

Uninterrupted Power Supply

Uninterrupted Power Supply: Uninterruptible power supply (UPS) is a type of power supply system that provide interrupts (Power outage, power blackout, Brownout, surge, spike, sag) free power supply to the load.

An Uninterruptible Power Supply system generally offers multiple outlets, allowing to maintain battery back-up power to more than one device and will also include additional outlets for surge protection.

Important Interrupts

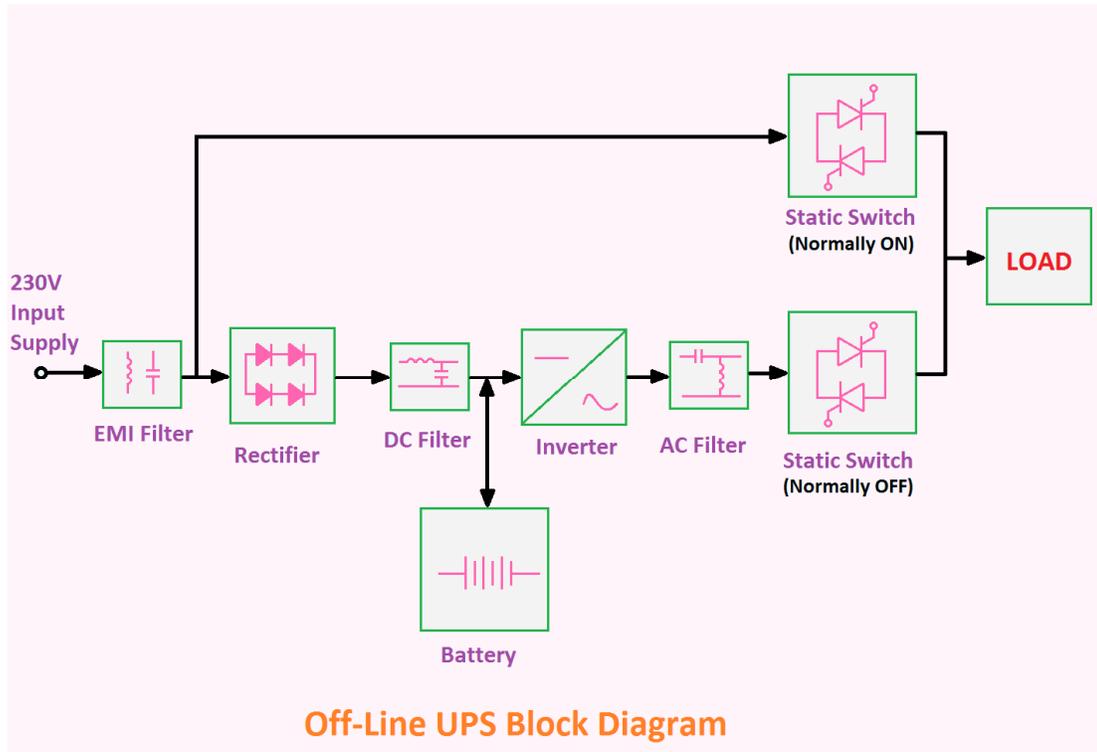
- i. **Surges:-** Oversupply of voltage from the electrical supply voltage (or current or both) for a very short period (less than a second) from power grids
- ii. **Spike:-** Electrical spike is increase in the electrical supply voltage (or current or both) for a very short period (less than a second),. Another name for an electrical spike is an electrical surge.
- iii. **Power outage:-** (also called a power cut, a power blackout, power failure or a Brownout) is a short-term or a long-term loss of the electric power to a particular area. There are many causes of power failures in an electricity network. Blackouts is due caused by bad weather. Brownouts is due to an overloaded power grid.
- iv. **Voltage Sag:-** A voltage **sag** is a short duration reduction in r. m. s. voltage which can be caused by a short circuit, overload or starting of electric motors.

Types of UPS

There are three types of UPS

- i. OFF Line UPS
 - ii. Online UPS
 - iii. Line Interactive UPS
1. **OFF Line UPS:** OFF-Line UPS are those UPS which passes the AC Mains Supply directly to the output load if the AC Mains Supply is present. Only in the case of power failure, it switches to inverter within few milliseconds to give power to load until mains supply returns. The off line UPS is also called as standby Uninterruptible Power.

