5.4 BATTERIES

Low carbon technologies are necessary to address global warming issues through electricity de-carbonization, but their large-scale integration challenges the stability and security of electricity supply. Energy storage can support this transition by bringing flexibility to the grid but since it represents high capital investments, the right choices must be made in terms of the technology and the location point in the network. Most of the potential for storage is achieved when connected further from the load, and Battery Energy Storage Systems (BESS) are a strong candidate for behind-the-meter integration. This work reviews and evaluates the state-of-the-art development of BESS, analyzing the benefits and barriers to a wider range of applications in the domestic sector. Existing modelling tools that are key for a better assessment of the impacts of BESS to the grid are also reviewed. It is shown that the technology exists and has potential for including Electric Vehicle battery reuse, however it is still mostly applied to optimize domestic photovoltaic electricity utilization. The barriers to a wider integration are financial, economic, technical, as well as market and regulation. Increased field trials and robust numerical modelling should be the next step to gain investment confidence and allow BESS to reach their potential.

Main Components and Working Principles

A battery is a device capable of converting electrical energy to chemical energy and vice-versa via oxidation-reduction (redox) reactions. The base element of a battery is the cell, which is composed of two electrodes (one positive, one negative), the electrolyte, and a separator. During the charging process, a voltage difference is applied between the two electrodes, imposing the current to flow in a certain direction. The consequent excess or deficit of electrons at the electrodes generates reactions between the molecules at their surface, in the electrolyte. The latter consists in the liquid or solid substance in which the electrodes are immerged. Its role is also to enable and facilitate the circulation of charge carriers between electrodes. During the discharge phase, the reverse chemical reactions take place when the circuit is connected to a load, leading to a flow of electron on the other direction until the chemical components are all consumed. The performance of a battery cell depends on the chemistry of its components, and the reactions created: Typically, the elements enabling the highest voltage difference between the electrodes,

at the lowest weight are sought for. The maximum amount of current and voltage a cell can deliver is limited so in order to reach higher values, a number of cells may be connected together in series or parallel. The term "Battery" or Battery Energy Storage System (BESS) are often used to refer to the complete system composed of this group of cells, some control electronics, and the protecting packaging around them. The electronic part is often called Battery Management System (BMS). In simpler systems, its role may only consist in ensuring that the cells' voltage, current and other physical quantities remain in the range of acceptable values and shutting down the system if not. In more complex systems, individual cell management based on State-of-Charge (SoC) calculation, voltage, temperature, and
other parameter measurements may be provided by more sophisticated BMS.

Chemistries

There are a wide variety of chemistry compounds out of which a battery cell can be made. However, the different chemistries bring about different properties, such as the energy density (total energy that can be stored by mass or volume unit) or the cycle-life (number of charge-discharge cycle executed before the overall performance drops significantly). The numbers provided are to be taken as guide values considering that each chemistry type is composed of a spectrum of variations, since the performance vary depending on the precise chemical composition. Lead-Acid (PbA) batteries are the oldest type of rechargeable batteries and have evolved in two main categories: Flooded and sealed batteries. They are now a very mature and established chemistry, widely used regarding many possible applications thanks to low costs, low maintenance requirements, and low self-discharge. Despite this, other chemistries are overtaking PbA batteries, as their applications are limited because of potential toxicity, weight, and low energy density, in particular Lithium-based chemistries since the early 2000s. The five most present Nickel-based (Ni-Based) batteries, are Nickel-Cadmium (NiCd), Nickel Metal Hydride (NiMH), Nickel Iron (Ni-Fe), Nickel Zinc (Ni-Zn), and Nickel Hydrogen (NiH2). NiCd batteries rapidly developed in the 1980s as the first competitor to PbA batteries which it remained for a few decades thanks to their robustness and long cycle-lives and good load performance for costs comparable to those of PbA cells NiMH cells appeared in the 1990s as an alternative to the cadmium (toxic element) present in NiCd batteries, with less memory effect, and higher capacities, at similar costs and durability. However, their self-discharge rates turned out to be even higher than the already high ones of NiCd, and their operation more delicate. The other Ni-based cells present variations in performance—which never enable them to overtake neither PbA nor Lithium-based batteries—but still can claim a fair share of the overall battery market, at least for some specific applications. Most of the domestic batteries available and developed nowadays are equipped with Lithium-Based (Li-based) batteries. This chemistry emerged in the late 1990s, first as expensive products, but with rapidly decreasing costs promoted by the need for light and portable Energy Storage (ES) solutions. The two main types of li-based cells are Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2 or more commonly NMC), and Lithium Iron Phosphate (LiFePO4, referred to as LFP). NMC batteries have higher energy and power densities but their stability is compromised by the presence of Nickel at the cathode. LFP batteries' market share increased in recent years, led by an interest in their much higher stability at high currents or temperatures, with a similar cycle life, its main disadvantage being lower energy density. LFP cells are more and more used for domestic batteries, where a moderate increase in mass or volume is acceptable if it brings about enough extra safety. Lithium Titanate (Li4Ti5O12) is another type of Li-based cell, which provides more safety and increased cycle-life, coming at the cost of lower energy density, and a doubled price compared to NMC cells. Other chemistries should be

mentioned: Lithium Cobalt Oxide cells present a high specific energy (therefore very present in portable electronics) but low stability and load capabilities, as well as a short life span. Lithium Manganese Oxide cells trade off a higher stability for lower capacity and a still limited life time, and Nickel Cobalt Aluminium Oxide cells present a great potential in many aspects, but remain a very expensive chemistry. Flow batteries have a slightly different functioning principle to the other batteries—which makes them difficult to be compared with the criteria used. They present the technical advantage of independence between energy capacity and power output and can achieve very long cycle life at full. Depth of Discharge (DoD). Still, they struggle to move away from laboratories for a few reasons, mainly because the energy density is limited by the ion concentration in the electrolyte. Additionally, the need for extra components such as tanks, pumps and pipes increase the costs and reduces the overall performance. Therefore, they are not likely to be part of the early models to be implemented as domestic batteries in the short term. For a more detailed review of the history of the chemistries, the readers are referred to Scrosati, and to Linden and Reddy for thoroughly detailed nuances of chemistries and operating principles of batteries.

Battery Ageing and Degradation

One determining parameter when deciding the chemistry and the operation strategy of a battery is ageing, described as the decrease of its performance over its calendar life (in years) or cycle life (in number of cycles). Aging corresponds to the total amount of energy that a battery can store, and the power output decreases with time and utilisation. The State of Health (SOH) defines the decrease in the maximum amount of energy that a cell can store, compared to its original capacity, and the End of Life (EOL) defined as the time, or number of cycles after which the SOH reaches a certain value (typically 80%, but it can vary depending on the constructor). There exist many different ageing processes depending on the chemistry considered. They stem from either side-reactions occurring in parallel to the normal energy storage process, or from side effects of normal operation reactions. The rate and impact of these reactions can be alleviated or worsen depending on the voltage, current, temperature and SOC operating values. High temperatures tend to increase the kinetics of chemical phenomenon, thus increased side-reactions, for instance the Solid Electrolyte Interphase (SEI) in Li-based cells or grid corrosion in PbA cells. Low temperatures on the other hand reduce this kinetics according to Arrhenius law, increasing the internal impedance which limits the performance, but also favouring lithium plating for instance. High and low SOC usually correspond to less stable states. At high SOC, Ni-based cell experience crystalline formation, reducing the performance, which can be reversed if handled early enough. Low SOCs favour the sulphating of the negative electrode of PbA cells. High rates of charge or discharge lead to higher reaction rates in general that can enhance SEI formation in Li-based cells or more generally elevate the temperature, with risk of bringing about issues mentioned above. For these reasons, the state of each cells in a battery pack is managed—in higher-quality models at least—to keep voltage, current, temperature and SOC values in ranges that are as unfavourable as possible to these unwanted phenomena. The degradation of cells was shown to have a considerable impact on achievable revenues by Al-Zareer, Dincer and

Rosen, and a significant increase in potential profitability can be achievable by optimising cell operations to decrease ageing.

Solar PV Batteries

There are still barriers to a large integration of ES - which does not only regard the domestic level. The main one to date being probably the economic viability. The latter is highly dependent on individual context elements, but according to Rappaport and Miles, and Staffell and Rustomji, the cost of domestic batteries is still too high to enable the breakeven point to happen before the end of life of the systems. Still, a higher remuneration of service provision would lead to earlier breakeven points. Under five years is achievable, especially if the technology costs were to decrease as stated by Neubauer and Simpson, and Muenzel et al. states that systems could become economically attractive "in the near future". Two specific cases studied and reported by Günter and Marinopoulos even conclude that storage can already be profitable, under particular conditions. From this literature, it seems that profitability for a full system—rooftop PV panels, Electric Vehicles (EVs), Heat Pumps (HPs), or a combination of them—associated with a battery can be reached in the more or less near future depending on the context. A few companies started the commercialisation of domestic batteries mostly as "Solar Batteries": Either as retrofitting or for a new PV installation. Elon Musk's Tesla Powerwall and Powerwall II played a significant role in the acknowledgement of domestic BESS as a potential future mainstream product. Tesla's batteries are equipped with lithium-based chemistry which also composes the majority of the other battery cells: The German Sonnen, the South Korean LG Chem RESU, the Chinese PylonTech US200B, and the American Simpliphi PHI. LFP and NMC are the most present chemistries in such batteries, as they present an advantageous trade-o_ between cost, cyclability, safety, and energy density, as developed. Still, a few others among the main models are not lithium-based, for instance the Chinese Nerada, the German BAE which are Lead-Carbon and Gel Lead-Acid respectively. This difference in technology illustrates a preference for lithium ion batteries as previously mentioned, due to the performance and lower volumes achievable by this technology.

Electric Vehicles' Batteries Reuse

With the increased acknowledgement of the potential of domestic batteries, the reuse of batteries from EVs or Hybrid EVs (HEVs) starts to be considered. EV and HEV manufacturers such as Nissan and BMW or independent companies such as Relectrify, claim they found a way to reuse vehicle batteries that reached their End of Life (EoL), and could thus buy them from the vehicles' owners, refurbish them, and sell them back to the domestic battery market. Reuse of such batteries has potential, as the performance of EV or HEV batteries are usually higher than that required for domestic applications. Thus, once a battery reaches its EoL, due to degradation processes, the performance achievable may still be good enough for domestic applications. Still, as explained by Robinson, EV or hybrid EV battery requires physical removal of the battery pack from the car, followed by an electric testing of the individual cell, and finally, reconditioning into a "new" battery pack ready for a second life. This whole process would take time, energy and cost money so it is not guaranteed yet that car companies would not just prefer to send batteries for recycling.

