long	Very long if erected carefully
6.	Types of labour required	Skilled	Very superior	Superior	Semi-skilled	Superior
7.	Appeara-nce	Bad	Fair	Good	Good	Very good
8.	Nature of applicati-on	Temporary	Domestic	Service mains	Domestic, office buildings	Very good Worksh-ops
9.	Repair, extensions or renewals	Easy	Difficult	Difficult	Very easy	Very difficult
10.	Time requires for erection	Short	Fairly long	Fairly long	Very short	Long
11.	General realibility	Poor	Good	Fair	Very good	Very good

Testing of Wiring Installation

Whenever a wiring system is installed it must be tested before connecting to electrical supply.

A MEGGER; is an instrument used to perform the testing. Which generates direct current D.C of low value when its handle rotated and measure high insulation resistance by sending a high voltage signal into the tested object, wire, generators, and motor windings which connected a cross its terminals . Fig (1.16).

Fig (1.16) Megohmmeters, Megger

There is a scale on which a needle moves to indicate the Resistance .Its scale is from ZERO to very high value (say 1000 **Ω**) and goes up to 20 M **Ω.**

The undermentioned tests which are generally conducted on the wiring installation before it is actually connected to the main supply, to ensure the installation is technically sound and free from any possible short circuits .the main reasons of testing are as follows

1) To know the failure cause of a particular circuit or equipment and to locate the exact break down position.

2) To ensure that it is free from faults and is as per electricity rules.

3) Tests will receive owner attention before any possible undue damage occurs.

1) Insulation Test between Conductors (L & N) and Earth

This test is performed to know the insulation standard of wires and cables used in the installation .It also ensures that insulation is sufficient enough to avoid any possible earth current leakage. The earth leakage current should not exceed 0.02% of the full load current.

Before performing insulation resistance test between conductors and earth the conditions to be fulfilled for the position of Main Switch, fuses, switches, and other points should be as follow:-

1) Main switch in OFF position. 2) All switches in ON position

3) Fuses beyond the main switch should be in position (INTACT IN).

4) All lamps and other equipment should be in their position (connected)

5) Wall Socket &Power switches, not appeared in Fig (1.17), must be (S.C)

To perform this test, the phase (L) and the neutral (N) is short-circuited temporarily at any suitable point as shown Fig (1.17).