The Block Diagram of Offline UPS is given below.



1. **EMI Filter:** It is made using inductors and capacitor. The main function of this EMI filter circuit is to reduce or filter the electromagnetic interferences.
2. **Rectifier Circuit:** The rectifier circuit is used to convert AC to DC. As the UPS has the battery inside it, and the battery can store only DC that is why we need to convert input AC supply into DC.
3. **DC Filter Circuit:** The DC filter circuit is used to filter the impure DC comes from the rectifier circuit. The DC output from the rectifier has some AC component. So the filter circuit is used to remove those AC components from the DC supply.
4. **Battery:** The battery is connected with the output of the DC filter circuit. When the UPS is connected to the power supply the battery will charge.
5. **Inverter Circuit:** Now we have DC supply but, we need AC supply as output to drive the load. So the inverter circuit is used to convert the DC to AC. The inverter Circuit is made high-speed solid state switches such as MOSFET, SCR, etc. If your load required DC supply then the Inverter Circuit is not required.

6. **AC Filter Circuit:** The AC filter circuit is used to filter the impure AC coming from the inverter circuit.
7. **Static Switch:** A static switch is connected between the AC filter Circuit and the Critical Load. Which allow or disallow the power flow from the UPS to load according to the given condition.

Another static switch is connected between the critical load and the main power supply after the EMI filter Supply. This switch allows or disallows the power flow from the main supply to the load.

In the case of Offline UPS, the upper static switch is normally ON and lower static switch is normally OFF. So in normal condition, the power directly flows from the main supply to the load. At the same time, the battery will charge. When the main power supply is not available, the upper static switch will be OFF and the lower static switch will be ON. So the load takes power from the battery.

This kind of UPS system offers a small size, high degree of efficiency, & pretty low costs, making of this UPS is easy.

Advantages of Offline UPS:

- i. Offline UPS has high efficiencies, since charger is not continuously on.
- ii. The power handling capacity of charger is reduced.
- iii. Cost of Offline UPS is low..
- iv. Internal control is simpler in offline UPS.
- v. Operation of Off-Line UPS is Silent when in standby mode.

Disadvantages of OFF-Line UPS:

- i. Since offline UPS provides mains supply when it is present, the output contains voltage spikes, brownouts, blackouts.
- ii. There is finite transfer time from mains to inverter when mains supply fails.
- iii. Output of offline Uninterruptible Power Supply is not perfectly reliable.
- iv. Minimal power protection - only protects against a small percentage of problems.
- v. Output voltage regulation is poor- sags and surges will be passed straight to the load.

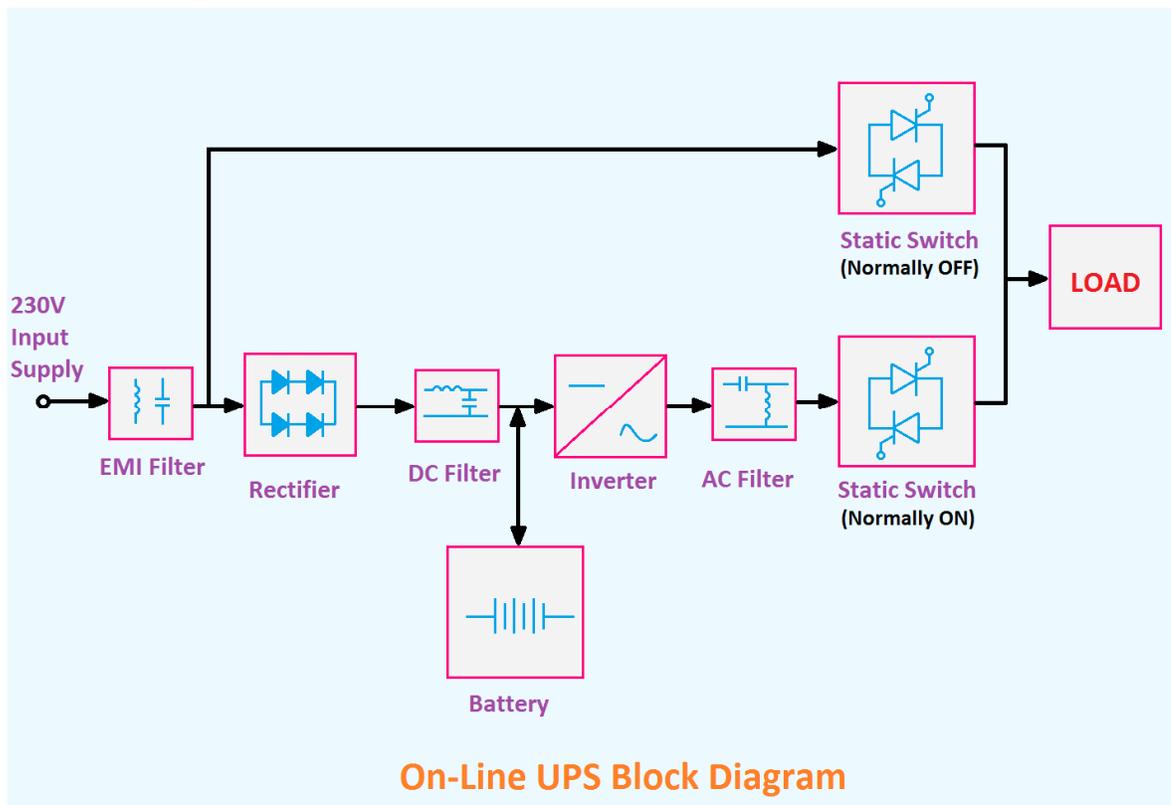
Applications of OFF-Line UPS:

