

Module 3: Electrical Machines and Power Backup Systems [04 hrs]

3.1 DC Motors: Brushed and Brushless – Principle, Construction, Applications

3.2 Single-phase Induction Motors – Working and Applications

3.3 Power Backup Systems: Inverter, UPS, SMPS – Block Diagram & Principle

3.4 Batteries: Lead-Acid and Lithium-ion – Construction & Characteristics

Self-Learning Topics: Comparison of DC Motor, Induction Motor, Inverter, UPS, Battery (Lead-acid and Li-ion) (basic specifications and applications)

3.1 DC Motors: Brushed and Brushless – Principle, Construction, Applications

Adc machine is a device that converts mechanical energy to electrical energy or vice versa.

DC machines are divided into categories

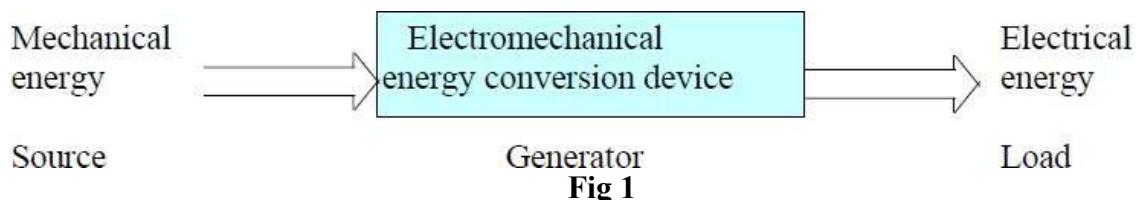
i] Generators and ii] Motors

Construction wise there is no basic difference between a dc generator and a dc motor. Any dc machines can be used as a dc generator or as a dc motor.

Principle of operation of DC generators

An electrical Generator is a machine which converts mechanical energy (or power) into electrical energy (or power). The generator operates **on the principle of the production of dynamically induced emf** i.e., whenever flux is cut by the conductor, dynamically induced emf is produced in it according to the laws of electromagnetic induction, which will cause a flow of current in the conductor if the circuit is closed.

When armature conductors are rotated externally in the magnetic field produced by field windings, an emf is induced in it according to Faraday's laws of electromagnetic induction. This emf causes a current to flow which is alternating in nature. It is converted in unidirectional current by the commutator.



The essential components of a generator are:

- 1] a magnetic field
- 2] conductor or a group of conductors
- 3] motion of conductor w.r.t the magnetic field

Principle of operation of DC Motors

A DC motor is a machine which converts electrical energy into mechanical energy.

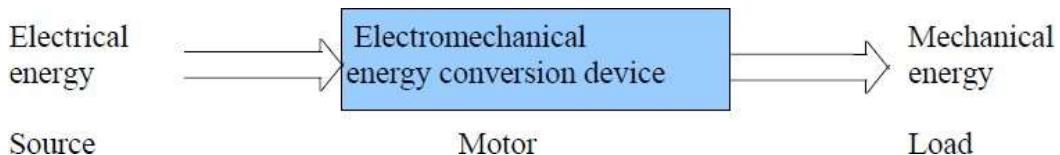


Fig 2

It is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's Left-hand rule and whose magnitude is given by

Force, $F = B I l$ newton Where B is the magnetic field in weber/m².

I is the current in amperes

l is the length of the coil in meter.

Fleming's left hand rule says that if we extend the index finger, middle finger and thumb of our left hand in such a way that the current carrying conductor is placed in a magnetic field (represented by the index finger) is perpendicular to the direction of current (represented by the middle finger), then the conductor experiences a force in the direction (represented by the thumb) mutually perpendicular to both the direction of field and the current in the conductor.

When field winding is excited and armature conductors are connected across the supply, it experiences a mechanical force whose direction is given by Fleming's left-hand rule. Because of this force, the armature starts rotating. It cuts the magnetic field and an emf is induced in the armature winding. As per Lenz's law, this induced emf acts in the opposite direction to the armature supply voltage. This emf is known as back emf (E_b).

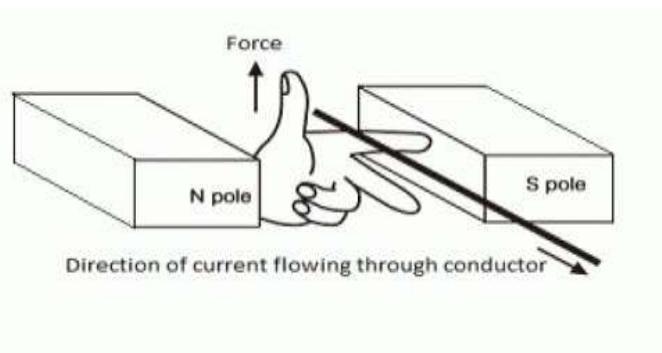


Fig 3

Construction of a DC machine

DC generator can be used as a DC motor without any constructional changes and vice versa is also possible. Thus, a DC generator or a DC motor can be broadly termed as a **DC machine**.