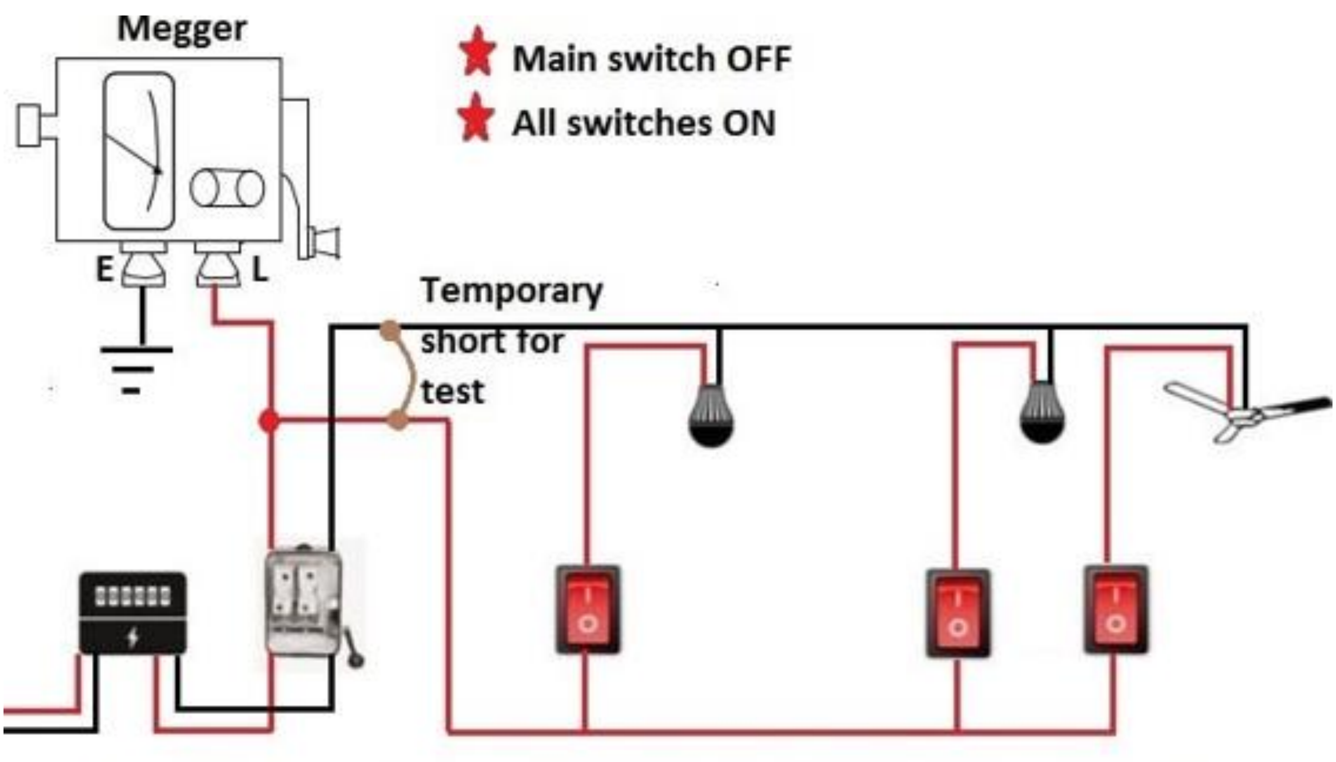


Fig (1.17) **Insulation Test Between Conductors and Earth**

The Line (**L)** of megger is connected to the (S.C) point of main switch, and earth terminal (**E**) is connected to earth point. Tester handle is turned at a high speed so that sufficient testing voltage is produced. Reading on dial of megger is noted.

The insulation resistance which measured should not be less than 0.5 MΩ on a fixed wiring. If insulation resistance is below this value, wiring section giving that value should be rewired or checked thoroughly until required value is obtained.

2) Insulation Test between Conductors

All (S.C) wires connected between (L&N), Wall Socket, and Power switches during previous test (Test N_o 1) should be removed. To ensure that insulation value between line (L) and Neutral conductors (N) of the cables or wires is not damaged and there is no leakage between them, this test is performed. Before test performing, position of main switch, fuses, switches, etc. should be as following:

1) Main switch in OFF position. 2) All switches in ON position

3) All lamps and other appliances should be removed,

4) Fuses beyond the main switch should be in position (intact in).