- i. Off-Line UPS are used in Computers, printers, scanners etc.
- ii. Off-Line UPS are used in Emergency power supplies, EPABX.

2. **ON-Line UPS:** ON-Line UPS are those UPS which supplies power to load via the inverter. Even if the mains supply fails, there is no interruption to the output load at all and always charges battery from incoming AC mains supply.

In this UPS, the total load power flow through both the inverter and the battery charger, resulting in reduced efficiency with its associated increased heat generation.

The block diagram of ON-Line UPS is shown below :-



1. **EMI Filter:** It is made using inductors and capacitor. The main function of this EMI filter circuit is to reduce or filter the electromagnetic interferences.
2. **Rectifier Circuit:** The rectifier circuit is used to convert AC to DC. As the UPS has the battery inside it, and the battery can store only DC that is why we need to convert input AC supply into DC.
3. **DC Filter Circuit:** The DC filter circuit is used to filter the impure DC comes from the rectifier circuit. The DC output from the rectifier has some AC component. So the filter circuit is used to remove those AC components from the DC supply.

4. **Battery:** The battery is connected with the output of the DC filter circuit. When the UPS is connected to the power supply the battery will charge.
5. **Inverter Circuit:** Now we have DC supply but, we need AC supply as output to drive the load. So the inverter circuit is used to convert the DC to AC. The inverter Circuit is made high-speed solid state switches such as MOSFET, SCR, etc. If your load required DC supply then the Inverter Circuit is not required.
6. **AC Filter Circuit:** The AC filter circuit is used to filter the impure AC coming from the inverter circuit.
7. **Static Switch:** A static switch is connected between the AC filter Circuit and the Critical Load. Which allow or disallow the power flow from the UPS to load according to the given condition.

Another static switch is connected between the critical load and the main power supply after the EMI filter Supply. This switch allows or disallows the power flow from the main supply to the load.

In the case of Online UPS, the lower static switch is normally ON and the upper static is normally OFF. So in normal condition the power flow from the main supply to the load through the total UPS circuitry. When the main power supply is not available, then the load takes power from the battery.

If the UPS is unable to deliver power to the load then the upper static switch will be ON and the lower Switch will be OFF. So in this case, the power will directly flow from the main supply to the load.

Online UPSs provide full protection from major power problems, such as surges, spikes, sags, blackouts and brownouts.

Advantages of Online UPS:

- i. It provides isolation between main supply and load.
- ii. Since inverter is always ON, the quality of load voltage is free from distortion.
- iii. All the disturbances of supply such as blackout, brownouts, spikes etc are absent in the output.
- iv. Voltage regulation of On-Line UPS is better.
- v. Transfer time is practically zero since inverter is always ON.