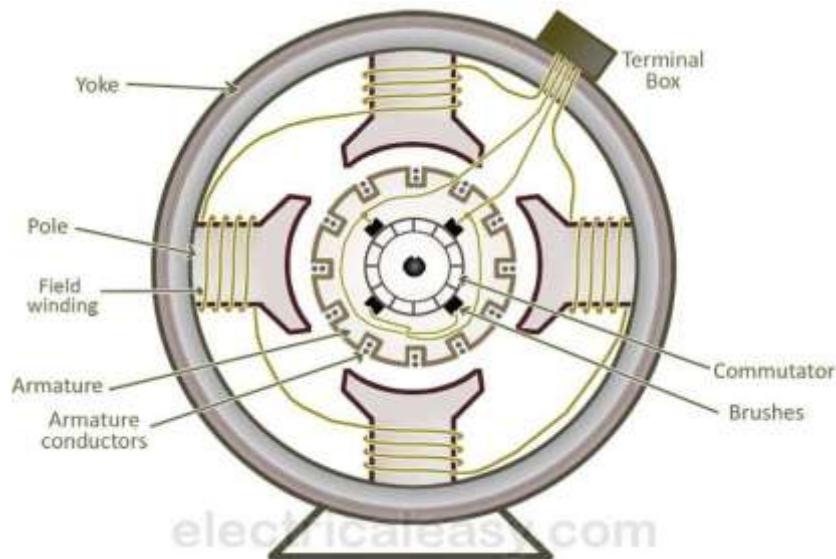


Fig 4

The above figure shows the constructional details of a simple **4-pole DC machine**. A DC machine consists two basic parts; stator and rotor. Basic constructional parts of a DC machine are described below.

1. **Yoke:** The outer frame of a dc machine is called as yoke. It is made up of cast iron or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.
2. **Poles and pole shoes:** Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes; (i) they support field coils and (ii) spread out the flux in air gap uniformly.
3. **Field winding:** They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.
4. **Armature core:** Armature core is the rotor of the machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.

5. **Armature winding:** It is usually a former wound copper coil which rests in armature slots.

The armature conductors are insulated from each other and from the armature core.

Armature winding can be wound by one of the two methods; lap winding or wave winding.

In Lap winding the armature conductors are connected in series through commutator segments in such a way that the armature winding is divided into as many parallel paths as the number of poles.

In wave winding the armature conductors are connected in series through commutator segments in such a way that the armature winding is divided into two parallel irrespective of the number of poles.

6. **Commutator and brushes:** Physical connection to the armature winding is made through a commutator-brush arrangement. The function of a commutator, in a dc generator, is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors.

A commutator consists of a set of copper segments which are insulated from each other. The number of segments is equal to the number of armature coils. Each segment is connected to an armature coil and the commutator is keyed to the shaft.

Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current.

Classification of DC machines

Depending upon the method of excitation of field winding, dc machines are classified into two classes:

- (i) Separately excited machines
- (ii) Self-excited machines

Separately Excited Machines – In a separately excited machines, the field winding is energized from a separate external source of dc current.

Self-Excited Machines – In a self-excited dc machine, no separate source is provided to drive the field current, but the field current is driven by its own emf generated across the armature terminals when the machines work as a generator. Self-excited machines are further classified into three types, depending upon the method in which the field winding is connected to the armature.

- a) Shunt-wound machines
- b) Series-wound machines
- c) Compound-wound machines

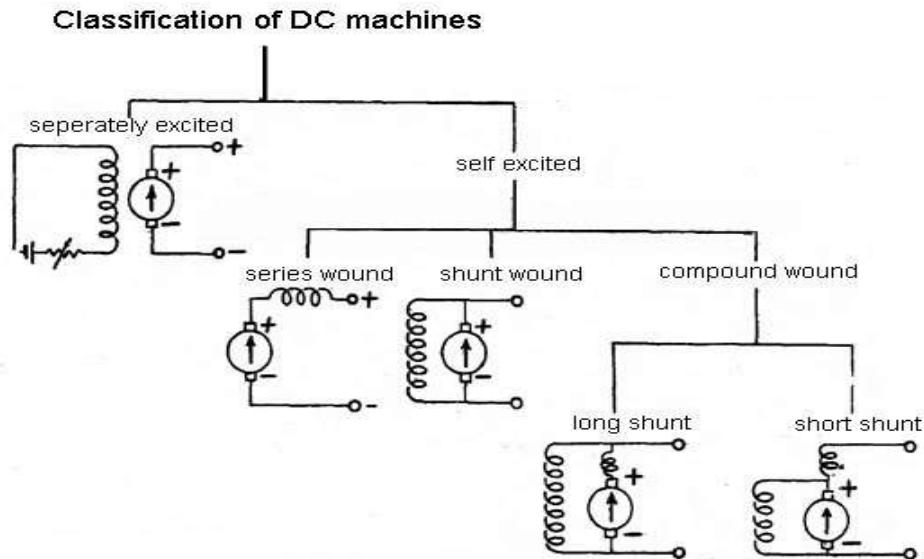


Fig 5

Shunt wound machines

In this type of dc machines, field winding is connected in parallel with the armature. The number of turns of the field winding may range from 300 to 1000.