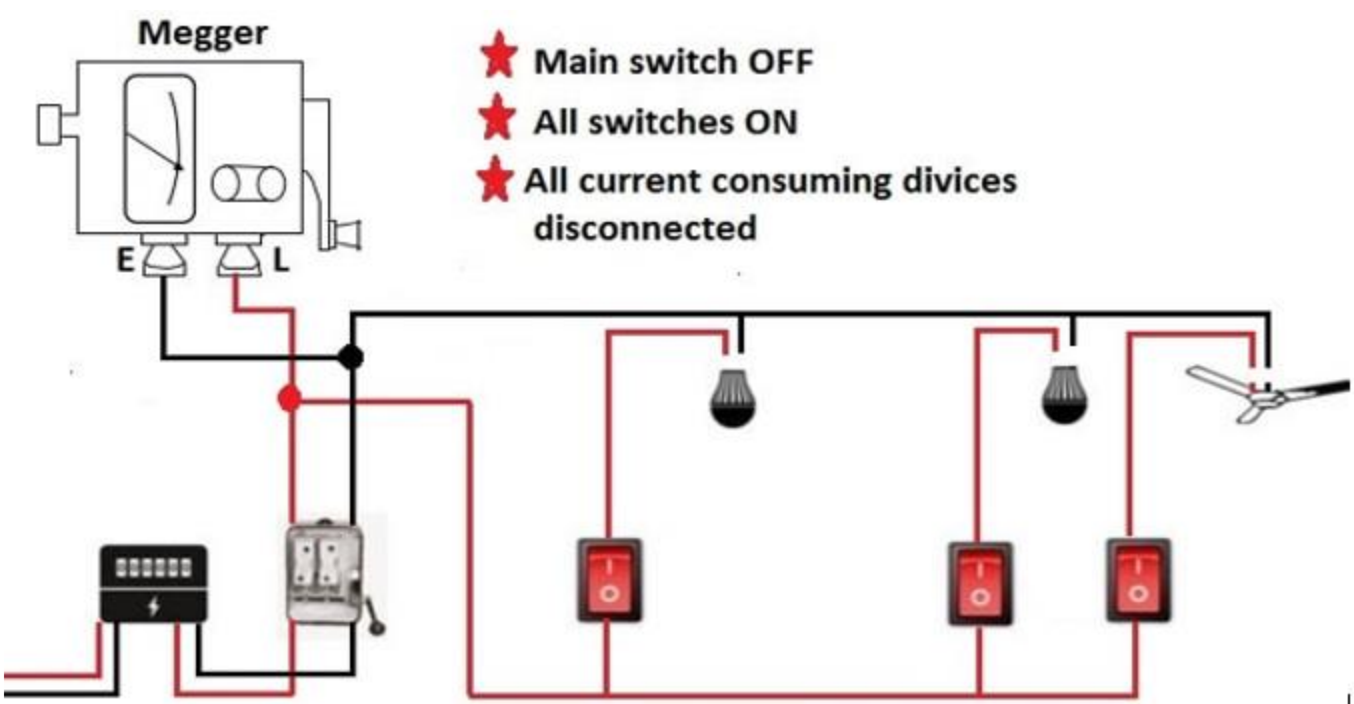


Fig (1.18) Insulation Test between Conductors.

In this test, Fig (1.18), megger scale must shows not less than **1 MΩ (**insulation resistance value), but if the reading is near ZERO, it means there is a short circuit (S.C) in the wiring installation which must be removed.

3) Earth Continuity Test

This test is done to confirm the earth continuity of the conduits and that are properly connected to the earth. If the insulation of any wire breaks down, the leakage current will start to flow, therefore the wiring in the metal pipes will start giving shocks, it is also possible that the joints become loosen or separated, which increase the resistance in the earth circuit, Fig (1.19). In this test, main switch is OFF, main fuses are withdrawn, all switches are (ON) and all lamps are put in position.

Line terminal of megger (**L**) is connected to hot wire of Main Switch and earth wire (E)of megger is connected to earth wire.

If the megger shows **ZERO** reading, it means that the conduit is properly earthed , but if the megger shows a high reading (more than 1 MΩ), it means that the main switch or conduit is not properly earthed or the earth wire is broken somewhere requiring correction**.**

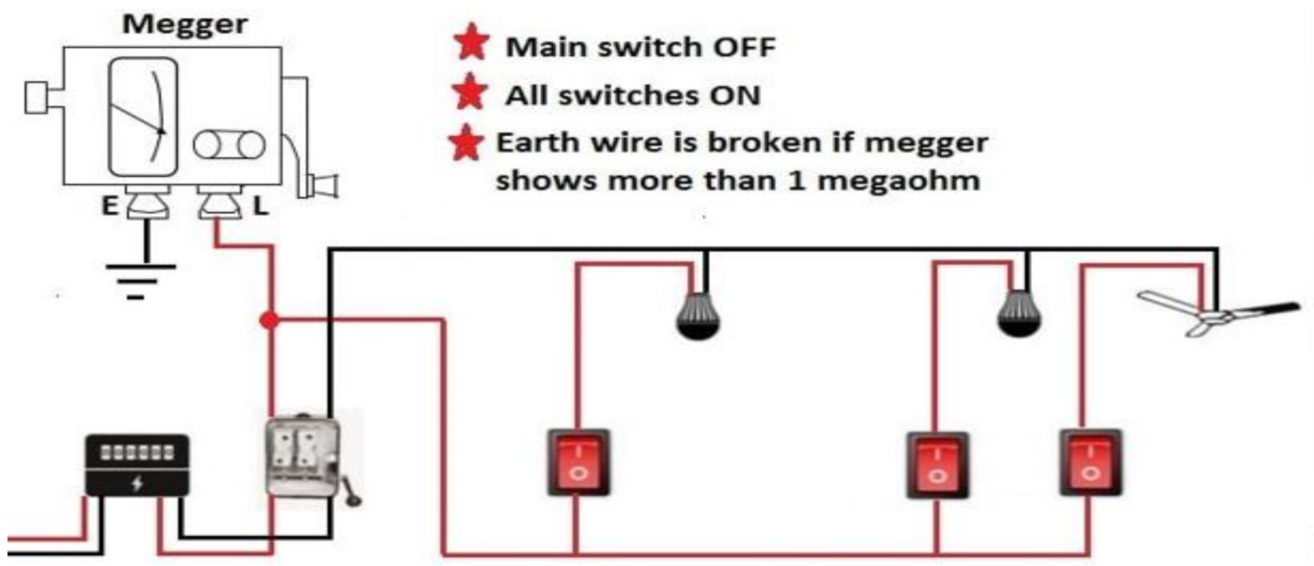


Fig (1.19). Earth Continuity Test

4)Polarity Test of Wiring

This test is only performed if the wiring in above 3 Test is found satisfactory. In a low voltage installation, this test is performed to verify that all single pole switches have been connected to (Hot line L) throughout the installation. So that when a switch is made OFF, the connected appliance is quite dead. If switch is connected to neutral (N) then appliance will get phase even a switch is OFF and remain alive.