Disadvantages of Online UPS:

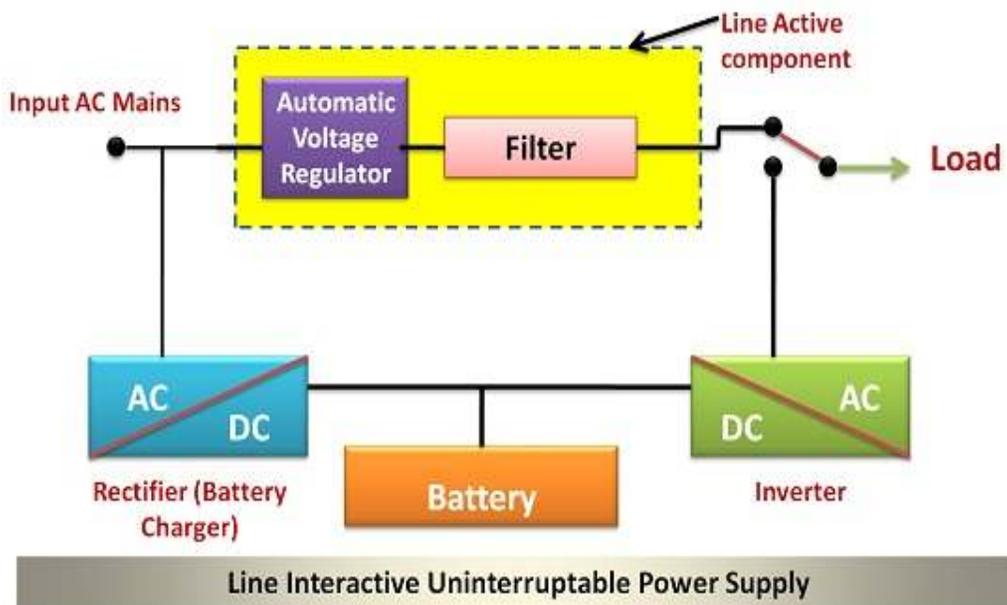
- i. Overall efficiency of UPS is reduced since inverter is always ON.
- ii. The wattage of the rectifier is increased since it has to supply power to inverter as well as charge battery.
- iii. Online UPS is costlier than other Uninterruptible Power Supply Systems.

Applications of Online UPS:

- i. ON-Line UPS are used in Induction motor drives and similar other motor control applications.
- ii. ON-Line UPS are used in Intensive care units, medical equipments.
- iii. ON-Line UPS are used in Computers, Data Centres, Server rooms, Search Data Centres
- iv. ON-Line UPS are used in Network Operation Centres
- v. ON-Line UPS are used in Process Industries

3. Line Interactive UPS : Line-interactive UPS is one type of Uninterruptible Power Source that can regulate voltage automatically. Line-Interactive technology is an incorporates technology that allows the UPS to correct minor power fluctuations (under and over voltages) without switching to battery.

Line Interactive UPSs provide full protection from major power problems, such as surges, spikes, sags, blackouts and brownouts..



1. **Automatic Voltage Regulator (AVR)** : An automatic voltage regulator (AVR) is a electronic device for automatically maintaining output voltage at a set value under varying load and operating temperature. It controls output by sensing the voltage V_{out} .
2. **Filter** : It is made using inductors and capacitor. The main function of this EMI filter circuit is to reduce or filter the electromagnetic interferences.
3. **Rectifier (Battery Charger)** : The rectifier circuit is used to convert AC to DC. As the UPS has the battery inside it, and the battery can store only DC that is why we need to convert input AC supply into DC.
4. **Battery**: The battery is connected with the output of the Rectifier. When the UPS is connected to the power supply the battery will charge.
5. **Inverter**: Now we have DC supply but, we need AC supply as output to drive the load. So the inverter circuit is used to convert the DC to AC. The inverter Circuit is made high-speed solid state switches such as MOSFET, SCR, etc.
6. **Static Switch**: A static switch is connected between the AC filter Circuit and Inverter Circuit to connect with the Critical Load. Which allow or disallow the power flow from the UPS to load according to the given condition.

The designing of line interactive UPS is like as Offline (standby) UPS, in addition the design Line Interactive generally includes an automatic voltage regulator(AVR). This AVR provide the regulation of input main supply voltage. The Voltage regulation is a significant feature when the conditions of a low voltage exist, otherwise the UPS would transfer to battery & then finally down the load.