Series wound Machines

In this type of machines, the field winding is connected in series with the armature. The number of turns of the field winding is small (2 to 10 turns) and the field winding will have a heavy area of cross -section to carry the large armature current.

Compound wound machines

Compound machines carry both the shunt and series field winding. The compound machines are further classified into long shunt and short shunt, depending upon the direction of current flow in the two types of field winding. Both the shunt field winding and the series field winding are generally wound on the same pole.

In case of a generator, load is connected across the armature whereas in case of a motor, dc supply is connected to the armature.

Application of DC Machines

Generator

Shunt Generator- Due to constant voltage characteristics they are used for:

Ordinary lighting and power supply, and charging batteries

Series Generators – Due to rising characteristics series generators are used as

- 1] As boosters in distribution systems
- 2] Constant current generators for welding generators and lamps.

Compound Generators

Lamp loads, heavy power services such as electric railways, and arc welding

Motors

A shunt motor is a constant-speed motor with medium starting torque. Its speed can be adjusted over a wide range. It is commonly used in applications such as:

1. Lathes, drilling machines, and milling machines
2. Centrifugal and reciprocating pumps
3. Blowers and fans
4. Printing machinery and paper machines

Series Motor- Series motor has very high starting torque and good accelerating torque. The speed is adjustable and varying. The motor has very low speed at high loads and dangerously high speed at low loads.

Electric locomotives, cranes and hoists, conveyors, trolley cars, and trolley-based rapid transit systems.

Compound Motor

Elevators, Conveyors, Rolling mills, Air compressors

Difference between DC motor and DC generators

- DC motor EMF is utilized by the motor coil and helpful to rotate the axle. Alternatively, in DC generator, EMF created around the coil is transferred to the load or perhaps a battery and utilized through them.
- When it comes to generator produced EMF is much more compared to terminal voltage & in d.c motor there is always emf in armature which usually is lower than terminal voltage.
- EMF produced known as generated EMF (E_g) in case of DC Generator where $E_g > V$, whereas it is back emf (E_b) in case of DC Motor where $E_b < V$.

- In the dc motor the more power you apply faster it rotates its shafts depending upon its rating, whereas, in generators, they will generate fixed amount of voltage at a fixed rpm
- Motors follow the Fleming's Left Hand, Rule while the generator depends upon Fleming's Right Hand Rule.

3.2 Single-phase Induction Motors – Working and Applications

The single phase induction motor, also known as the asynchronous motor, is a commonly used type of electric motor that can operate using a single-phase power supply. The single-phase induction motor remains one of the most widely used motors for domestic, commercial, and small industrial applications where only single-phase power is available. The single-phase induction motor stands out as one of the most ubiquitous and essential devices. This type of motor is widely used in various household and industrial applications due to its simplicity. A single-phase induction motor consists of a single-phase winding which is mounted on the stator of the motor and a cage winding placed on the rotor. A pulsating magnetic field is produced when the stator winding of the single-phase induction motor is energized by a single-phase supply. It consists of two main parts - a stator having one or more electromagnetic coils supplied with single-phase AC power and a rotor attached to the output shaft. The rotor is made up of bars short-circuited using rings at both ends, like a squirrel cage rotor of a three-phase induction motor. The single-phase supply produces a pulsating rotating magnetic field in the stator due to which current is induced in the rotor coils. However, due to the pulsating nature of the field, the rotor fails to produce torque for self-starting. Various techniques are therefore used to derive a quasi-rotating magnetic field for enabling self-starting capability in single phase induction motors. This is also known as a single-phase motor.

Working Principle of Single-Phase Induction Motor

The working principle of a single-phase induction motor is based on electromagnetic induction. When the stator winding is connected to a single-phase AC supply, it produces a pulsating magnetic field. The word Pulsating means that the field builds up in one direction falls to zero and then builds up in the opposite direction. Under these conditions, the rotor of an induction motor does not rotate. Hence, a single-phase induction motor is not self-starting. It requires some special starting means. If the 1-phase stator winding is excited and the rotor of the motor is rotated by an auxiliary means the starting device is removed, and the motor continues to rotate in the direction in which it is started.

The performance of the single-phase induction motor can be understood through two theoretical frameworks: the Double Revolving Field Theory and the Cross Field Theory.