There is absolutely no difference in the functioning of the switch in either case, but from the safety point of view to avoid shock, the phase should always be given through the switch and neutral direct to the point. The simple method of conducting the polarity test is by using a test lamp. Before performing this test main switch position, fuses, switches, etc. should be as following, Fig (1. 20):

1) main switch in ON position, 2) all switches in OFF position

3) All lamps and other appliances should be removed.

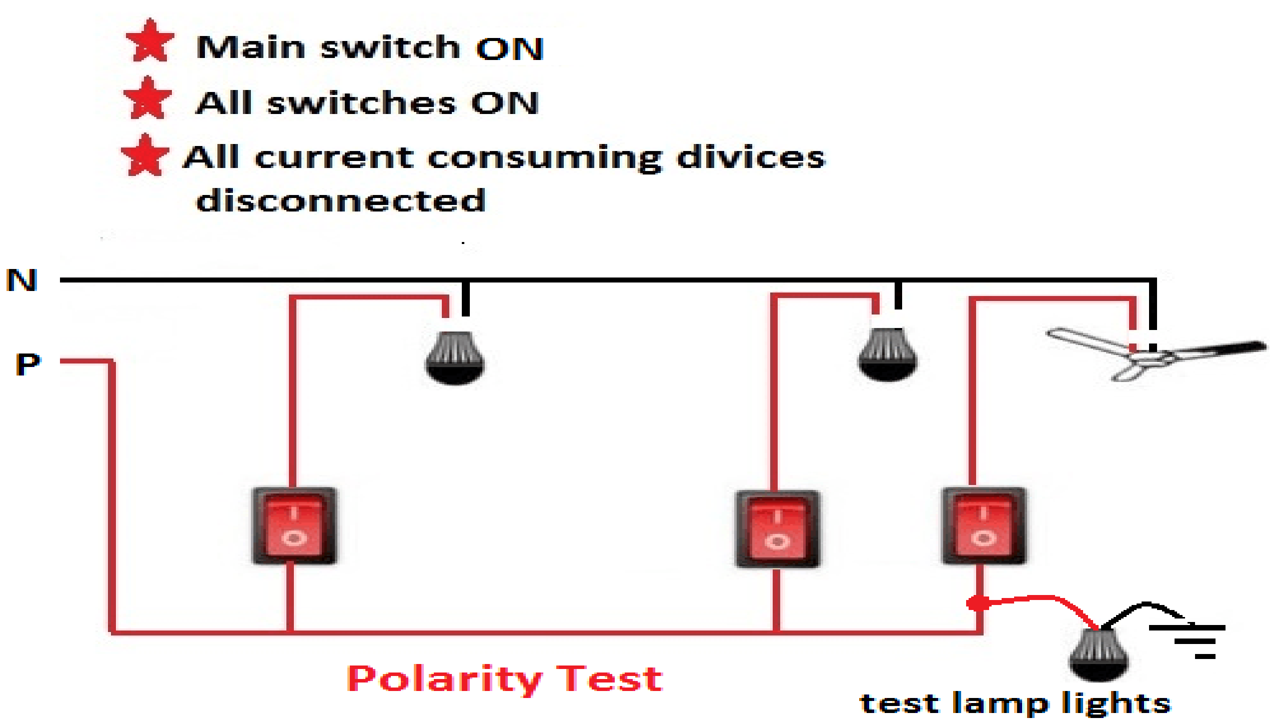


Fig (1. 20) **Polarity Test of Wiring**

One end of the test lamp is connected to earth wire and the other end to the incoming terminal of the switch. If the lamp lights, it indicates that the switch is connected to phase wire, otherwise to neutral wire**.**

Determining The Minimum number of Lighting Circuits

The load permitted for dwelling Units is (3Watt) per square Foot (= 0.093 m) of occupied area for general lighting .The calculated Load for the total occupied area (2582 Ft^2 = 240 m^2) is :

2582 Ft^2 × (3Watt / Ft^2) = 7746 Watt.

The total required amperage is determined as:

Amperes (**A**) = Watts (**W**) / Volts = 7746 /230 = 33.678 Amp.