.A good line-interactive UPS, Inverter will supply a sine wave output to the load. Upon the return of mains power, the output is switched back onto mains supply and the inverter will be turned off. In Line Interactive UPS, Electronic Switching to and from battery is faster than an offline UPS.

Advantages:

- i. The cost of Line interactive UPS is lower than online UPS
- ii. It gives better protection than offline UPS.
- iii. The operation of Line Interactive UPS is Silent when in standby mode.

Disadvantages:

- i. In Line Interactive UPS, Fluctuations, such as spikes, can still be passed straight to the load
- ii. There is finite transfer time from mains to inverter when mains supply fails
- iii. Line Interactive UPS has No failsafe - UPS will drop the load if there is a high start-up current, overload or inverter failure.

Simply put, an **on-line UPS** offers a higher level of protection than a **line interactive** at a higher cost.

Comparison between Online, Offline UPS and Line-interactive UPS :

Sr. No	Parameter	Online UPS	Offline UPS	Line-interactive UPS
1	Inverter	Always ON	Turned On when mains fails	Turned On when mains fails
2	Rectifier cum charger	Supplies power to inverter as well as charges battery	Charges only battery	Charges only battery
3	Output waveform	Sine wave	Quasi square wave	Sine wave & Quasi square wave
4	Harmonic distortion	Low	High	Low
5	Efficiency	Low	High	High
6	Load	Isolated from supply	Not isolated from Supply	Not isolated from Supply but regulated by AVR
7	Cost	High	Low	Medium

High Voltage Direct Current Transmission (HVDC Transmission):

A High-Voltage Direct Current (HVDC) electric power transmission system is a Transmission system which uses direct current for the bulk transmission of electrical power.

The bulk transmission of electricity in the form of DC over long distances by means of overhead transmission line is the high voltage direct current transmission.

This type of transmission is preferred over HVAC transmission for very long distance when considering the cost, losses and many other factors.

HVDC Transmission System

We know that AC power is generated in the generating station. This should first be converted into DC. The conversion is done with the help of rectifier. The DC power will flow through the overhead lines. At the user end, this DC has to be converted into AC. For that purpose, an inverter is placed at the receiving end.

Thus, there will be a rectifier terminal in one end of HVDC substation and an inverter terminal in the other end. The power of the sending end and user end will be always equal.