Performance and Characteristics

A range of performances are available using different chemistries and technologies as already mentioned, and the selection is made depending on the size of the habitation, energy and power requirements, available resource (usually PV) and the budget of the owner. Energy capacity ranges between a couple of kWh or more (usually corresponding to a single storage unit), and up to slightly lower than 20 kWh (a stack of a number of units in some cases). Higher capacities are expected with reused EV batteries but are not available yet. The power ratings usually depend on the invertor, and range between slightly higher than 1 kW to up to 10 kW. The tolerance of a power output also varies depending in how long this output is maintained. Some systems such as the Tesla Powerwall or the Sonnen ECO are equipped with an integrated inverter/charger, and some other models require the purchase and installation of a compatible inverter.

5.1 DOMESTIC UTILIZATION OF ELECTRICAL ENERGY

HOUSE WIRING

Different colour types of wires

- The electric power line enters our house through three wires- namely the live wire, the neutral wire and the earth wire.
- To avoid confusion, we follow a colour code for insulating these wires.
- The red wire is the live wire, and the black wire is neutral.
- The earth wire is given green plastic insulation.

5 Different Types of Electrical House Wiring Systems

- Cleat Wiring. This wiring comprises of PVC insulated wires or ordinary VIR that are braided and compounded
- Casing and Capping Wiring
- Batten Wiring
- Lead Sheathed Wiring
- Conduit Wiring

Different Types of Electrical Wires and Cables

- Communications Cable. Coaxial Cable. Hard line Coaxial or Heliax Cable. ...
- Direct-Buried Cable (DBC)
- Non-Metallic Sheathed Cable (NM, NM-B)
- Metallic Sheathed Cable (Armored Cable, AC or BX, MC) Armored Cable (AC) Metal Clad (MC) Cable.
- Multi-Conductor or Multicore Cable:
- Paired Cable.
- Portable or Extension Cord.
- Ribbon Cable.

WIRING MATERIALS

Electrical wire is made of materials like copper, aluminium and silver. As silver is expensive, mostly copper and aluminium are used in wiring. Copper is a metal that is well-known for its excellent electrical conductivity and ductility. Unlike aluminum, copper is a more stable and reliable material to use for electrical wiring. It allows for smaller conductors to be utilized for transmission of power loads, thereby reducing wiring expenses.

How to choose wire for house wiring?

To determine what gauge wire you need, consider the carrying capacity and the amount of current the wire needs to conduct (measured in amperage or amps). Wire gauge is directly related to how many amps you need to run through it. The distance you need the wire to go can also impact the gauge of wire you need. Most homes have three-wire service—two hot wires and one neutral. Throughout the house, one hot wire and one neutral wire power conventional 120-volt lights and appliances. Both hot **wires** and the neutral wire make a 240-volt circuit for large appliances such as air conditioners and electric furnaces.

MAIN FEEDER WIRES

Main Feeder Wires: Main power feeder wires are the wires that connect the service weather head to the house. They're made with stranded or solid THHN wire and the cable installed is 25% more than the load required.

Panel Feed Wires: Panel feed cables are generally black insulated THHN wire.

SIZING A WIRE

Wire is sized by the American Wire Gauge (AWG) system. Wire gauge refers the physical size of the wire, rated with a numerical designation that runs opposite to the diameter of the conductors - in other words, the smaller the wire gauge number, the larger the wire diameter. The wire gauge indicates the electrical wire sizing, as defined by the American Wire (AWG) system. The most common gauges are 10, 12 or 14. The gauge and diameter of the wire are inversely related. In other words, as the gauge number gets higher, the diameter of the wire gets smaller.

Wire size is measured in AWG (American Wire Gauge) as

a) The AWG number identifies the size of the conductors the smaller the number the larger the diameter (AWG 0000 – 0.46 in, AWG 18 –0.04 in)
b) NEC defines process for calculating wire size based on Current, Voltage and length of wire.
c) Changes in routing may require a change in the wire used to cabinets or field elements.

d) Most household wiring is usually 12 or 14 AWG Wire Size
e) DOT Signal, Lighting and ITS wires range from 18 AWG for communications interconnect to 00+ for power service.
f) AWG # wire can be either solid or stranded.

NUMBER OF CIRCUITS IN A HOUSE

Fifty years ago, a kitchen might have been served by a single electrical circuit, but today, a newly installed kitchen with standard appliances requires at least seven circuits and often more. Kitchens must have at least two 20-amp 120-volt "small appliance" circuits serving the receptacles in the countertop areas.

INSULATION AND JACKETING IDENTIFIED IN STANDARD SPECIFICATIONS

- XLP or XLPE (Crosslinked Polyethylene) – moisture resistant, flexible, use in wet environments (pull boxes and conduits)
- THHN or THHW (Thermoplastic high heat resistant Nylon, heat and water resistant Nylon) – Suitable for dry or wet locations, high thermal stability, high strength.
- PVC (Poly-Vinyl Chloride) – Low heat resistance, not resistant to sunlight, Not appropriate for wet locations, low flexibility. Rated for Wet location in accordance with NEC 310.104(A)

REQUIREMENTS OF WIRE

1. TypeUSE-2or RHH or RHW-2 copper conductors are suitable for use in raceways installed underground in wet locations
2. Type UF-B(Underground Feeder Cable) has a broad range of usage as defined in Article 340 of the National Electrical Code (NEC). Type UF-B may be installed as interior wiring in wet, dry, or corrosive locations at temperatures not to exceed 90°C
3. Stranded or Solid – Requirements vary by application

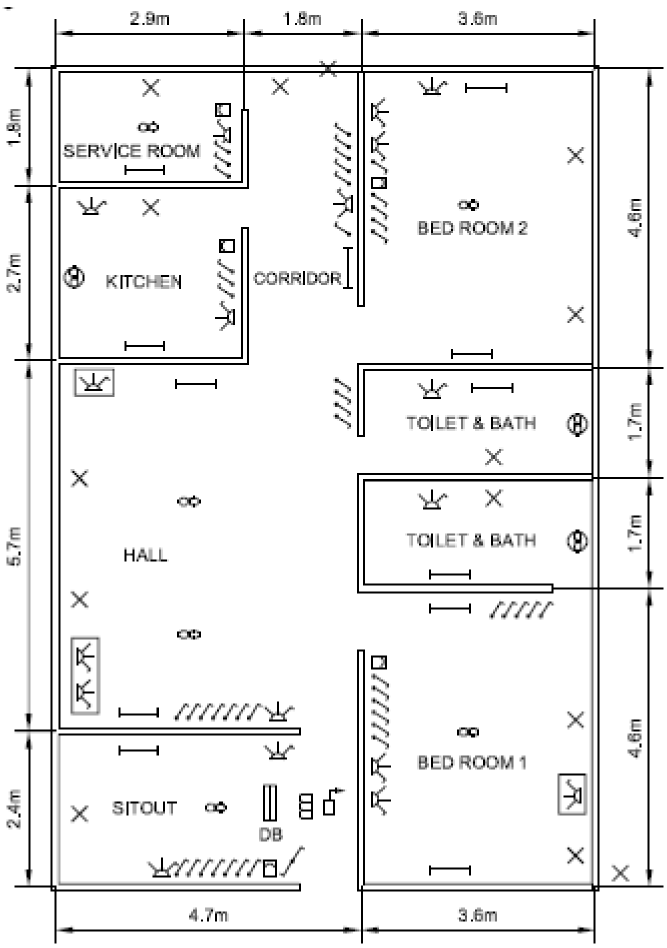

Figure 5.1.1 Accessories position diagram

[Source: "Electrician (NSQF Level-5)", National Instructional Media Institute,Page:102]

5.6 EARTHING

If a person touches an appliance, which has heavy currents flowing through it, with his bare hands there are high chances of encounter being fatal. The electrical potential of the Earth is considered to be zero. Hence on connecting the electrical channels of any appliance to the Earth, its potential would become zero too. This is the main concept behind Earthing, which is a process bonding noncurrent bearing parts of an electrical device or the neutral summit of the electrical organization to the earth through wires possessing minor resistance to flow of current.

Requirement of Earthing

- To warrant that all pieces of equipment in use by the occupants of a building are at Earth Potential, thus safeguarding them from electric shocks through direct contact
- To protect electrical apparatus from getting damaged due to weighty currents along electrical lines
- To sustain stable voltages in three phase circuits even under unstable load state
- To protect tall buildings from getting harmed under lightning

TYPES OF EARTHING

1. System Earthing

   This is the type of earthing which is associated with current carrying conductors. It is quite relevant because there might be overflows of currents during the process of its transmission. This type of earthing is put to use in stations and substations of electrical supply.

2. Equipment Earthing

   This is the prime type of earthing for homes and other buildings. It deals with the safeguarding of noncurrent carrying apparatus and metallic conductors. This type of earthing serves the dual function of protecting the user of the appliance against shocks, while at the same time safeguarding the appliance from getting harmed.

METHODS OF EARTHING

1. Plate Earthing

A 2.5m deep pit is dug into the ground and a galvanised Iron (GI) plate is placed inside along with charcoal and sand for the purpose of maintain low resistance around the plate. An earth wire, which is of GI or tinned copper, is bolted to the plate before burying it by means of nuts, bolts and washers. The wire is made to pass through a GI pipe through which some water is poured in to increase conductivity. The earth wire is connected to the Earth point of the socket and is finally covered. The earthing plate is placed deep into a pit (usually dug up to 1.5 to 3 meters), along with back filling component eg. Bentonite. The plate is connected via Copper conductor, or GI Conductor or concealed copper cable to the respective electrical set-up. A funnel is attached to add water at regular intervals. The plate electrode is buried vertically. The whole earthing system must be copper or GI, and bolts should be used of Brass. Copper earthing is the best in plate type earthing system because of very low resistance than GI.