Where; 230 is A.C. phase Voltage for lighting Circuits.

If the Circuits Rating is 10 amp. : The min. **No** of required Circuits **=** The total Amperage divided by Ampere Rating of each Circuit:

33.678 / 10 = 3.3 OR →→ 4 Circuit min.

i. e 4 Circuit is the min. number of Circuits may be used if desired.

The Residence plans show that (12), in general, lighting Circuits are actually used.

Electrical Service Switch

The purpose of Main Electrical Service Switch is to disconnect all the electric service in the building except Emergency equipment (e.g Fire system).It must be located at the entrance point.

1) Switches (Isolator):

Is an electrical switch device intended for ON - OFF control of circuits, and for electrical isolation of Equipment. Switches are rated by Current, Poles, Voltage, duty, fusibility, and enclosure; following various Switch types, Fig (1.21), can be classified as:

a) Surface Switch (Single way, 2 – way, 3 – way) **b**) Flush Switch

c) Grid Switch **d**) Push – Button Switch **e**) Dimmer Switch

f) Industrial (Iron – Clad) Switch **h**) Quick – Break Knife Switch

2) **Single – pole Circuit Breakers**:

Single – Pole Breakers control currents on loads that use only one leg of the incoming (230 V), standard single pole Breakers come in(1,2,4,5,6,8,10,12,15,16, ,20,25,30,32,40,50,60,63,80,100) Amps, most people rarely use anything other than (10,15,&20) Amps, Fig (1.22) , shows 1 Pole C.B's.

3) Double – Pole Breakers:

Double – pole Breakers ; which rated at (230 V),they normally consist of Two legs, one is the hot line (L) and other is Neutral(N).If we added Two Single Pole (L+L) Breakers with one handle and a shared internal Trip mechanism we obtained (380 V) 2 phase Circuit Breakers, see Fig (1.23).

4) **Multi – Case Circuit Breakers (MCCB)** :

Multi (or Molded) case C.B. (3 or 4) poles Circuit Breakers are switches that can carry rated load (rated current) continuously and can interrupt over load current without injuring the switch ,normal 3 – phase current ratings are:

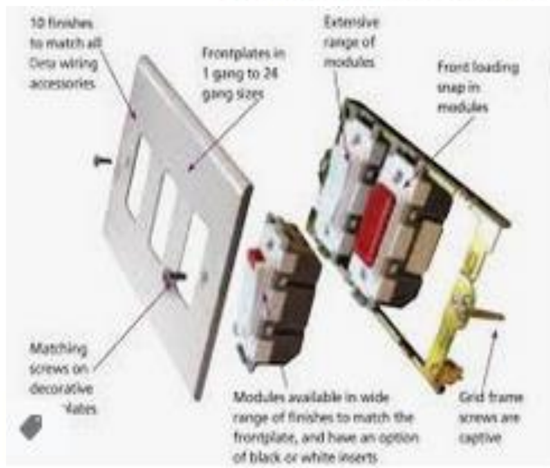
(20,25,30,40,50,60,63,80,100,125,150,200,250,300,400,500,600,630,700,800, 1000,1200,1500,2000,2500, &3000) Amps. And also operated manually.

Also Neutral (N) be added to obtained (3 Ph+N) C.B., sometimes called 4 pole Circuit Breakers, as shown Fig (1.24b) .

AC isolator switch 3P 63A FAIS ...

Surface Mounted Single 25...

Flush Switch 20A - Baumanns Of Still...



Deta G3402 Gridswitch 2 Module Mountin...

Push Button Switch

GE 18019 Knob-Style Single...

Industrial light switch (...

Knife Switches, चाकू स्विच, नाइफ ...

Fig (1.21) Isolator & different types of switch

Fig (1.22) Single – pole (C.B) **Fig (1.23) 2– pole Circuit Breaker**

Fig (1.24) Multi Case Circuit Breakers (MCCB) (a) 3Phase, 3pole **(b)** 3Phase- 4 pole

The Main Distribution Panels

The main panel has several important functions:

1 – It serves as a distribution center for all Branch circuits.