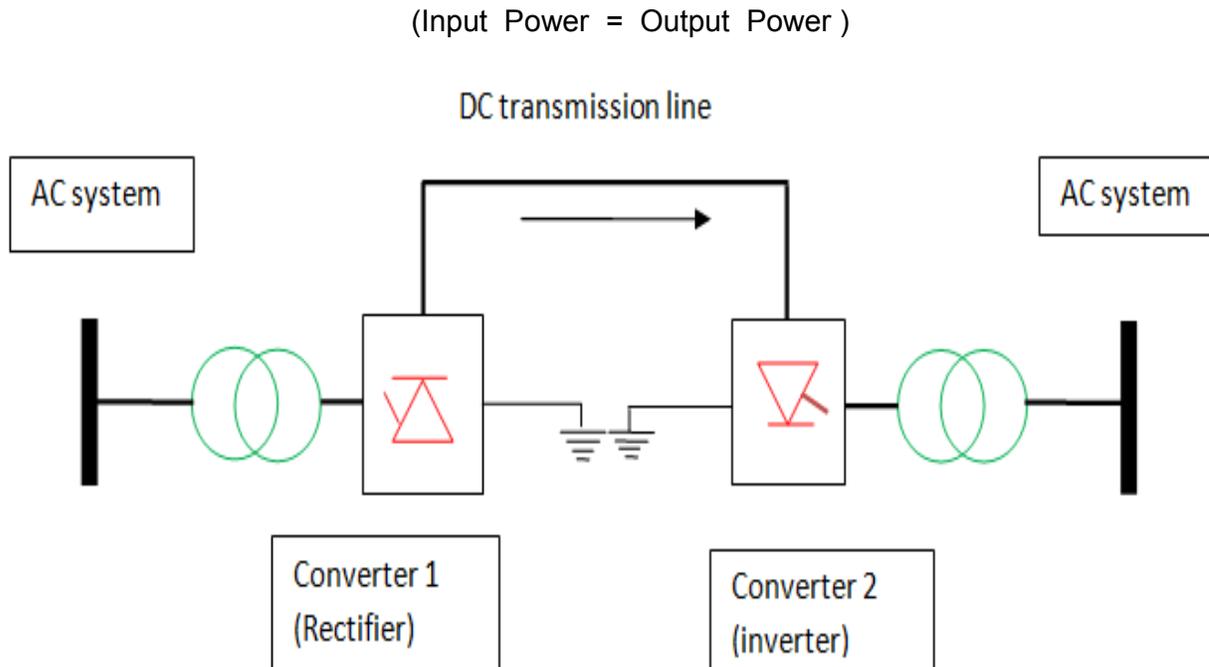


Figure 3: Mono Polar Link

The components of the **HVDC Transmission** system and its function are explained below:

- i. **A. C. System** : AC power Generating System at the generating station will generate A. C. Power.
- ii. **Converter 1 (Rectifier)**: The Rectifier Converter at the transmitting end converts AC Power in to DC Power before Transmission.
- iii. **DC Transmission Lines**: It can be cables or overhead lines which transfer High Voltage Direct Current to the destination / receiving end.
- iv. **Converter 2 (Inverter)**: The Inverter Converter at the receiving end converts DC Power in to AC Power after receiving at the destination.

Advantages of HVDC Transmission:

- i. HVDC Transmission System have Low losses.
- ii. HVDC Transmission System have Better Voltage regulation and Control ability.
- iii. HVDC Transmission System Transmit more power over a longer distance.
- iv. HVDC Transmission System need Less insulation.
- v. Reliability of HVDC Transmission System is high.
- vi. HVDC Transmission System Reduced line cost due to fewer conductors.

Disadvantages of HVDC Transmission

- i. In HVDC, Converters with small overload capacity are used.
- ii. In HVDC, Circuit Breakers, Converters and AC filters are expensive especially for small distance transmission.
- iii. HVDC link is extremely complicated.
- iv. In HVDC, power flow is uncontrollable.

Application of HVDC Transmission

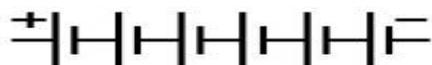
- i. HVDC Transmissions are used in Undersea and underground cables.
- ii. HVDC Transmissions are used in AC network interconnections
- iii. HVDC Transmissions are used in Interconnecting Asynchronous system.

Comparison of both HVAC and HVDC Transmission System

HVDC Transmission System	HVAC Transmission System
i. Low losses.	i. Losses are high due to the skin effect and corona discharge
ii. Better Voltage regulation and Control ability.	ii. Voltage regulation and Control ability is low.
iii. Transmit more power over a longer distance.	iii. Transmit less power compared to a HVDC system.
iv. Less insulation is needed.	iv. More insulation is required.
v. Reliability is high.	v. Low Reliability.
vi. Asynchronous interconnection is possible.	vi. Asynchronous interconnection is not possible.
vii. Reduced line cost due to fewer conductors.	vii. Line cost is high.
viii. Towers are cheaper, simple and narrow.	viii. Towers are bigger compared to HVDC.

Battery: A battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the Anode and its negative terminal is the Cathode.

Symbol:



Types of Batteries

Batteries generally are of two major types;

- i. Primary Batteries
- ii. Secondary Batteries
- i. **Primary Batteries:** Primary batteries are batteries that cannot be recharged once depleted. Primary batteries are made of electrochemical cells whose electrochemical reaction cannot be reversed.

The most popular type of primary batteries are **alkaline batteries** Pace makers, Animal trackers, Wrist watches, remote controls and children toys.

- ii. **Secondary Batteries:** Secondary batteries are batteries with electrochemical cells whose chemical reactions can be reversed by applying a certain voltage to the battery in the reversed direction. Also referred to as rechargeable batteries, secondary cells unlike primary cells can be recharged after the energy on the battery has been used up.

The Secondary batteries can be further classified into several other types based on their chemistry. There are basically four major chemistries for rechargeable batteries;

- i. Nickel Cadmium(Ni-Cd)
- ii. Nickel-Metal Hydride(Ni-MH)
- iii. Lead-Acid
- i. **Nickel-Cadmium Batteries:** The nickel–cadmium battery (Ni-Cd battery or Ni-Cad battery) is a type of rechargeable battery which is developed using nickel oxide hydroxide and metallic cadmium as electrodes. Ni-Cd batteries excel at maintaining voltage and holding charge when not in use. However, NI-Cd batteries easily fall a victim of the dreaded “memory” effect when a partially charged battery is recharged, lowering the future capacity of the battery.