Earthing Plate Size:

Copper plate:

For LT – 600 mm x 600 mm x 3.18 mm; For HT – 900 mm x 900 mm x 6 mm

GI plate:

For LT – 600 mm x 600 mm x 6.35 mm; For HT – 900 mm x 900 mm x 6 mm

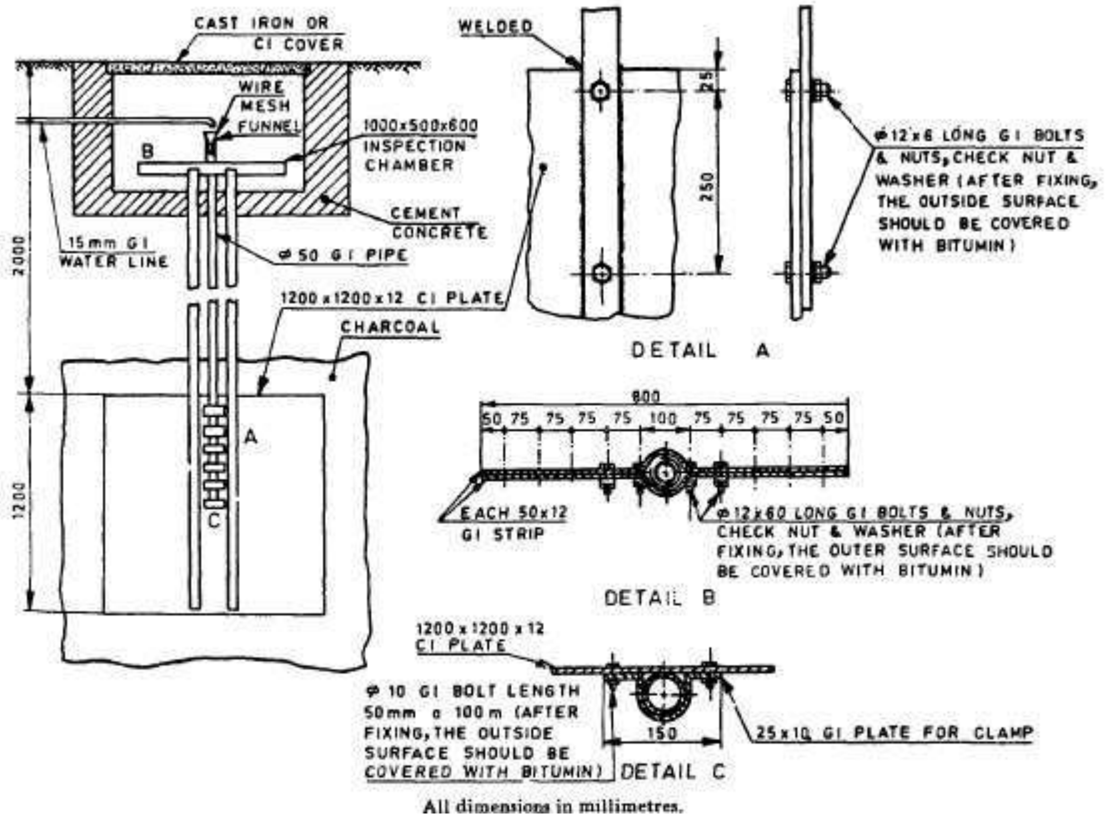

Figure 5.6.1 Plate Electrode

[Source: "Indian Standard Code of Practice for Earthing," Page: 25]

2. Pipe Earthing

A 2.5m long pipe measuring about 35-75 mm in diameter is buried in the dig out pit along with sand and charcoal. The pipe is provided with several perforations to maintain dampness around and hence conductivity. The earth wire is tied and clamped near the summit. Water may be poured into it during summers. The earth wire is safer against damage in such a setup. Pipe earthing is the best form of earthing and is very cheap in cost. In this method of earthing, a cast iron pipe of approved length and diameter is placed up right in the ground. The size of the pipe depends upon the current to be carried and the type of the soil. Usually it is of diameter upto 110 mm and 1.5 to 3 meters deep in length for ordinary soil or of greater length in case of dry and rocky soil.

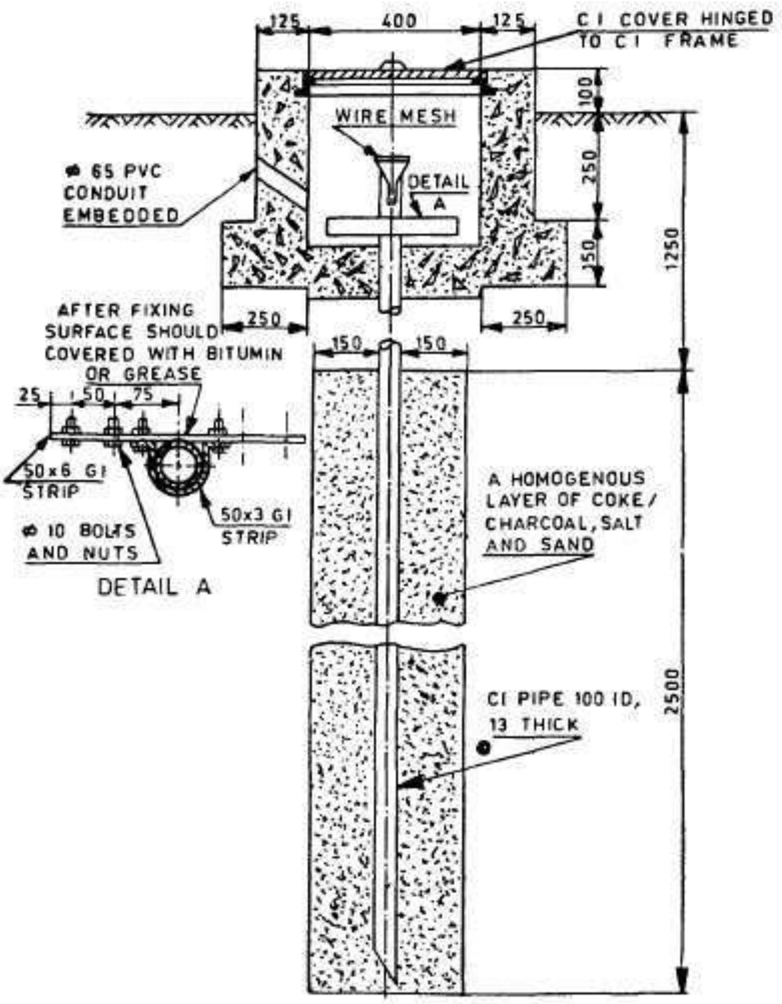

Figure 5.6.2 Pipe Earthing

[Source: "Indian Standard Code of Practice for Earthing," Page: 24]

3. Rod Earthing

This method employs hammering of zinc and copper rods of about 1-1.5 metres length and 12-20 mm diameter into the general mass of the earth. Successive rods are screwed together and this chain is tried making as long as possible for lowered resistance by the surrounding soil. The earth wire is tied and clamped near the summit. This is a very economical and quick procedure for earthing.

4. Earthing through water pipe

We know that hand pumps are used to extract water from the water bed, which lies well inside the ground. To the GI pipe of a hand pump, the earth wire is tied and clamped. This pipe serves as an excellent electrode for carrying excessive currents deep below the ground. However, the difficulty lies in the probable shocks to users of hand pumps if the earth wire is not clamped tight enough.

METHOD OF INSTALLATION

1. Piling

Installation process start with piling. Pile diameter should be twice of earthing electrode diameter. Similarly, earth pit holes can be made by manual as well as boring process depending upon number of earth pits to be done so that it should be cost effective.

2. Back Filling

Variety of back filling procedure is adopted by customers depending upon soil conditions. Commonly used practice is to form alternate layers of back fill compound and soil treated with water for moisture. Generally, recommend 20 kg bag for LT earthing and 40 kg bag for HT earthing depending upon soil conditions.

3. Inserting Electrodes

Earthing electrode is inserted in soil. Specification of electrodes depends upon load, type of soil, and other related parameters.

4. Earth Pit

After successful installation of earthing electrode, earth pit chamber is made below or above ground level as per requirement which can be covered by cast iron cover available in different sizes.

Earth Pit Design Detail: Earthing Pit Size: 1000 X 1000 X 1800 mm Depth

M.S. / C.I. Plate Size: 500 X 500 X8 mm Thick

DOMESTIC EARTHING

The following is the method of implementation of earthing:

1. Low earth resistance is required to give effective earthing protection to electrical fittings.
2. Dry earth has more resistance whereas moist earth has less resistance.
3. The location of earthing point should be minimum 3 feet away from residential unit.
4. The location of earth pit should be such where the soil has reasonable chances of having moisture. If possible, earth plates or pipes should be located near water tap, water drain or rain water pipe.
5. Electric earthing may be either pipe or plate earthing.
6. Normally GI pipe (2.5inch diameter) or plate (600 mm X 600 mm X 3.18 mm) is used but if the soil is corrosive then copper pipe or plate should be used.
7. Use Double GI Strip size 25 mm X 2.5 mm to connect GI Plate to System Earthing.
8. SWG GI wire should be used for internal connection.
9. Use back filling component like bentonite for low soil resistance.
10. The position of the earth plate or pipe when fixed should be clear from all building foundations.
11. Inside building in addition to all electrical appliances, all switch boxes, meter boxes etc. should be earthed also.

INDUSTRIAL EARTHING

Within industrial plants with potentially explosive atmospheres earthing plays an essential role in maintaining the electrical systems in safe condition. The earthing system, although a single physical system, it carries out many different functions including automatic detection and clearance of electrical faults, prevention of dangerous potential differences which could cause injury, prevention and dissipation of static charges and save or increase the life of equipment which comes under grounding. The objective of earthing system is to provide a surface under and around a station, industry which shall be at a uniform potential (nearly zero or absolute earth potential). This Earth surface should be as nearly as possible to the system. This is in order to ensure that, all parts of apparatus other than live parts and attending personnel shall be at earth potential at all times. Due to this there exists no potential difference, which could cause shock or injury to a person, when short circuit or any other type of abnormalities takes place.

NECESSITY OF EARTHING

1. To provide the grounding of all conductive enclosures that may be touched by personnel, thereby eliminating shock hazards.
2. To reduce static electricity that may be generated within facilities.
3. To provide protection from large electrical disturbances (such as lightning) by creating a low resistive path to earth.

FACTORS ON WHICH EARTH RESISTANCE DEPENDS

a) Type of soil
b) Temperature of soil
c) Wetness of soil
d) Minerals in earth
e) Shape of earth electrode
f) Size of earth electrode
g) Depth of electrode in earth
h) Diameter of earth electrode
i) Number of ground electrodes
j) Distance between two electrodes

STEP POTENTIAL

It is the potential difference available between the legs while standing on the ground. It is the difference in the voltage between low points, which are one meter apart along the earth when ground current is flowing.

