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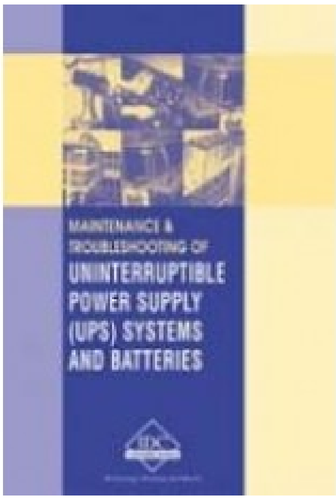
# UP-E - Uninterruptible Power Supply (UPS) Systems

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### Short Description

Supplying reliable electric power for critical systems is an essential part of modern industrial installations. Uninterrupted DC emergency power supply systems are used in various installations ranging from power generating stations to consumer-end substations and various applications such as control power to emergency lighting and small but critical motive loads. AC uninterrupted supply equipment find wide use in critical applications such as control, instrumentation, computer and communication systems as well as other types of installations.

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Electrical engineers in any industry or other large facilities in diverse areas such as commercial buildings, transportation systems such as railways, airports etc. are bound to come across AC or DC uninterrupted power supply systems. This manual covers the basic understanding of various options of UPS systems available, the principle of operation and of the main energy source in most of the modern UPS installations, viz., the battery.

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**First Chapter**

## Overview - Maintenance and Troubleshooting of Uninterruptible Power Supply (UPS) Systems & Batteries

## 1 Overview

*In this chapter, we introduce the subject of uninterrupted power supply (UPS) systems and storage batteries which are used to power most UPS systems. The various issues, which we will discuss in detail in this course, will be covered briefly in this chapter.*

**Learning objectives**

- Power quality issues and improvement measures
- Continuity of power-planning for continuity
- UPS systems-alternatives
- Solid state devices, rectifiers and inverters
- Static UPS systems
- Different types of batteries-charging and discharging characteristics of batteries
- Selection and sizing of batteries for DC and UPS systems
- Maintenance and disposal of batteries

### 1.1 Introduction

This course is about uninterrupted power supply systems (UPS) and storage batteries. In industrial applications, there are always certain critical electrically operated loads whose stoppage may have widespread repercussions on the operation of other equipment and on the production process itself. In some cases, even equipment damage can result, or the safety of plant personnel can be compromised. Such loads must receive power supply from sources, which provide extremely high reliability. Use of UPS systems is one of the ways of supplying reliable electric power to critical loads. We will mainly deal with static UPS systems in this course though other options will also be discussed in some detail. Static UPS systems are deployed to ensure electric supply under conditions of failure of normal power supplies and are mainly powered by storage batteries that provide the required backup power. We will also discuss the subject of storage batteries in detail in the latter part.

The term Uninterrupted Power Supplies (UPS) is sometimes used in the context of systems that give uninterrupted AC output and also those that give uninterrupted DC output. In this text, however, the term UPS has been used for systems which work using AC input and deliver uninterrupted AC output. Systems that require uninterrupted DC output are commonly used in electrical and communication installations. In this case, batteries supply the load directly in the event of a power failure and under normal conditions load is fed through rectifier equipment powered by AC mains. In addition to feeding the loads, these rectifiers are also used to keep the battery in fully-charged condition. These rectifiers are therefore known as chargers. We will discuss in detail such DC uninterrupted systems also and the different types of charger configurations.

## 1.2 Power quality

The need for providing UPS systems is influenced at least in part, by the quality of power that is normally available to a facility. Power quality has many different connotations. Some of the factors, which can be taken as contributing to poor power quality, are:

- Voltage variations
- Interruptions in supply
- Occurrence of surges and presence of noise
- Presence of harmonics in the power supply system
- Frequency disturbances

While no system will be totally free of these disturbances, the number of instances of the occurrence of such disturbances and the extent of deviations from the acceptable range of the relevant parameter decides whether the electrical system can be considered as supplying quality power or otherwise. Poor power quality will necessitate measures for improvement to be taken by the power consumer, thus adding to the cost of the installation. As far as UPS systems are concerned, they are mainly provided to protect the loads from power interruptions, though some of the more advanced UPS systems do address the other quality issues as well; this includes voltage and frequency improvements, control of harmonics and blocking the surges and noise emanating from the supply system from reaching the critical loads. However, other independent measures are also available to address each specific aspect of power quality.

## 1.3 Power quality improvement

As discussed in the previous section, UPS systems represent one of the methods of improving power quality but they are not the only method. In fact, UPS systems are mainly used for ensuring continuity of electric power without any break to loads that need such continuity but can also effect improvements in some of the other power quality aspects as well. However, other methods of power quality improvement may provide improvements to the system as a whole and not just for the critical load segment. In fact, it would be quite impractical to have an UPS system to provide quality power to the entire distribution system, whereas the other methods result in power quality improvements to the overall system.

Some examples are:

- Voltage regulation
- Standby source(s)
- Surge protection devices
- Noise control measures
- Harmonic filters
- In-plant source for independent frequency/voltage control

These techniques will be discussed in some detail in a later chapter. What needs to be stressed here is that an UPS system is a solution that has to be applied very selectively and not for effecting overall improvements of power quality. Usually, improvement of power quality aspects other than interruptions is just a by-product of UPS systems whose main purpose is to address the issue of continuity of power.

## 1.4 Importance of continuity of electric power supply

It will be clear from the foregoing discussion that the emphasis of this course is on the continuity of electric power. Why is it important to have continuity of power supply? A power failure can throw the entire operation of an industrial facility (or for that matter any facility) into jeopardy. Widespread disruptions of power in a whole geographical area are always a grave emergency and become headline news. While failure is confined to a particular facility that does not receive so much public attention, the damage potential can be just as great and can even affect persons not directly connected with the facility.