Nickel – Cadmium battery

In comparison with other types of rechargeable cells, Ni-Cd batteries offer good life cycle and performance at low temperatures with a fair capacity but their most significant advantage will be their ability to deliver their full rated capacity at high discharge rates. They are available in different sizes including the sizes used for alkaline batteries, A to D. Ni-Cd cells are used individual or assembled in packs of two or more cells. The small packs are used in portable devices, electronics and toys while the bigger ones find application in aircraft starting batteries, Electric vehicles and standby power supply.

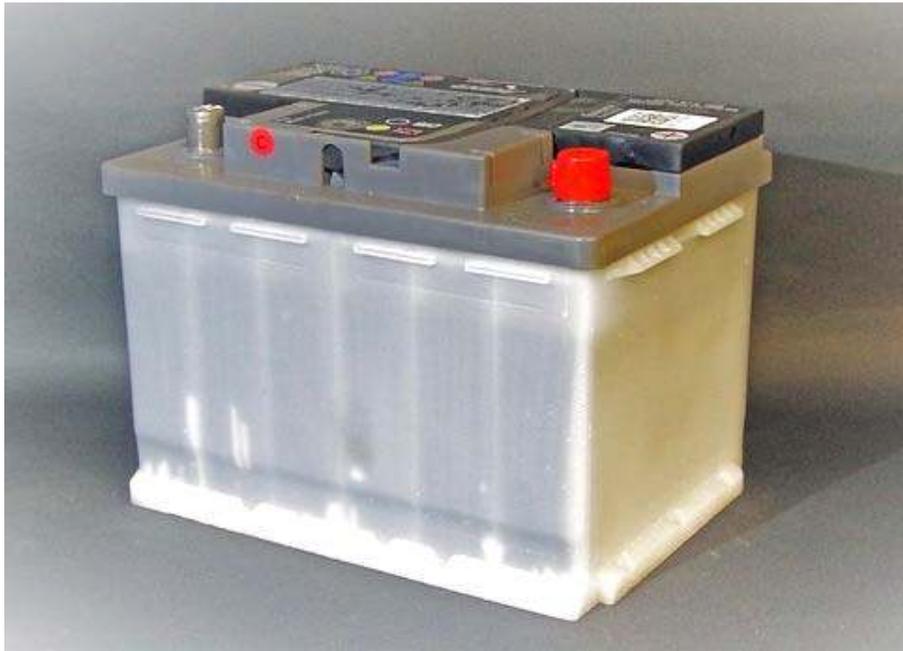
- ii. **Nickel-Metal Hydride Batteries:** Nickel metal hydride (Ni-MH) is another type of chemical configuration used for rechargeable batteries. The chemical reaction at the positive electrode of batteries is similar to that of the nickel–cadmium cell (Ni-Cd), with both battery type using the same nickel oxide hydroxide (NiOOH). However, the negative electrodes in Nickel-Metal Hydride use a hydrogen-absorbing alloy instead of cadmium which is used in NiCd batteries



Ni-MH Battery

NiMH batteries find application in high drain devices because of their high capacity and energy density. A NiMH battery can possess two to three times the capacity of a NiCd battery of the same size, and its energy density can approach that of a lithium-ion battery.

- iii. **Lead-Acid Batteries:** Lead acid batteries are a low-cost reliable power workhorse used in heavy duty applications. They are usually very large and because of their weight, they're always used in non-portable applications such as solar-panel energy storage, vehicle ignition and lights, backup power and load leveling in power generation/distribution. The lead-acid is the oldest type of rechargeable battery and still very relevant and important into today's world. Lead acid batteries have very low energy to volume and energy to weight ratios but it has a relatively large power to weight ratio and as a result can supply huge surge currents when needed. These attributes alongside its low cost makes these batteries attractive for use in several high current applications like powering automobile starter motors and for storage in backup power supplies.