TOUCH POTENTIAL

It is the potential difference between the leg and hand touches to the equipment.

ELCB- EARTH LEAKAGE CIRCUIT BREAKER

An Earth-leakage circuit breaker (ELCB) is a safety device used in electrical installations with high earth impedance to prevent shock. It detects small stray voltages on the metal enclosures of electrical equipment, and interrupts the circuit if a dangerous voltage is detected. Once widely used, more recent installations instead use residual current circuit breaker which instead detect leakage current directly.

CONSTRUCTION OF ELCB

Basically, there are two types of ELCB: voltage operated and current operated ELCB. Voltage operated ELCB operates at a detected potential of around 50 V to open a main breaker and isolate the supply from the protected zones. But since it operates at 50 V, it is not been used in newer domestic wiring as the 50 V is still considered as safe voltage for alternating current. Basically, there are two types of ELCB: voltage operated and current operated ELCB.

TYPES OF EARTHING SYSTEM

TT system

This arrangement covers installations not provided with an earth terminal by the Electricity Supply Company. Thus, it is the method employed by most (usually rural) installations fed by an overhead supply. Neutral and earth (protective) conductors must be kept quite separate throughout the installation, with the final earth terminal connected to an earth electrode by means of an earthing conductor. Effective earth connection is sometimes difficult. Because of this, socket outlet circuits must be protected by a residual current device (RCD) with an operating current of 30 mA . Fig. 2 shows the arrangement of a TT earthing system.

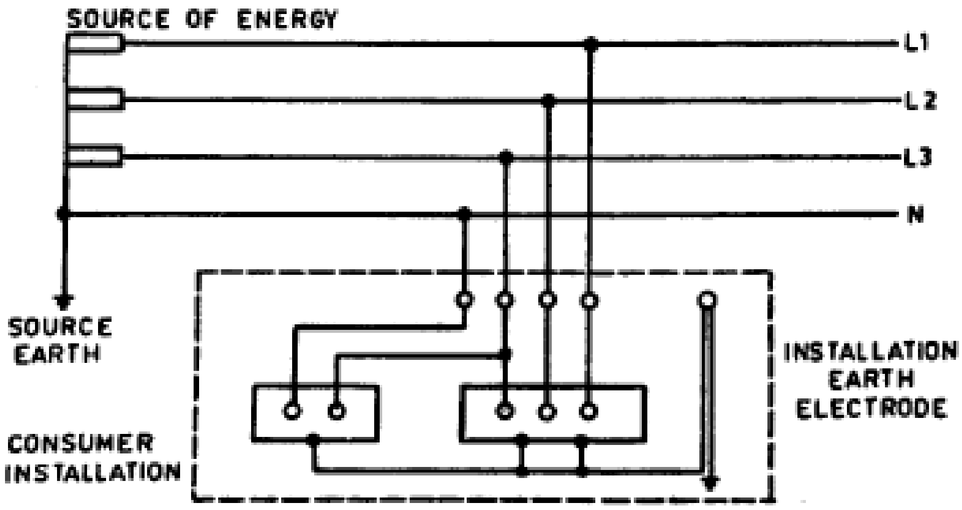

Figure 5.6.3 TT system

[Source: "Indian Standard Code of Practice for Earthing," Page: 14]

TN-S system

In this type of earthing, after building distribution point, protective earth (PE) and Neutral (N) conductors from transformers to consuming device not connected together at any place

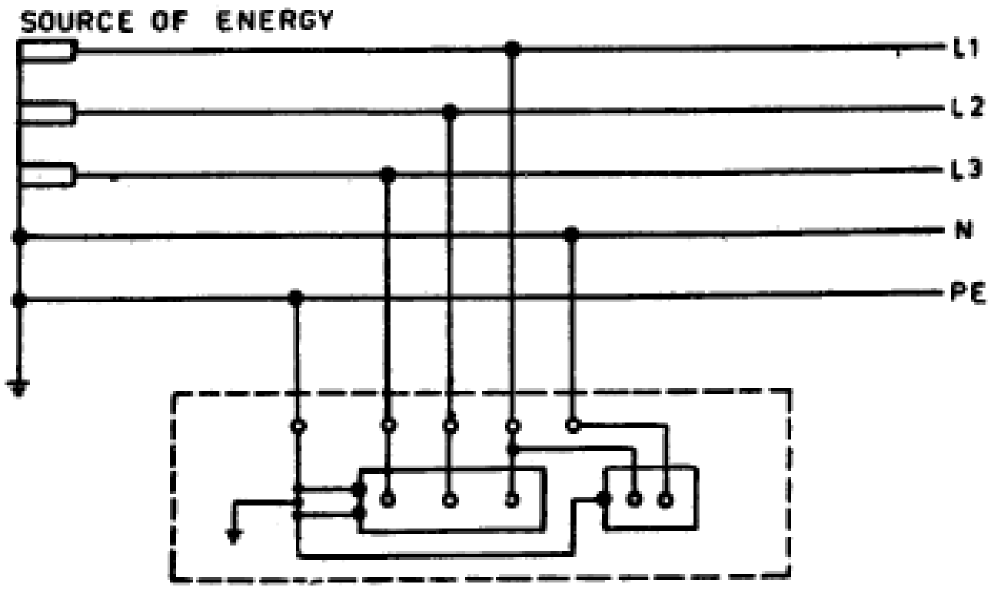

Figure 5.6.4 TN-S system

[Source: "Indian Standard Code of Practice for Earthing," Page: 12]

TN-C system

Protective earth (PE) and Neutral (N) conductor combined in all the way from the transformer to the consuming device. This installation is unusual, because combined neutral and earth wiring is used in both the supply and within the installation itself. Where used, the installation will usually be the earthed concentric system, which can only be installed under the special conditions (mostly used in France).

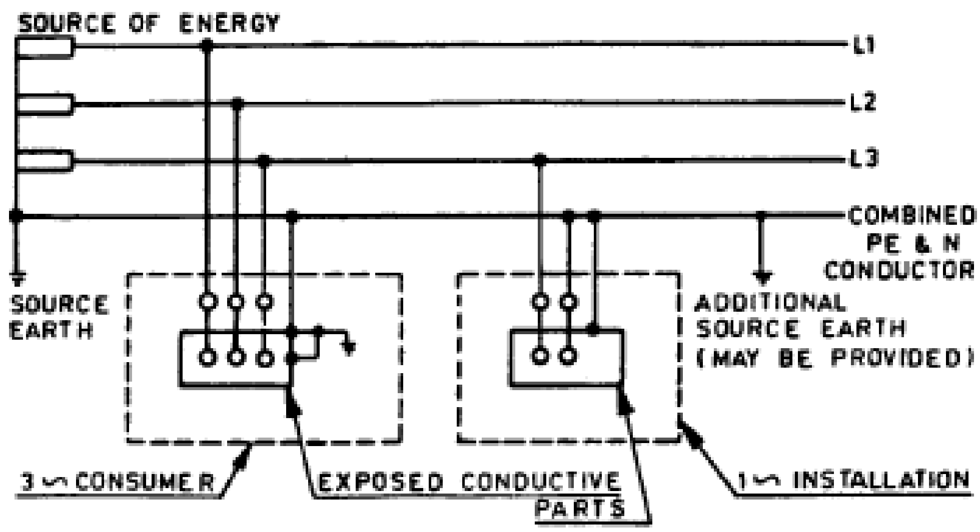

Figure 5.6.5 TN-C system

[Source: "Indian Standard Code of Practice for Earthing," Page: 13]

TNC-S system

Combined PEN conductor from transformer to building distribution point, but separate PE and N conductors in fixed indoor wiring and flexible power cords.

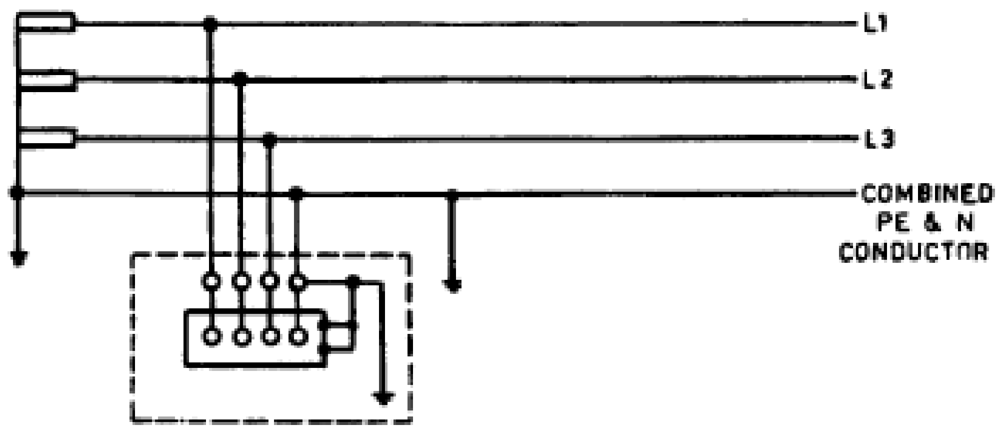

Figure 5.6.6 TNC-S system

[Source: "Indian Standard Code of Practice for Earthing," Page: 13]

IT system

The installation arrangements in the IT system are the same for those of the TT system. However, the supply earthing is totally different. The IT system can have an unearthed supply, or one which is not solidly earthed but is connected to earth through a current limiting impedance

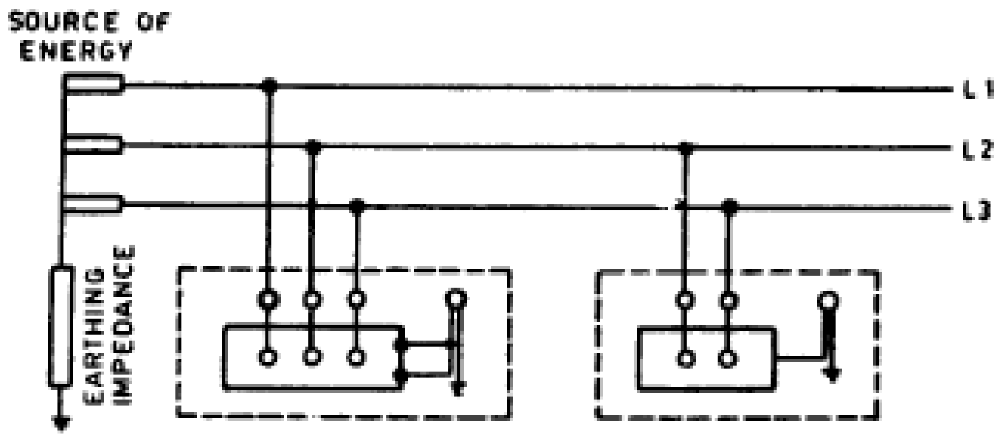

Figure 5.6.7 IT system

[Source: "Indian Standard Code of Practice for Earthing," Page: 12]