2 – It houses all over –Current devices that protect individual branch circuits.
3 - It houses a Switch that you can manually throw to cut OFF all out going electrical Power from the Service Panel.

Elements of the Main Panel:

The most important sections of the Main Panel are;

A) Main Breaker B) The hot Bus

C) Neutral Bus D) Grounding Bus , see Fig (1.25).

A) Main Breaker; also called the main disconnect Switch or just (The MAIN) ,is normally located at the top of Main Panel ,all the power that comes into the house goes through this switch . All adults in the home should know what this switch does and where it's located. Although it can be used as a(manual disconnect). The Main Breaker is over current protection device.

The Main Breakers disconnects incoming Power from Buses .It monitors the total current amount coming into the house so that it can't exceed the current capacities of Cable, Meter Base, this amount, in Amps, is written on the Breaker.

B) Hot Bus; The Main Breakers transfers Power to Hot Bus , which consists of TWO copper strips ,they are located immediately below the main ,run down to the Panel center, each Hot leg has a row of tabs that allow for the insertion of Circuit – Breakers . Hot Bus takes the power and distributes it to circuits.

C) Neutral Bus (N); It's provides a common return point for current after the load has used it. Neutral Bus consists of two long aluminum or copper strip with many screws; they are usually located on the outer edges of Hot Buses.

D) Grounding Bus; Even though the Neutral is grounded at utility transformer, an additional ground is provided at the main panel, this is ground Rod connection and it is normally a large – diameter solid copper wire(10 or16 m.m) gauge.