Lead Acid Batteries

Selecting the right battery for your application

One of the main problems hindering technology revolutions like IoT is power, battery life affects the successful deployment of devices that require long battery life and even though several power management techniques are being adopted to make the battery last longer, a compatible battery must still be selected to achieve the desired outcome.

Below are some factors to consider when selecting the right type of battery for your project.:

- i. **Size of Load:** It means the total KVA requirement of load to be connected.
- ii. **Energy Density:** The energy density is the total amount of energy that can be stored per unit mass or volume. This determines how long your device stays on before it needs a recharge.
- iii. **Power Density:** Maximum rate of energy discharge per unit mass or volume. Low power: laptop, i-pod. High power: power tools.
- iv. **Safety:** It is important to consider the temperature at which the device you are building will work. At high temperatures, certain battery components will breakdown and can undergo exothermic reactions. High temperatures generally reduces the performance of most batteries.
- v. **Life cycle durability:** The stability of energy density and power density of a battery with repeated cycling (charging and discharging) is needed for the long battery life required by most applications.
- vi. **Cost:** Cost is an important part of any engineering decisions you will be making. It is important that the cost of your battery choice is commensurate with its performance and will not increase the overall cost of the project abnormally.

FILL IN THE BLANKS:

1. UPS stands for
2. UPS in which Inverter is even the main power is ON is called ON-Line UPS.
3. The Online UPS provides an Between the Load and AC supply.
4. On-Line UPS System is Reliable than OFF Line UPS.
5. The back-up Time depends on the of the Battery and theof Inverter.
6. UPS in which Inverter iswhen the main Power is ON is called OFF-Line UPS.
7. UPS also called Double Conversion UPS.
8. In UPS, the primary power source is mains line power, and secondary power source is battery.
9. The UPS is also called Backup UPS.
10. In an UPS is one where the Inverter is running 100% of Time interacting continuously with the changing state of the Input AC Utility Line.
11. In an UPS, the batteries are always connected to the Inverter, so that No Power Transfer Switches are necessary.
12. In ON-Line UPS, the Inverter is all the time.
13. HVDC Stand for
14. For charging of Batterysupply is required.
15. HVAC System are economical only for transmission.
16. System has full control over the Transmission Line.
17. SMF stand for
18. In OFF-Line UPS, the Inverter is when the main supply is present.
19. A Switching Mode Power Supply is a multistagesupply.
20. Sealed Maintenance Free Batteries (SMF) than Lead Acid Batteries.

Answers:

- | | | | |
|----------------------------------|---------------------------------|-------------------------------------|-------------|
| 1) Un-Interruptable Power Supply | 2) ON | 3) Isolation | 4) more |
| 5) Capacity, Efficiency | 6) OFF | 7) ON-Line | 8) OFF-Line |
| 9) OFF-Line | 10) Line Interactive | 11) ON-Line | |
| 12) ON | 13) High Voltage Direct Current | 14) DC | |
| 15) Short Distance | 16) HVDC | 17) Sealed Maintenance Free Battery | |
| 18) DC | 19) DC | 20) Costlier | |

TRUE / FALSE Statements:

1. In ON-Line UPS, the Inverter is ON all the time.
2. Sealed Maintenance Free Batteries (SMF) Cheaper than Lead Acid Batteries.
3. ON-Line UPS also called Double Conversion UPS.
4. The ON-Line UPS is also called Backup UPS.
5. UPS are never used in street light.
6. Sealed Maintenance Free Batteries (SMF) costlier than Lead Acid Batteries.
7. The output of a regulated power supply changes when input AC Supply Changes.
8. In an OFF-Line UPS, the batteries are always connected to the Inverter, so that No Power Transfer Switches are necessary.
9. In OFF-Line UPS, the primary power source is mains line power, and secondary power source is battery.
10. A HVDC Transmission Line are Cheaper than HVAC Line.
11. A Switching Mode Power Supply is a multistage DC supply.
12. UPS in which Inverter is OFF when the main Power is ON is called OFF-Line UPS.

Answers:

- | | | | | |
|----------|-----------|----------|----------|-----------|
| 1) TRUE | 2) FALSE | 3) TRUE | 4) FALSE | 5) TRUE |
| 6) TRUE | 7) FALSE | 8) FALSE | 9) TRUE | 10) FALSE |
| 11) TRUE | 12) FALSE | | | |