PRINCIPLE OF EARTHING SYSTEM

1. The path followed by fault current as the result of a low impedance occurring between the phase conductor and earthed metal is called the earth fault loop. Current is driven through the loop impedance by the supply voltage.
2. The extent of the earth fault loop for a TT system is made up of the following parts:
    - Phase conductor from the transformer to the installation
    - Protective device(s) in the installation
    - Installation phase conductors from the intake position to the fault
    - Fault itself (usually assumed to have zero impedance)
    - Protective conductor system
    - Main earthing terminal
    - Earthing conductor
    - Installation earth electrode
    - General mass of earth
    - Supply Company's earth electrode
    - Supply Company's earthing conductor
    - Secondary winding of the supply transformer

- For a TN-S system (where the Electricity Supply Company provides an earth terminal), items 8 to 10 are replaced by the PE conductor, which usually takes the form of the armouring (and sheath if there is one) of the underground supply cable.
- For a TNC-S system (protective multiple earthing) items 8 to 11 are replaced by the combined neutral and earth conductor.
- For a TN-C system (earthed concentric wiring), items 5 to 11 are replaced by the combined neutral and earth wiring of both the installation and of the supply.
- It is readily apparent that the impedance of the loop will probably be a good deal higher for the TT system, where the loop includes the resistance of two earth electrodes as well as an earth path, than for the other methods where the complete loop consists of metallic conductors.

Earthing system has three main components

1- Earthing conductors

The earthing conductor is commonly called the earthing lead. It joins the installation earthing terminal to the earth electrode or to the earth terminal provided by the Electricity Supply Company. It is a vital link in the protective system, so care must be taken to see that its integrity will be preserved at all times.

2- Earth electrodes

The principle of earthing is to consider the general mass of earth as a reference (zero) potential. Thus, everything connected directly to it will be at this zero potential. The purpose of the earth electrode is to connect to the general mass of earth. Calculation of earthing resistance for one electrode driven at the earth

Equation used to calculate earthing resistance is:

$$R = \left(\frac{\rho}{2\pi l}\right)\left[\ln\left(\frac{8l}{d}\right) - 1\right]$$

where ρ = earth resistivity in ohm-m; l = length of the electrode (m); d= diameter of the electrode in (m). For any number of rods in parallel, we can calculate the earthing resistance from the following equation is

$$R_{eq} = \left[\frac{RI}{Number\ of\ rods}\right] \times F$$

where, F is a multiplying factor.

The resistivity (ρ) in Ωm for various types of soils are

F	No.of rods
1.16	2
1.29	3
1.36	4
1.68	8
1.8	12
1.92	16
2.0	20

3- Inspection points (Earthing well)

For protection of the earthing rod and earthing conductors and also for maintenance and inspection purposes an earth well is constructed as shown in Fig.9. Earthing conductors, as well as protective and bonding conductors, must be protected against corrosion. Probably the most common type of corrosion is electrolytic, which is an electro-chemical effect between two different metals when a current pass between them whilst they are in contact with each other and with a weak acid. The acid is likely to be any moisture which has become contaminated with chemicals carried in the air or in the ground. A main earth terminal or bar must be provided for each installation to collect and connect together all protective and bonding conductors. It must be possible to disconnect the earthing conductor from this terminal for test purposes, but only by the use of a tool. This requirement is intended to prevent unauthorized or unknowing removal of protection. Where the final connection to the earth electrode or earthing terminal is made there must be a clear and permanent label Safety Electrical Connection - Do not remove. With the increasing use of underground supplies and of protective multiple earthing (PME) it is becoming more common for the consumer to be provided with an earth terminal rather than having to make contact with earth using an earth electrode.

SUBSTATION EARTHING (33kV Substation)

Provision of adequate grounding in a substation and switching stations are very important for the safety of operating personnel as well as electrical devices do not rise above tolerable thresholds and that the earth connection is rugged to dissipate the fault to the earth. The importance of an effective, durable and a dependable earth for ensuring safety from electrical hazards does not require to be elaborated upon more. By earthing, connecting the electrical equipment to the general mass of the earth, this has a very low resistance.

Values of earth resistance in substation should be less than

1. Generating station 0.5 Ω
2. Large substation 1.0 Ω
3. Small substation 2.0 Ω
4. From earth electrode to internal assembly 2.0 Ω
5. Neutral bushing 2.0 Ω

6. Service connection 4.0 Ω
7. LT lightning arrester 4.0 Ω
8. LT pole 5.0 Ω
9. HT lightning arrester 8.0 Ω
10. HT pole 10.0 Ω
11. Tower 25.0 Ω

ISOLATORS AND SWITCHES

A flexible earth conductor is provided between the handle and earthing conductor attached to the mounting bracket and the handle of switches is connected to earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

LIGHTNING ARRESTERS

Conductors as short and straight as practicable to ensure minimum impedance shall directly connect the bases of the lightning arresters to the earth grid. In addition, there shall be as direct a connection as practicable from the earth side of lightning arresters to the frame of the equipment being protected. In the case of lighting arresters mounted near transformers, earthing conductor shall be located clear off the tank and coolers in order to avoid possible oil leakage caused by arcing. The resistance of earthing should be as low as possible, so that the current in lightning arrester, which is caused by excessive electrical pressures on the line, due to lightning stroke, should go into the uncontrolled soil and avoid potential damage.

CIRCUIT BREAKERS

For every breaker there will be five earth connections to the earth mat with: MS flat

1. Breaker body
2. Relay panel
3. CTs of the breaker
4. Two side of the breaker structure.

TRANSFORMER

It is essential to earth transformer for better performance and safety of transformer. Mainly transformer consists of four earthings out of which two are connected to neutral to the star point of LV side of the transformer and two for the body i.e. transformer tank to pass the leakage current and ground it for better safety.

Purpose of transformer neutral bushing

1. Leakage or unbalanced current is dissolved by the earthing.
2. Possible to install high sensing protection equipment.
3. Help to reduce extra high voltage on line due to lightning or switching surge.
4. Helps to control fault current by connecting resistance in neutral earth.
5. Always helps to keep neutral voltage zero.

The tank of each transformer shall be directly connected to the main grid. In addition, there shall be as direct connection as practicable from the tank to the earth side of projecting lightning arresters. The earthing of neutral bushing shall be by two separate strips to the earth grid and shall likewise be run clear to rank cell and coolers.

CURRENT TRANSFORMERS AND POTENTIAL TRANSFORMERS

The supporting structures of Current Transformer and Potential Transformer unit of bases, all bolted cover plates to which the bushings are attached connected to the earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

OTHER EQUIPMENT

All equipment's, structures, and metallic frames of switches and isolators shall be earthed separately

FENCES

The Sub-station fence should be generally too far outside the substation equipment and grounded separately from the station ground. The station and the fence ground should not be linked. If the distance between the fence and station structures, cannot be increased at least five feet and if the fence is too near the substation equipment structure etc., the station fence should be connected to the fence ground.

GROUND WIRE

All ground wires over a station must be connected to the station earth grid. In order that the station earth potentials during fault conditions are not applied to transmission line ground wires and towers, all ground wires coming to the station must be broken at and insulated on the station side of the first tower or pole external to the station by means of 10" disc insulator.

CABLES AND SUPPORTS

Metal sheathed cables within the station earth grid area must be connected to that grid. Multi-core cables must be connected to the grid at least at one point. Single core cables normally should be connected to the grid at one point only.

PANELS AND CUBICLES

Each panel or cubicle should be provided near the base with a frame earth bar of copper to which shall be connected the metal bases and covers of switches and contactor unit.

INSTRUCTIONS ABOUT EARTHING IN SUBSTATION

1. On pole of HT line, fittings of all metal parts i.e. cross arm, top fittings, pins of insulator, clamps, etc. should be fixed by using GI wire of 8 SWG.
2. On pole of LT line, fittings of all metal parts and stay should be connected to neutral and then this neutral is to be solidly earthed with multiple earthing.
3. The earth wire of lightning arrester should not connect to any pole, it directly passes from the alkathene pipe and tightly connected to earth electrode.

Type of Earthing to Be Used – CI Pipe Type

Size of Electrode – Ø 120 mm, 3000 mm length

Size of GI Strip – 25mm x 2.5 mm

$$\text{Number of earthing pipes used} = \frac{\text{Total fault current}}{\text{Maximum current dissipated by one earthing pipe/electrode}}$$

5.2 INDUCTION BASED APPLIANCES

Induction appliances get energy from the mains voltage, which is rectified by a bridge of diodes. A bus filter is designed to allow a high-voltage ripple, getting a resultant input power factor close to one. Then an inverter topology supplies the ac (between 20 and 100 kHz) to the induction coil. Today, burners of domestic induction appliances are designed to deliver up to 3.5 kW ac. A schematic diagram of the power stage of a domestic induction apparatus is shown in Figure 2. Formerly, the power electronics was located in a forced air- cooled separate box placed on the floor, using thyristors as switching devices. However, in the later 1990s, the application of the resonant inverter topologies caused the integration of the electronics and the inductors in a compact hob, whose housing is compatible with the conventional resistive cookers. Having in mind that hobs are normally placed over an oven, an environment temperature of 75°C (167°F) is usually considered for electronics design purposes, and a highly efficient energy conversion is mandatory. Today, resonant inverter topologies are commonly used in induction hobs. The most used topologies are the full bridge, half bridge, and two single-switch inverter topologies, namely zero-voltage switching (ZVS) and zero current switching. At present, the half-bridge topology is the most popular one because of its robustness and cost savings. Multiple-burner appliances with two or four inductors are commonly manufactured. In a multiple-burner induction cooker, the easiest approach is to use one inverter per burner or one inverter for two or more burners as other usual approaches, with benefits such as a lower overall cost and higher utilization ratio of electronics. In the last case, a common technique uses a single-output inverter, multiplexing the loads along the time periodically by means of electromechanical switches, causing a very low-frequency switching with power distribution and acoustic noise not completely satisfactory. The methods to avoid these problems have been proposed. An upgraded full-bridge inverter with two outputs has been proposed, and this concept has also been applied to the half-bridge inverter. It is a cost-effective proposal that provides new benefits, such as quick heating function, with an optimum utilization of electronics. Both the full- and half-bridge two-output inverters are based on sharing a common leg and adding two low-cost relays (S1 and S2) for paralleling the independent legs when only one output is required. Thus, the converters can be configured to supply either both outputs or only one. In addition, the topologies in resonant capacitors Cr_1 and Cr_2 and the snubber capacitors Cs_1–Cs_6 to get a ZVS operation of main switches. Considering a real implementation of the two output, full-bridge topology.