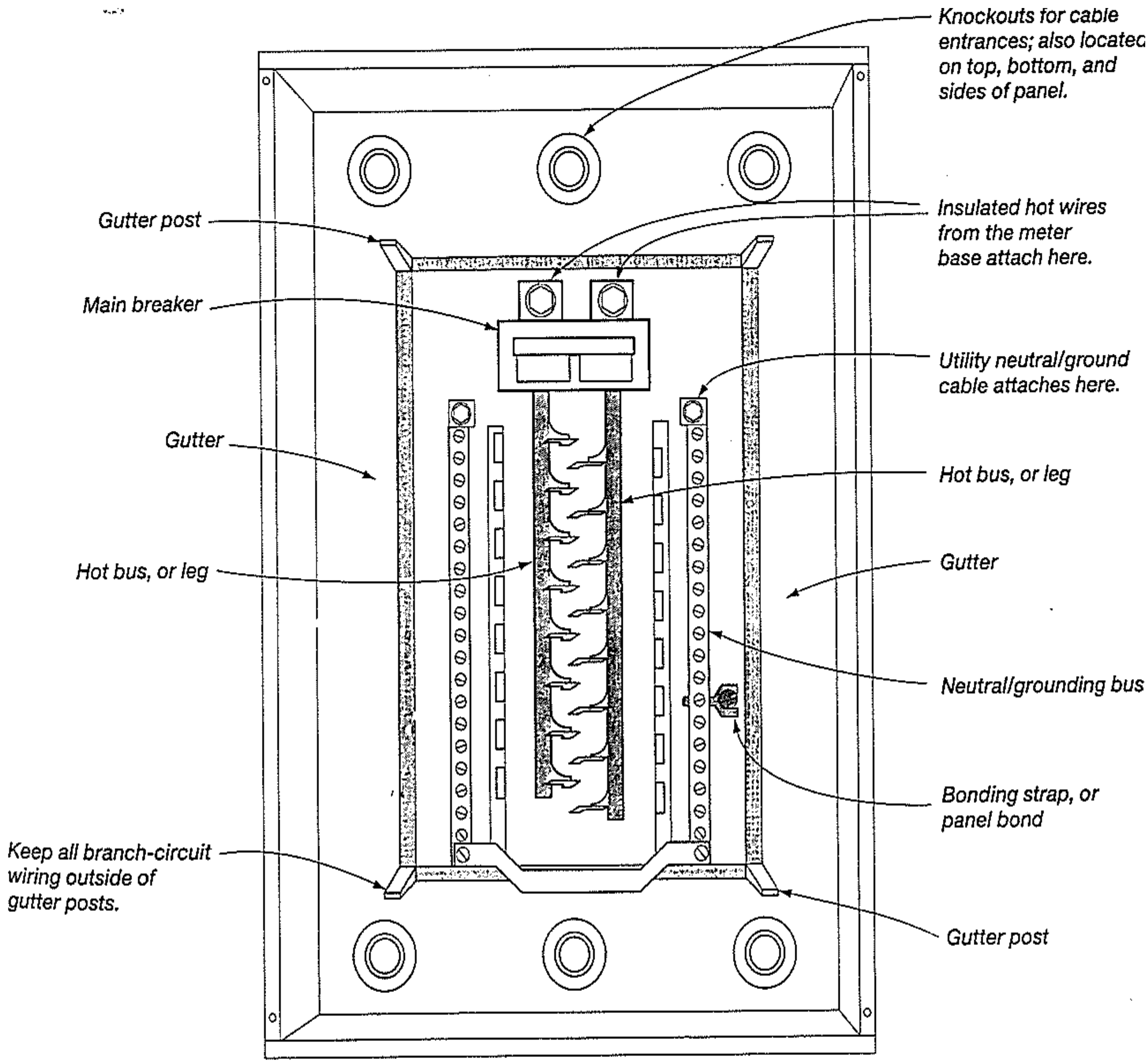


Fig (1.25) Main Distribution Panel

Main Panel Design

While circuiting the loads a Panel schedule is drawn up which lists the circuit numbers ,load description, Voltage, Wattage,the Current rating and the number of poles (C.B.) of the circuit protective device feeding each circuit.

Spare circuits are included to the extent that the designer considers necessary and consonant with economy,(normally not less than20%) of the active circuits ,spares are left for future Circuit Breaker in the same quantity (i.e =20) as the number of Spare circuits.

Panels are normally manufactured with Even numbers of Poles.

In calculating Panel loads to choosing the Cable, the official electrical load is sized according to NEC (National Electrical Code) guide lines.

Once you know the building load (or house) you can choose the correct size of the Meter Base (KWh), Cable, and Main C.B.

A figure of the load for 2000 Sq. FT house:

1- Calculate the square footage of the house excluding un – inhabited areas ,such as unfinished attic ,garage ,and Carport, to obtain the general lighting requirements .Multiply the square footage by 3 to obtain the power required ;

$$2000 \times 3 = 6000 \text{ Watts} \quad , \text{OR} \quad \text{VA.}$$

2 – Add; 1500 VA for each small appliance circuit in Kitchen (a minimum of TWO is required by the NEC code).

Then add 1500VA for the laundry, excluding the dryer; Total = 4500 VA.

3 – List all appliances to be included and write down their Power rating in VA or Watts, some common appliances include a dishwasher 1500 VA ,water heater 3000 Watts ,clothes dryer 2000Watts,water pump 500Watts .

Let’s assume that the total in this case is 10000 Watts;

4 –Add the numbers up; 6000 + 4500 + 10000 = 20500 Watts.

Because all loads don’t operate at the same time, take the first 10000 at the face value, then take 40% of the rest;

$10000 + (0.4 \times 10500)$.

5 – Add the power of only the heating unit or the air conditioner, whichever is the larger, and add it to the total load, the air – conditioner load is 8000 VA.

$10000 + (0.4 \times 10500) + 8000$.

6 – Divide the total wattage by the service Voltage (230V) to find the total electrical current of the house;

Using the standard Wire Gauge (SWG) Table to find the size of a single phase or 3 – phase load Cable , 3 – core Cable is the best .

Example (1):-

Assume a single floor of an office building (100 × 200) Ft. Assume further that 15 % of the area is corridor and storage. Calculate the number of Panel Circuits, and Feeder size, assume a good grade construction.

Solution:

Office Space $85\% \times (100 \times 200) = 17000$ Ft^2

Corridor and storage $15\% \times (20000) = 3000$ Ft^2

With respect to minimum loads , the Code specifies that they be increased by 25 % of loads, if loads are continuous (3 or more hours), this requirement allows for Breakers to heat up in panels while carrying continuous load, for C.B which are ambient compensated, are rated to carry 100 percent load ;

Office load : $17000\ Ft^2 \times (5\ Watt / Ft^2) = 85$ Kw

Storage : $3000\ Ft^2 \times (0.5\ Watt / Ft^2) = 1.5$ Kw

To calculate the minimum Feeder capacity, the 25 % additional Capcity for continuous load added: 1.25×86.5 Kw = 108 Kw

Because of the large building size, 3 – Panels are required to keep branch circuit below 100 Ft in length.

To utilize an initial branch circuit loading of 1300 Watt per Circuit:

Therefore N_O of 1Pole C.B = 86.5 Kw/1300 w = 66.5 → 67 → = 68

(Must take even Number).