These theories are parallel in their explanations of how torque is produced once the rotor begins to rotate. A single-phase induction motor includes a single-phase winding on the stator and a cage winding on the rotor. When this stator winding is powered by a single-phase electrical supply, it generates a pulsating magnetic field. This term "pulsating" describes how the magnetic field intensifies in one direction, diminishes to zero, and then strengthens in the reverse direction. Due to this behaviour, the rotor of a single-phase induction motor does not start spinning on its own. Thus, single-phase induction motors are not self-starting and require additional starting mechanisms to operate.

Construction of a Single-Phase Induction Motor

The construction of a single-phase induction motor involves two main parts:

1. **Stator:** The stationary part that creates the magnetic field. It consists of a laminated iron core with slots that house the stator windings.
2. **Rotor:** The rotating part that is placed inside the stator. It is typically a squirrel cage rotor made of aluminium or copper bars short-circuited by end rings.

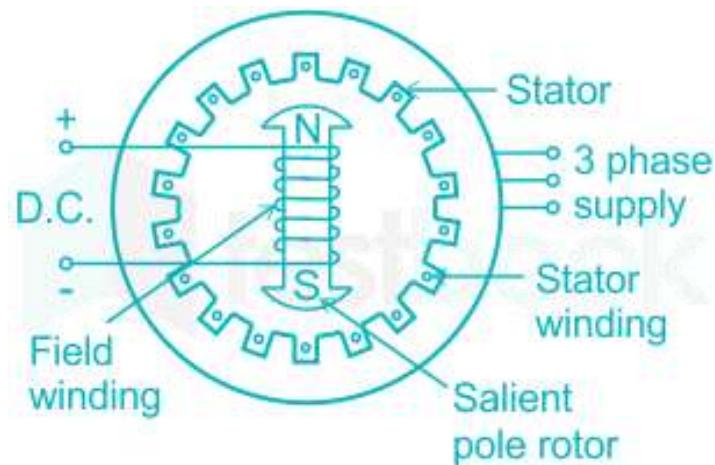


Fig 6

Double-revolving Field Theory

When a single-phase supply is connected to the stator winding, it produces two equal magnetic fields rotating in opposite directions with the same amplitude. The fields neutralize each other, producing a pulsating magnetic field. This pulsating field fails to produce the torque required for starting the motor.

When the rotor is at rest, it experiences alternate pushing and pulling from the pulsating magnetic fields without any resultant force. As it starts rotating even slightly, it enters a zone of leading field

first and then lags the following field. This makes the magnetic fields cut the rotor conductors sequentially, generating EMF and current in them. The interaction between the stator and rotor magnetic fields produces a starting torque enabling self-starting.

Applications of Single-Phase Induction Motors

Single phase motors are not self-starting and less efficient than three phase induction motor and available in 0.5HP to 15HP and still they are widely used for multiple purposes such as:

Clocks, Refrigerators, freezers, and heaters, Fans, table fans, ceiling fan, exhaust fans, air coolers and water coolers, Blowers, Washing machines, Machine tools, Dryers, Type writers, photostats and printers, Water pumps and submersible, Computers, Grinders, Drilling machines, Other Home instrument, equipment, and devices etc.

3.3 Power Backup Systems: Inverter, UPS, SMPS – Block Diagram & Principle

A power backup system, also known as an emergency power system or standby power system. This ensures continuous operation of critical equipment and essential services during power outages.

Purpose of power backup system

Power backup systems are designed to prevent disruptions caused by power outages, which can range from minor inconveniences to major disruptions in daily life and business operations. Backup power systems are crucial for maintaining essential functions, preventing data loss, and ensuring safety during power outages.

Examples of Power Backup Systems: Inverter, UPS, SMPS

Inverter

An inverter is an essential power electronic device that converts Direct Current (DC)—from sources like batteries or solar panels—into Alternating Current (AC), which is needed to run most household and industrial electrical equipment.

Most electrical appliances (like fans, refrigerators, and motors) run on AC power. But sources like batteries or solar panels provide DC power. So, we need an inverter to bridge this gap.

Fig 7

General Block Diagram of Inverter



Battery (DC Source): The inverter starts with a DC power supply, typically provided by a battery, solar panel, or other DC sources. This block supplies the constant direct current required for the inverter to function. Since most renewable energy systems generate DC power, the inverter acts as a bridge to convert this into usable AC power for appliances and machines.

Control Logic & MOSFET Switches: The DC voltage from the battery is fed into a set of semiconductor switches such as MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors). These switches are controlled by a control logic circuit that generates high-frequency PWM (Pulse Width Modulation) signals. The switches rapidly turn ON and OFF, creating a pulsating DC waveform. This pulsating signal mimics an alternating pattern, which is essential for generating AC.

Step-up Transformer: The pulsating DC from the switching circuit is sent to a step-up transformer. This transformer works on the principle of electromagnetic induction. It converts the low-voltage input to a higher-voltage AC output, depending on the number of turns in the primary and secondary windings. For example, it can convert 12V DC input into 230V AC output, suitable for household or industrial use.