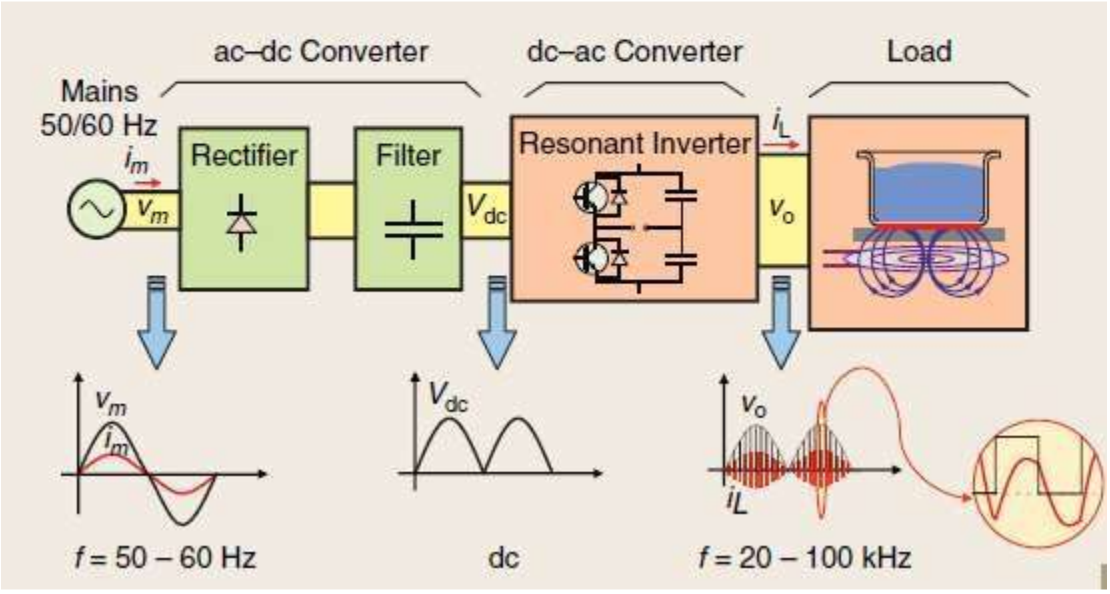

Figure 5.2.1 Power Electronic Circuit of Induction Cooker

[Source: "IEEE Industry Applications Magazine," Page: 40]

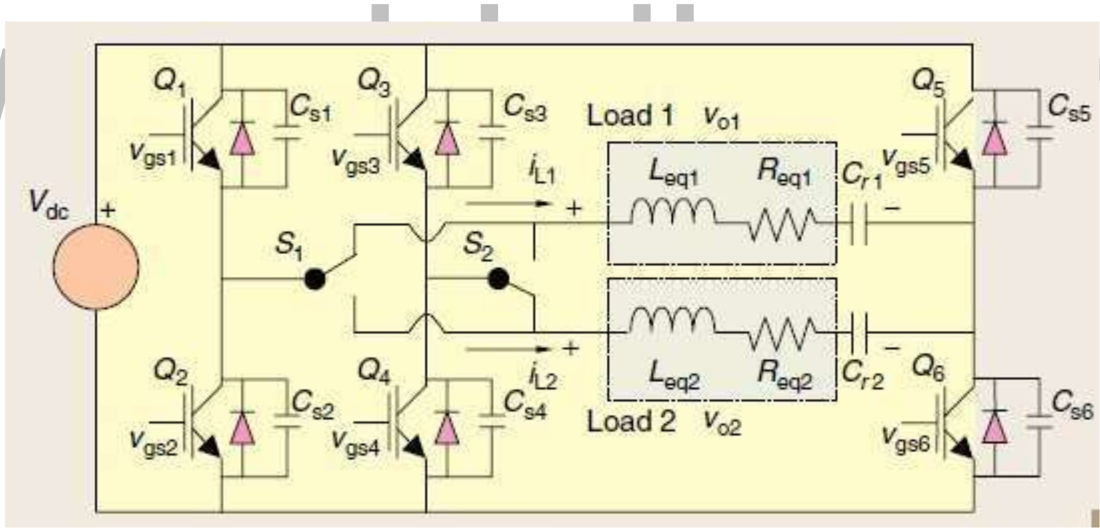

Figure 5.2.2 Full-bridge Resonant Inverter

[Source: "IEEE Industry Applications Magazine," Page: 40]

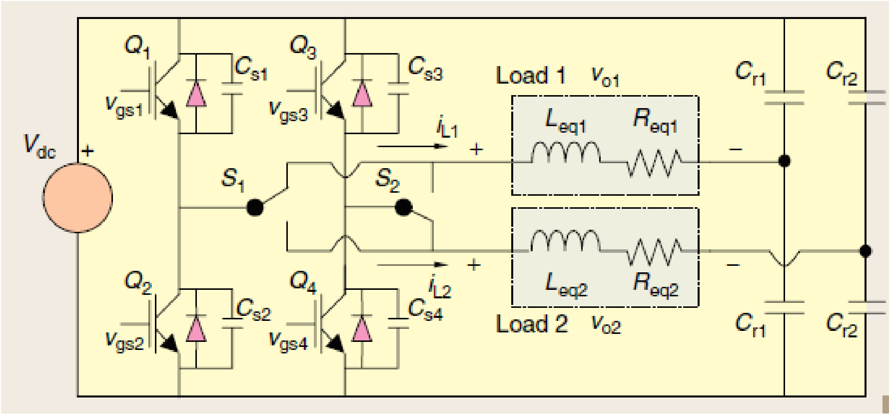

Figure 5.2.3 Half-bridge resonant inverter

[Source: "IEEE Industry Applications Magazine," Page: 41]

INDUCTION COOKER

Induction cooking works by using an electromagnetic field to heat the cookware. This is very different from the traditional gas flame or electric coil cooking experience. Special cookware is also needed. Cookware used on an induction cooktop must have iron content. This is what makes the pan magnetic and allows the transfer of energy to the pan or pot you are using. Electromagnetic Energy + Magnetic Pans = Fast, Efficient Induction Heating The key to induction cooking is electromagnetic energy. This kind of energy is around us every day in the form of AM and FM radio, cell phones, wireless laptops, microwave ovens, infrared, and visible light. It operates on a two-part system. First, beneath the ceramic surface of an induction cooking product is a copper coil. When an electrical current is passed through this coil it creates an electromagnetic field of energy. Second, an iron core pan is placed on the cooktop. At this point the heat is activated around the pan. The surface remains cool until both these steps are completed. The video below further illustrates the mechanics of induction cooking. Magnetic Cookware Required for Induction Heating for induction heat to occur, the bottom of the pan must be made of some iron, making the pan magnetic. You can perform a simple test to see if your pan will work with an induction cooktop. If a magnet sticks to the bottom, the pan will work on an induction cooktop. When the magnetic pan is placed on the cooking surface, the iron molecules in the pan begin to vibrate 20,000-50,000 times per second. It is the friction between those molecules that creates heat. All of the heat is contained in the bottom of the pan; this is why the surface remains cool while your cookware stays hot.

5.3 UNINTERRUPTIBLE POWER SUPPLY (UPS)

Electrical apparatus that provides emergency power to a load when the input power source, typically the utility mains, fails. A UPS differs from an auxiliary or emergency power system or standby generator in that it will provide near-instantaneous protection from input power interruptions, by supplying energy stored in batteries, super-capacitors, or flywheels. The on-battery runtime of most uninterruptible power sources is relatively short (only a few minutes) but sufficient to start a standby power source or properly shut down the protected equipment. A UPS is typically used to protect hardware such as computers, data centers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, fatalities, serious business disruption or data loss. The world's largest UPS, the 46-megawatt Battery Electric Storage System (BESS), in Fairbanks, Alaska, powers the entire city and nearby rural communities during outages.

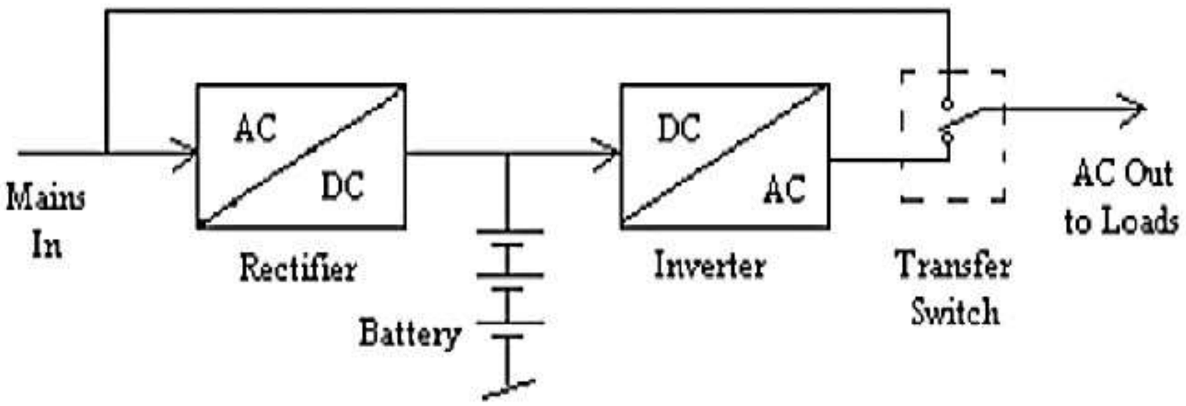

Figure 5.3.1 Basic Block Diagram of UPS

[Source: "Uninterruptible Power Supply", Mohamad Zhafran Zakariya, Page: 8]