Since this building is of good grade construction, we anticipate 40 % expansion:

40 % × 68 = 27 Circuits, the additional Circuits are provided for future receptacles. NOW:

Lighting + Receptacles: 68 + 27 = 95 Circuits.

Spares 20 % : = 20 Circuits.

Total number of Circuits: 95 + 20 = 115 Circuits.

Each Panel would then: 115 / 3 = 38 Circuits.

If we take 4 – Spares: →→ N_o of Circuits: 38 + 4 = 42 Circuits.

Assuming EVEN distribution of Panel load:

38 C.B × 1300 Watt = 49. 5 Kw.

\+ 25 % future growth = 12.5 Kw.

Total Feeder load = 62 Kw.

Thus, from above the feeder current is: $\mathbf{Kw = \sqrt{3}\, V_L \times I_L \times Cos\theta}$ **(Cos θ = 0.75)**

$6200 = \sqrt{\mathbf{3}} \times \mathbf{380} \times \mathbf{I_L} \times 0.75$

$\mathbf{I_L}$ = 6200/493.634 = 125. 59 Amp. Use (SWG) Table to select Cable gauge.

Example (2):- (Single – phase feeder size) .

In an office building , lighting Panel serves 6000 Ft^2 of floor area ,and has a connected load of 28000 VA; This consists of 20 Branch Lighting and receptacle circuit which are each controlled and protected by 1 Pole C.B's

In foreseeable future, a growth in connected of 80 % is anticipated, and feeder with Panel capacity is to be installed now to handle 1.5 of this growth.

Electrical system is 1 phase 230 Voltage. Find the size of feeder conductors.

Solution: 1 – Connected Load: = 28000 VA

2 – Add 4(1 pole) Spare C.B of 1400VA: 1400 × 4 = 5600 VA

3 – Add 6 pole spaces for future load of 1400VA: 1400 × 6 = 8400 VA

4 –Total load → → → → → → = 42000 VA

For future load, this is somewhat more that required, but for this size Panel (28 to 30 Poles) Four (4) Spares should be the minimum.

The Six (6) spaces could be reduced to (4) spaces, but very little cost reduction would result, so let us settle on 4 – Spares and 6 – Space.

The total load = 42000 VA

Since our building is an office building, the lights may well be 100 % on at time; But t receptacle and other load (Coiffeurs, water coolers, Computers, copy machine, … etc) will not reach anywhere near 100% usage.

Let us assume a demand Factor of 90 %. Feeder design Load is then:

42000 VA × 0.9 = 37800 VA , Feeder Amperage is then equal to:

I = 37800VA /230V = 164.34 Amps, use (SWG) to select 1 – core feeder.

Table . PANEL BOARD WIRING
Plain copper conductor PVC Insulated Unsheathed 650/1100 V Single Core

Area sq. mm	*Conductor construction*	*Conductor dia. mm*	*Max Resistance ohm / km at 20° C*	*Insulation thickness mm*	*Nominal Cable dia. mm*	*Current rating Amps.*
0.50	16/0.2	0.94	37.10	0.6	2.2	4
0.75	24/0.2	1.20	24.70	0.6	2.5	7
1.00	32/0.2	1.34	18.50	0.6	2.6	11
1.50	48/0.2	1.64	12.70	0.6	2.9	14
2.50	80/0.2	2.08	7.60	0.7	3.5	19
4.00	56/0.3	2.61	4.71	0.8	4.3	26
6.00	85/0.3	3.50	3.073	1.0	5.6	30
10.00	140/0.2	4.60	1.866	1.0	6.7	33
16.00	101/0.45	5.90	1.150	1.2	8.4	41
25.00	168/0.45	7.60	0.6911	1.40	10.50	54
35.00	220/0.45	8.70	0.5277	1.40	11.60	66
50.00	325/0.45	10.60	0.3572	1.60	13.90	85
70.00	440/0.45	12.30	0.2639	1.60	15.50	115
95.00	485/0.50	14.70	0.2040	1.80	18.50	140
120.00	614/0.50	16.70	0.1530	2.00	20.90	160
150.00	943/0.45	18.30	0.123	2.00	22.50	189
185.00	925/0.5	20.00	0.101	2.20	24.60	240
240.00	1221/0.5	23.00	0.0763	2.20	27.60	300

Note: Cables above 4 sq.mm. are not covered by IS : 694.