Filter (Optional): In many applications, especially where sensitive electronic equipment is involved, the output waveform needs to be a pure sine wave. For this purpose, a filter circuit is used after the transformer. This filter smoothens the waveform and removes any high-frequency switching noise, resulting in clean, high-quality AC power like grid supply.

AC Output: The final output of the inverter is alternating current (AC), which can now be used to power various electrical appliances, machinery, or lighting systems. The voltage and frequency of the AC output can be regulated depending on the design of the inverter and the requirements of the load.

Applications of Inverters:

Home UPS systems, Solar energy systems, Electric vehicle drives, Industrial motor control, Portable power banks

Types of Inverters

Based on the type of input source used, inverters are broadly classified into two categories:

1. Voltage Source Inverters (VSI), 2. Current Source Inverters (CSI)

Uninterruptible Power Supply (UPS)

An Uninterruptible Power Supply (UPS) is an electrical device that provides emergency backup power to connected loads during a main power supply failure. It uses batteries or supercapacitors to store energy, which is instantly delivered to critical equipment when an outage occurs.

A standard UPS is typically designed to provide short-term power, ranging from a few minutes up to 30 minutes, depending on the load and capacity. This makes UPS systems ideal for temporary backup until the main power is restored or a generator takes over.

Beyond providing emergency power, a UPS plays a crucial role in protecting sensitive electronics from disturbances like voltage fluctuations, line transients, and harmonic distortions. Devices such as computers, data centres, televisions, industrial process control systems, and monitoring equipment benefit from this protection.

UPS systems are widely used with personal computers to prevent data loss and hardware damage due to abrupt shutdowns. In such cases, the UPS gives users enough time to safely save their work and shut down the system.

Modern UPS systems come in a variety of types and capacities, ranging from 200 VA for a single computer to multi-MVA units for industrial plants. Some advanced models feature smart software that allows automated power management, enabling unattended and safe shutdown of systems.

In industrial settings, a UPS also ensures uninterrupted operation of essential instruments and prevents unexpected plant shutdowns. Certain devices require a controlled power-down sequence, and a sudden outage could cause equipment failure or data corruption.

Other common names for a UPS include uninterruptible power source, battery backup, or flywheel backup.

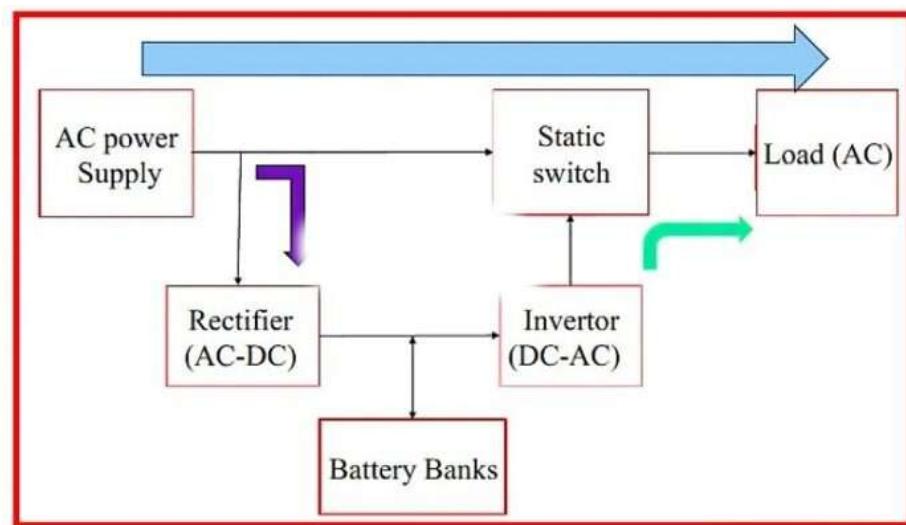


Fig 8

Major Components of a UPS System

A UPS (Uninterruptible Power Supply) system is designed to provide continuous power to critical loads during mains power interruptions or failures. It ensures smooth transition and protects equipment from power disturbances. The key components of a typical UPS system include:

1. Battery (Energy Storage Unit)

The battery serves as the heart of the UPS system's backup functionality. It stores electrical energy in DC form and provides it to the inverter when the main AC supply fails. The battery ensures uninterrupted power delivery for a defined period, allowing safe system shutdown or continuity of operations. Different types of batteries used in UPS systems include Sealed Maintenance-Free Batteries (SMFB), Lead-Acid Tubular Batteries (LATB), and Nickel-Cadmium (Ni-Cd) batteries.

2. Rectifier / Charger Circuit (AC to DC Converter)

The rectifier is responsible for converting incoming AC (typically 230–240V) power into DC power, which is then used to charge the battery and supply the inverter. Modern UPS systems often use 6-pulse or 12-pulse thyristor-based rectifiers, where a 12-pulse configuration offers reduced current distortion. The rectifier ensures the battery remains fully charged and ready to deliver power when needed.