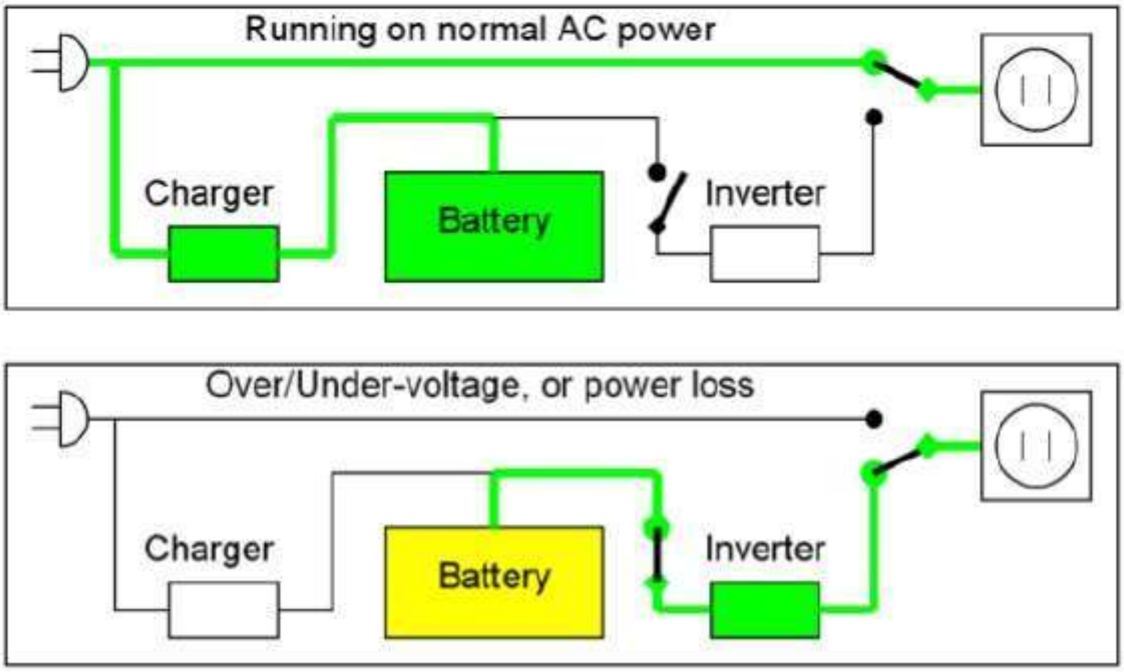

Figure 5.3.2 Basic Operation of UPS

[Source: "Uninterruptible Power Supply", Mohamad Zhafran Zakariya, Page: 9]

TYPES OF UPS

1. Offline UPS
2. Online UPS
3. Line Interactive UPS

An Uninterrupted power supply is essentially a back-up battery to power electronic gadgets like Computer in the event of a power failure. If it happens, the Gadget will draw power from the UPS and will run the load for a prescribed time depending on the capacity of the battery. The change over time from the mains to battery power is a fraction of a second, so that the computer will not shut down. This is essential to protect the data in the computer. Uninterrupted power supply may be AC/AC or AC/DC based on the output power supply. In AC/AC UPS, the energy source is the AC lines and the output is exactly the same voltage generated by the inverter. In AC/DC type, the UPS delivers DC voltage by converting AC to DC.

ONLINE UPS

Online UPS on the other hand uses an Inverter which always on to give sine wave AC in the output socket. The incoming AC is first converted into DC by a transformer to charge the battery as well as to give power to the inverter transformer. The inverter transformer converts the DC to AC continuously to power the load. If power fails, the battery backup circuit switches on and takes the load. Online UPS is more efficient than the Offline UPS and uses a “Constant duty Inverter”. It also has a “Static bypass” system that transfers the load to the AC power if the inverter system fails. The advantage of the Online UPS is that, it cleans up the AC waveform by converting it into DC then reconverting this DC to fresh AC. In this type of UPS, the system always remains on battery, whether mains ac is present or not. When mains ac is present, it provides power to DC supply of inverter section as well as charges the battery simultaneously. When mains ac is not present, it will run the connected load till the battery has a recommended dischargeable level.

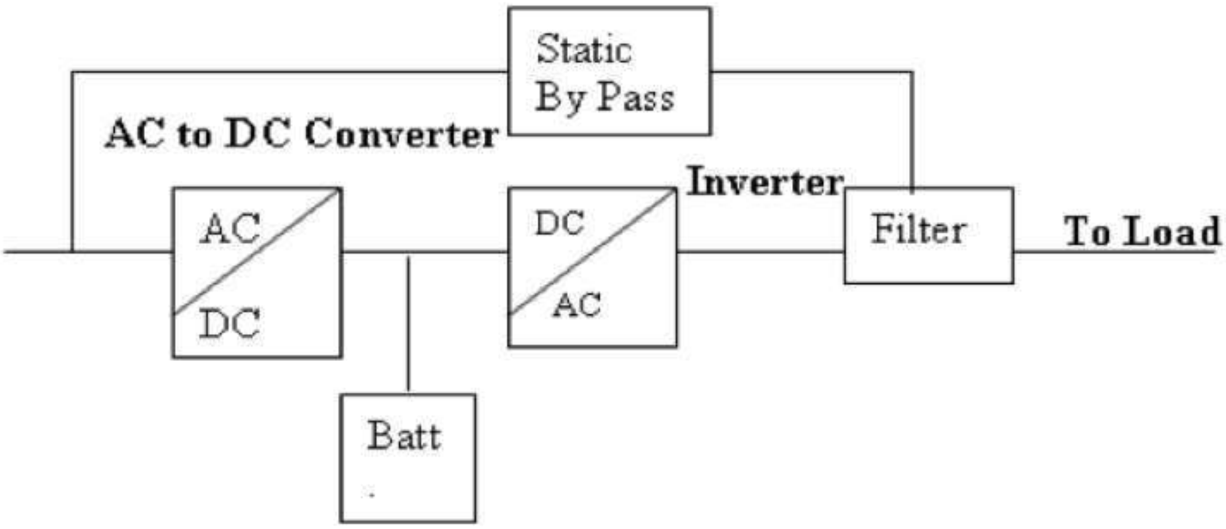

Figure 5.3.3 Block diagram of online UPS

[Source: “Uninterruptible Power Supply”, Mohamad Zhafran Zakariya, Page: 15]

OFFLINE UPS

Offline UPS passes the input AC to the output sockets if the AC power is available. It always monitors the voltage level in the mains, and if there is a voltage drop or mains failure, it switches on the inverter to give AC power to the device until the mains supply returns to normal. The switch over time from AC to inverter AC is less than five milli seconds so that the functioning of the gadget is not affected. The mains to battery changeover time or battery to mains changeover time in offline UPS is very low as compared to inverter. Typically, changeover time in inverters is 500 milliseconds & Offline UPS has changeover time of 3-8 milliseconds. In a time, when mains ac is present, Inverter provides the output as is the input mains. While, Offline UPS has built in Automatic Voltage Regulator (AVR) to regulate the output voltage close to 220V ac. Offline UPSs are normal weight UPSs and are widely used for domestic computers.

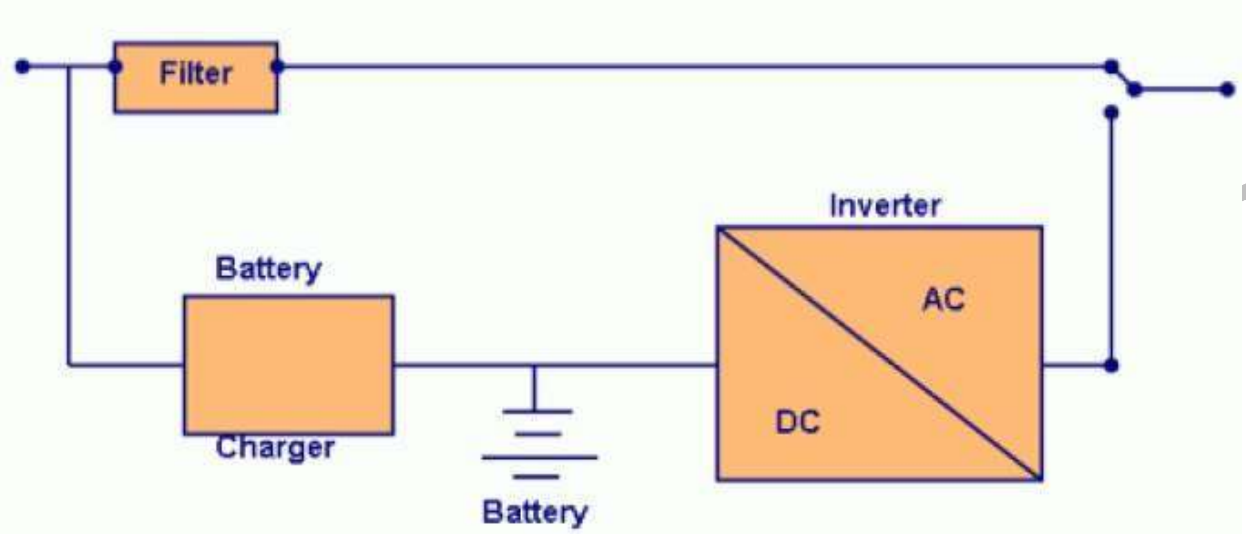

Figure 5.3.4 Block diagram of offline UPS

[Source: "Uninterruptible Power Supply", Mohamad Zhafran Zakariya, Page: 13]

LINE INTERACTIVE UPS

In this design, the battery to AC power converter (inverter) is always connected to the o/p of the UPS. Battery charging is done during times when the I/P AC power is normal when the I/P AC fails, transfer switch opens and then the inverter starts functioning to provide power to load immediately. AC input fails → transfer switch open → inverter ON mode.

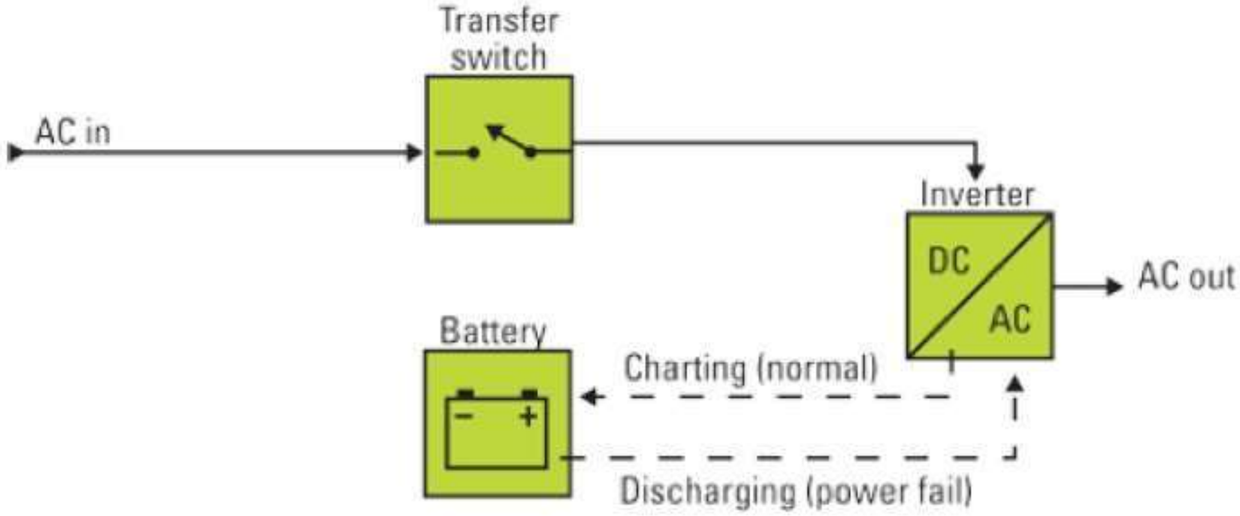

Figure 5.3.5 Block diagram of line interactive UPS

[Source: "Uninterruptible Power Supply", Mohamad Zhafran Zakariya, Page: 17]

5.5 POWER QUALITY ASPECTS - NONLINEAR and DOMESTIC LOADS

With increasing the quantity of harmonics generating devices in power systems, the matter of their impact on the performance of system elements like induction motors, Personal laptop, CFL, Air Conditions and printers wants any assumption. The use of nonlinear loads is increasing day by day. This increasing use of nonlinear loads has created a lot of distortions in current and voltage waveforms. This enhanced power quality disturbances have result in numerous optimizations techniques and filter styles. Harmonic distortions are the main cause for power quality issues. About, of 60% in all over the globe are nonlinear loads. So, study of their conditions below serious harmonic contaminated networks would be attention-grabbing for understanding of that however we should always treat with the electrical load. For this analyzing the harmonics present in nonlinear loads is critical. Here a survey is formed to indicate details of harmonics gift in numerous nonlinear loads. The main objective of the electrical utility is to deliver curving voltage at fairly constant magnitude throughout their system. This objective is difficult by the actual fact that there are hundreds on the system that turn out harmonic currents. as a result of electrical devices that act as nonlinear loads draw current non dimensionality, they're accountable for injecting harmonic currents into the electricity network. Harmonics may be a lot of vital issue for the business, commerce and therefore the home shopper currently than it absolutely was many decades past. The equipment's in laboratory area unit Compact Fluorescent Lamps (CFLs), Personal Computers, Laptops, Printers and Air Conditions wherever all of them is equally as harmonic vital.

There are many causes of harmonics in a very facility. In distribution system, transformers area unit capable of producing harmonics thanks to core saturation. The consequences of harmonics on instrumentality are: extra heating and better insulator stress on the capacitors, interruption capability of circuit breakers, the electrical phenomenon of the conductors, scale back lamp life, activity errors in instrument like wattmeter, meter etc, heating, rhythmic torsion and noise on rotating machines. The value to finish users comes once the harmonic currents is additional to the traditional load and increase losses and loading on their distribution systems. The increased losses scale back the capability of the system, together with conductors, transformers. The increased loading generates heat and accelerates the aging of power instrumentality, like transformers.

Harmonic distortion isn't new and it constitutes at this time one among the most issues for engineers within the many stages of energy utilization inside the ability industry. Within the past, harmonics described less of a retardant because of the conservative style of power instrumentation and to the common use of delta-grounded wye connections in distribution electrical device. But, the increasing use of nonlinear loads in industry is keeping harmonic distortion in distribution networks on the increase. In a perfect power grid voltage and current waveforms are strictly curved. In practice, non-sinusoidal currents result once the current flowing through the load is nonlinearly involving the applied voltage. In an exceedingly straightforward circuit containing solely linear circuit components (resistance, inductance and capacitance), current that flows are proportional to the applied voltage. In order that it leads to an ac current flow. Things wherever the load is straightforward full wave rectifier, current flows only if the provision voltage exceeds that keep on the reservoir capacitance. It says that waveforms tend to distort from the sine wave and this is often the cause for harmonics. Non-linear loads produce harmonics by drawing current in abrupt short pulses, instead of in an exceedingly sleek curved manner. Power grid issues involving harmonics are rare however it's attainable for variety of undesirable effects to occur. High levels of harmonic distortion will cause many effects like enlarged electrical device, capacitor, motor or generator heating, false operation of equipment (which depends on voltage zero crossing detection or is sensitive to wave shape), incorrect readings on meters, false operation of protecting relays, interference with phone circuits, etc. Since harmonic distortion is caused by nonlinear components connected to the facility system, any device that has non- linear characteristics can cause harmonic distortion. samples of common sources of power grid harmonics, a number of that ne'er cause serious issues, are: electrical device saturation and influx, electrical device neutral connections, MMF distribution in AC rotating machines, arc furnaces, fluorescent lighting, pc switch mode power provides, battery chargers, imperfect AC sources, variable frequency motor drives (VFD), inverters, and tv power provides.

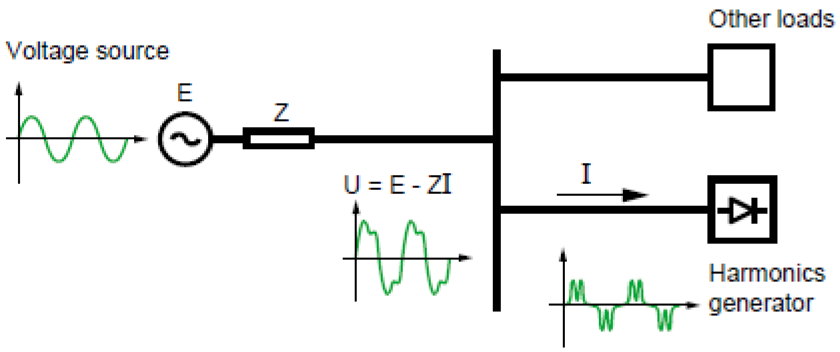

Figure 5.5.1 Degradation of network voltage due to non-linear load

[Source: "Power Quality", Philippe Ferracci, Page: 10]

Due to the changes in the operating conditions and the rapid growth of advanced power conversion devices, electronics equipment's, computers, office automation, air-conditioning systems, adjustable speed heating ventilation can cause current distortions. This is due to increase in harmonics drastically. According to the Electric Power Research (EPR) in 1995, 35-40% of all electric power flows through electronic converters. All these devices are named as non-linear loads and become sources of harmonics. The measurement results for the several modern set of non- linear based on is tabulated in Table. A survey is done for various non -linear loads to know the levels of harmonics present in each load.

These surveys are generally conducted with the objectives such as

1. Identify the trends of harmonic distortion level present in the system,
2. Identify the future trends of metering in the presence of non-sinusoidal current and voltage waveforms. And increased awareness and concern for customer's quality of service.

CHARACTERISTICS AND MODELING OF EQUIPMENT

One important step in harmonic analysis is to characterize and to model harmonic source and all components in system. As we know, the equipment's in Power System Analysis & Control laboratory UniMAP are Compact Fluorescent Lamps (CFLs), personal computer, Television where all of them can be similarly as industry medium scale.

Each equipment can be modeled as follows:

Personal Computer

Personal computer has considerably contributed to harmonics issue by lowering voltage distribution system. The current THD for private pc exceed one hundred, because the results of high-level individual distortions introduced by the third and fifth harmonics. The full current drawn by laptop computer and its monitor is a smaller amount than two A, however a typical high-rise building will contain many hundred computers and monitors. The net impact of this on the full current harmonic distortion of a facility isn't tough to examine. And in fig.3 & 4 shows the SIMULINK model of PC and their comparative harmonics distortion.

Compact fluorescent lamp

The CFL was the primary major advance to be a commercial success in small-scale lighting since the tungsten incandescent bulb. Fluorescent lamps are concerning two to four times as economical as incandescent lamps at manufacturing lightweight at the wavelengths that are helpful to helpful to humans. because of significant use of non-linearity gas lamp, the fluorescent lamps that use magnetic or electronics ballast that are thought of as a major contributor to harmonic.

Television

Television receivers have power supplies which create current harmonics. Whilst the harmonic current levels are small in magnitude, the cumulative effect of large numbers of receivers can be significant. One way to examine the effect of television receivers on network harmonic levels is to monitor harmonic levels during periods of increased television viewing.

Air conditioning

Air conditioner makers have responded by exploring a range of technological innovations to extend the energy efficiency of their product. One example of innovation is that the variable speed cooling system, with enhanced efficiency gained by application of power electronics technology. The bulk of air conditioners contain a mechanical device driven by a single-speed induction motor, and exhibit mounted efficiency and cooling capability. Studies indicate that variable-speed air conditioners need four-hundredth less energy than single speed air conditioners, and are capable of conjugation a given cooling load at well reduced energy prices.

A survey of harmonics presents within the voltage associated current waveforms is conducted with an objective to understand {the existing the prevailing the present} level of harmonic distortion present within the installation and future trends. Harmonics injected by some terribly usually used nonlinear loads are studied. It's determined that important distortion within the current exists because of the employment of computers and alternative electronic equipment's in residential and industrial areas too. Increasing use of those equipment's could end in serious issues in close to future. the present distortion differs wide from one section to the next. Although, voltage distortion is recorded below the suitable limit, however it's found higher than the counseled limit at the places of high current distortion, because it depends on the circuit resistivity additionally as harmonic generation characteristics. important distortion within the current is recorded at client finish with high share of fifth and seventh harmonic elements. Though numerous optimization techniques are present, analysis is being in deep trouble the simplest eliminated results of THD.