3. Inverter (DC to AC Converter)

The inverter converts the DC power stored in the battery into clean, stable AC power to supply the load during a power outage. Most inverters today use IGBT (Insulated Gate Bipolar Transistor) based PWM (Pulse Width Modulation) technology to produce a sinusoidal output waveform that mimics the utility power, ensuring compatibility with sensitive electronic equipment.

4. Static Switch (Semiconductor Transfer Switch)

The static switch is a high-speed semiconductor device, such as a thyristor or triac, used to switch the load between the utility (mains) supply and the inverter output without interruption. It ensures zero-transfer time, especially important for critical loads where even a 5–10 ms delay could lead to equipment malfunction. In case of inverter overload or fault, the static switch transfers the load back to mains (bypass) instantaneously, ensuring system protection and continuity.

Types of UPS

There are 3 different types of UPS as follows

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

Applications of UPS

1.Information Technology (IT) and Data Centres 2. Healthcare and Hospitals 3. Industrial Automation and Manufacturing 4. Telecommunications 5. Banking and Financial Institutions 6. Offices and Commercial Establishments 7. Homes and Small Businesses 8. Transportation and Infrastructure 9. Educational and Research Institutions 10. Military and Defence

Switch Mode Power Supply (SMPS)

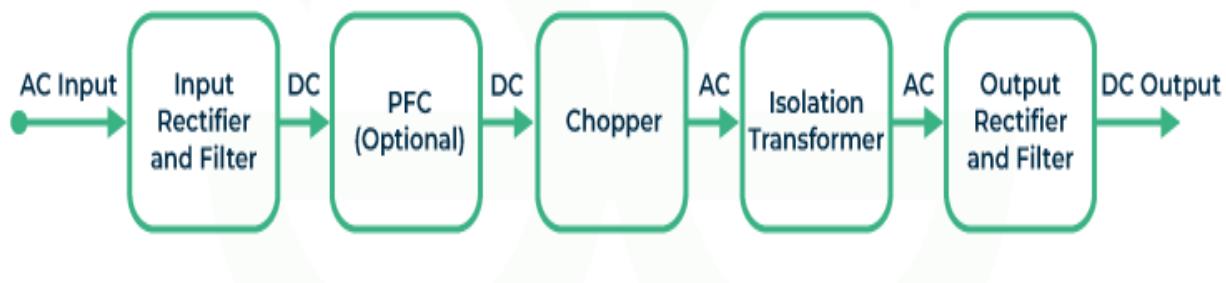
A switching regulator is included in an electronic power supply called a switched-mode power supply (SMPS) to facilitate effective electrical power conversion. An SMPS converts voltage and current while transferring power to DC loads via a DC or AC source, just like other suppliers.

Working Principle of SMPS

A switching regulator is integrated into an electronic power supply called a switch mode power supply (SMPS), which is sometimes referred to as a switcher, switched power supply, switching-mode power supply, and simply switcher. This power supply effectively converts electrical power. An SMPS, like other kinds of power supplies, converts current and voltage characteristics while transferring power from an AC or DC source (often mains power; see AC adapter) into DC loads, like a personal computer. Switched-mode energy sources can also be significantly lighter and more compact than linear power supplies since their transformers can be considerably smaller. This is since, in contrast with the 50 to 60 Hz mains frequency, it works at a high rate of switching that extends from a few kHz to several MHz.

The power supply architecture and the need for EMI (electromagnetic interference) suppression in commercial systems lead to a typically significantly higher component count and accompanying circuit complexity despite the smaller transformer.

Switching regulators are employed in SMPS devices to maintain & regulate the output voltage by turning on or off the load current. The mean value between on and off is the appropriate power output for a system. The SMPS reduces depletion strength because, in contrast to the linear power supply, it carries transistor switches between low dissipation, full-on as well as full-off phases and spends significantly fewer seconds in high dissipation cycles.

**Fig 9**

- In the initial stage, a rectifier and filter are used to process the AC power that comes in into DC.
- Because the SMPS operates at high frequencies, the DC signal is processed by a high-frequency switch to produce a medium-frequency pulsating DC signal.
- A power transformer reduces the high-voltage DC output to the proper level of DC signal.
- Reversing and filtering the stepped-down DC signal results in a constant steady DV output.
- To guarantee a constant output stream of the intended voltage, the control circuitry continuously monitors the generated voltage and modifies the high-frequency switch.

Application of SMPS

1. Computers and Laptops
2. Telecommunication Equipment
3. Industrial Automation Systems
4. Consumer Electronics
5. Battery Chargers
6. LED Lighting Systems
7. Medical Equipment
8. Aerospace and Defence Systems
9. Electric Vehicles and Charging Stations
10. Renewable Energy Systems (Solar Inverters, etc.)

3.4 Batteries: Lead-Acid and Lithium-ion – Construction & Characteristics

Almost every portable and handheld device consist a battery. The battery is a storage device where energy is stored to provide the power whenever needed. There are different types of batteries available in this modern electronics world, among them Lead Acid battery is commonly used for high power supply. Usually Lead Acid batteries are bigger in size with hard and heavy construction, they can store high amount of energy and generally used in automobiles and inverters.

Construction of Lead Acid Battery

If we break the name Lead Acid battery we will get Lead, Acid, and Battery. Lead is a chemical element (symbol is Pb and the atomic number is 82). It is a soft and malleable element. We know what Acid is; it can donate a proton or accept an electron pair when it is reacting. So, a battery, which

consists of Lead and anhydrous plumbic acid (sometimes wrongly called as lead peroxide), is called as Lead Acid Battery. A Lead Acid Battery consists of Plates, Separator, and Electrolyte, Hard Plastic with a hard rubber case.

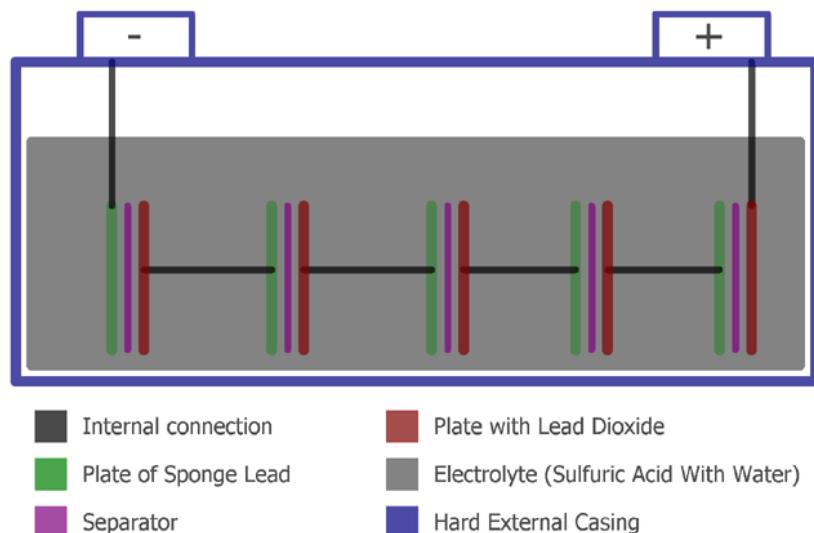


Fig 10

In the batteries, the plates are of two types, positive and negative. The positive one consists of Lead dioxide and negative one consists of Sponge Lead. These two plates are separated using a separator which is an insulating material. This total construction is kept in a hard plastic case with an electrolyte. The electrolyte is water and sulfuric acid.

The hard plastic case is one cell. A single cell store typically 2.1V. Due to this reason, A 12V lead acid battery consists of 6 cells and provide $6 \times 2.1\text{V}/\text{Cell} = 12.6\text{V}$ typically.

Working of Lead Acid Battery

A lead-acid battery works on the principle of chemical reactions that take place between lead plates and sulfuric acid. It has two main states – charging and discharging. When the battery is used (discharging), it provides electrical energy to connected devices. Inside the battery, the positive plate is made of lead dioxide (PbO_2), and the negative plate is made of spongy lead (Pb). These plates are immersed in a diluted sulfuric acid solution which acts as the electrolyte. During discharge, the sulfuric acid reacts with both plates, and they are gradually converted into lead sulphate (PbSO_4). At the same time, water is formed, and the acid becomes weaker. This chemical reaction produces electrons, which flow through the external circuit, supplying power to devices.

When the battery is charged again using an external power source, the chemical reactions are reversed. The lead sulphate on the plates is converted back into lead dioxide (at the positive plate)

and pure lead (at the negative plate). The water formed earlier is converted back into sulfuric acid, making the acid stronger again. This process restores the battery's ability to supply power.

In simple terms, when the battery is discharging, it gives energy by turning acid into water and lead sulphate. When charging, it stores energy by turning water and lead sulphate back into acid and active materials. This cycle of charging and discharging allows the battery to be reused many times.

Lithium-ion Battery

A lithium-ion battery is a type of rechargeable battery having features such as high energy density, fast charge, long cycle life, and wide temperature range operation. A lithium-ion (Li-ion) battery is a type of rechargeable battery that uses lithium ions as the main component of its electrochemical cells. It is characterised by high energy density, fast charge, long cycle life, and wide temperature range operation. Lithium-ion batteries have been credited for revolutionising communications and transportation, enabling the rise of super-slim smartphones and electric cars with a practical range such as portable electronics and electrified transportation.

Lithium-ion Battery Construction

A lithium-ion battery consists of an anode (negative electrode), cathode (positive electrode), separator, electrolyte, and two current collectors (positive and negative).

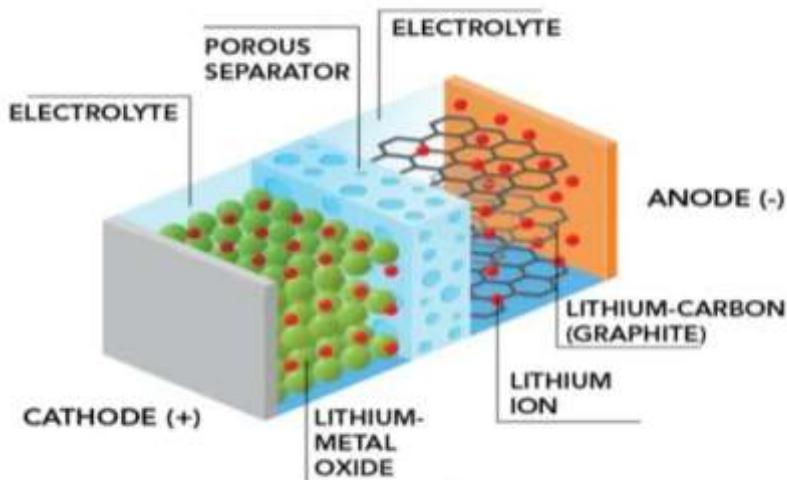


Fig 11

Cathode: The cathode of a lithium-ion battery is typically made of a lithium metal oxide, such as lithium cobalt oxide (LiCoO_2), lithium manganese oxide (LiMn_2O_4), or lithium iron phosphate (LiFePO_4).

The choice of cathode material influences the performance characteristics of the battery.

Anode: The anode is usually composed of graphite. During discharge, lithium ions move from the anode to the cathode through the electrolyte, and during charging, they move back to the anode.

Electrolyte: The electrolyte is a conductive medium that allows the flow of lithium ions between the cathode and anode.

It is typically a lithium salt dissolved in a solvent.

Separator: The separator is a permeable membrane that keeps the cathode and anode apart to prevent a short circuit while allowing the passage of lithium ions.

Rechargeability: One of the key advantages of lithium-ion batteries is their rechargeability.

They can be recharged hundreds to thousands of times, depending on the specific chemistry and use conditions such as overcharging or undercharging.

Working of Lithium-ion Battery

A lithium-ion battery works on the principle of electrochemical reactions, specifically oxidation and reduction (redox) reactions, during charging and discharging. In the discharging process, when the battery is supplying power, lithium atoms in the anode (usually graphite) lose electrons and become lithium ions (Li^+). This reaction is called oxidation. These lithium ions travel through the electrolyte and a micro-permeable separator to reach the cathode (usually made of cobalt oxide), where they recombine with electrons and get stored. The movement of these ions and electrons generates electricity to power devices.

During the charging process, the chemical reactions reverse. Lithium ions move from the cathode back to the anode, and electrons also move back through the external circuit. At the cathode, a reduction reaction takes place where cobalt oxide combines with lithium ions and electrons to form lithium-cobalt oxide (LiCoO_2). This process stores energy in the battery. Lithium-ion batteries are popular because they can store a lot of charge and deliver high voltage in a small and lightweight design.

Self-Learning Topics: Comparison of DC Motor, Induction Motor, Inverter, UPS, Battery (Lead-acid and Li-ion) (basic specifications and applications)

Comparison of DC Motor and Induction Motor

DC Motor	Induction Motor
Works on DC supply	Works on AC supply
Has commutator and brushes	No commutator, mostly brushless
High starting torque	Starting torque is moderate
Speed can be controlled easily	Speed control is more complex
Requires more maintenance	Needs less maintenance
Used in electric vehicles, toys, trains	Used in fans, pumps, machines
Construction is complex	Construction is simple and rugged
More expensive	Cheaper and more durable

Comparison: Inverter, UPS, Lead-Acid Battery, and Li-ion Battery

Feature / Device	Inverter	UPS	Lead-Acid Battery	Lithium-ion Battery
Power Type	Converts DC to AC	Backup power with instant switch	Rechargeable DC source	Rechargeable DC source
Input Supply	DC (from battery/solar)	AC (with internal battery)	DC Charging	DC Charging
Output	AC (for appliances)	AC (instant power to load)	DC Output	DC Output
Backup Time	Depends on battery	Short (few mins to 1 hour)	1–5 hours (based on size)	2–8 hours (based on size)
Switching Time	Few milliseconds (not instant)	Instant (<10ms)	Not applicable	Not applicable
Maintenance	Low	Low to medium	Needs water refill (if not sealed)	Maintenance-free
Life Span	~5–8 years	~3–6 years	~3–5 years	5–10 years
Weight	Light	Moderate	Heavy	Lightweight
Cost	Medium	Medium to high	Cheaper	Costlier
Applications	Homes, offices (TV, fan)	Computers, hospitals, servers	Inverters, vehicles, solar systems	Mobiles, laptops, EVs, solar backup