A power failure can have the following effects:

- Directly affect human safety
- Cause serious equipment damage
- Create potentially hazardous conditions (e.g. loss of safety devices, control power)
- Result in disruption of production

Power interruptions have a considerable monetary impact as well. The impact can be:

- Direct (loss of production, equipment damage, accidents) and/or
- Indirect (legal liabilities, loss of goodwill)

Like every other thing, power quality too has its price. The cost of ensuring reliability of power can however be easily justified by the economic/monetary parameters when one takes into account the cost of an interruption (both direct and indirect).

## 1.5 Planning for reliability

Ensuring continuity of power has to be built into the design and should not be the result of 'getting wise after the event'. In fact, providing an UPS system is only one way of ensuring continuity of power or overcoming the effect of an unscheduled interruption. There are other equally important measures that can improve the continuity of power and that too for an entire system. Some of these measures are:

- Providing duplicate feeders to vital installations
- Providing an emergency source operating in parallel with the normal power source
- Providing a standby power source
- Direct prime movers for ultra-critical loads (e.g., engine driven equipment such as pumps)
- DC systems with battery backup
- Non-electrical backup systems to prevent adverse effects of a power failure
- Providing UPS systems

Thus, it may be seen that a host of options are available to ensure continuity of power or at least, to minimize the instances of interruptions and reduce their duration, should an interruption occur. UPS is an option that is to be adopted for a very specific segment of loads that are so critical in nature that there should be no interruption of power to them under any circumstances whatsoever.

## 1.6 UPS system options

Though the term UPS is associated by most users with static systems, it is by no means the only kind of uninterrupted power supply system. Primarily, UPS systems can be categorized under the following broad categories.

- Rotary UPS systems
- Static (Electronic) UPS systems
- Hybrid UPS systems (having a mix of rotary and static components)

In fact, under certain specific situations, it may be impossible to use the static option. We will discuss the details of each of these categories in detail in a later chapter. The point to remember is that, one should explore all possibilities of UPS systems that are available for a given situation and evaluate the most suitable option. That said, in many small power applications – there isn't a viable alternative to the static variety of UPS.

## 1.7 Static UPS systems

Static UPS systems do have a number of sub-categories, each suitable for a specific application segment. We will discuss the various options of static UPS systems in a separate chapter. Before doing so, we will also discuss by way of a refresher, the basics of the solid-state devices which form the core of any static UPS system. We will also discuss the important subsystems of any static UPS system, viz., the rectifier and inverter subsystems.

We will also discuss in detail the role of UPS in improving power quality. It should however be stated here that power quality improvement is possible in only certain UPS configurations while the others merely provide backup power during an actual failure while allowing the mains power to flow directly to the load under normal conditions. We will discuss various possible types and configurations of UPS systems, particularly in the context of power supply to computer systems, which is one of the main application segments of static UPS equipment, be it a process industry involving computerized control systems or an office environment using computer equipment in day-to-day working. The peculiarity of computer loads and how the switched mode power supply of a computer system behaves will be discussed in some detail so that the suitability of specific UPS configurations for feeding power to computer equipment can be better appreciated.

We will touch upon the issue of redundant UPS systems; remember that UPS is just another electronic circuit, which is just as likely to fail as any other circuit with similar components. Absolute reliability of a static UPS system can therefore necessitate redundant modules. We will also discuss the issue of grounding UPS derived power supplies, mainly in the context of controlling the noise emanating from the mains power supply from passing into the UPS output. The advantage of galvanically isolating the input and output UPS systems will also be discussed.

## 1.8 Batteries

We have seen that UPS systems are meant to ensure reliable power to critical loads under mains failure situations. It therefore follows that they would require some form of energy source to do that. A storage battery is the component, which provides the required input power to the UPS to enable it to produce output AC power. Batteries are of two basic types. The first type is the Primary battery, which converts chemical energy into electrical energy by an irreversible chemical reaction. The other category known as Secondary batteries, also convert chemical energy into electrical energy but the resulting chemical reaction can be reversed and the reactants restored to their earlier state, by the use of electrical energy. In other words, they store electrical energy, which can be released as and when required with both storage and release of electrical power being accompanied by an appropriate chemical reaction. These batteries are therefore commonly called as Storage batteries.

Storage batteries for high-energy applications are mainly of two kinds; the first is the lead acid type and the other is the alkaline type of which the nickel-cadmium is the most common variety. Both these types have several subtypes based on the materials/construction/application etc. But the main variants are the flooded type and the sealed type. The flooded type has the electrolyte in liquid form whereas the sealed type has the electrolyte in gel form or as liquid held in an absorbent separator. We will discuss the details of these batteries in a later chapter. Lead acid is the most common variety of battery used in UPS systems. While sealed batteries are the norm in small capacity UPS units, the flooded type is almost universally used for higher ratings. Nickel-cadmium batteries have their specific application segments too but the high cost of this type of battery often becomes a constraint in their widespread use.

## 1.9 Charging and discharging performance

Batteries, by the very nature of their application are subject to repeated cycles of charging and discharging. While in most standby applications such as UPS systems the rate of cycling is far less, in other situations such as traction applications the cycling duty is far more severe. Even in a battery that is idle (that is, not supplying any load), a small compensating current has to be supplied to the battery continuously for keeping the battery fully charged. This is called as trickle charging. It is however the usual practice in stationary applications (such as electrical substations) to simultaneously keep the battery on trickle charging and also supply the load at the same time. In this approach, the battery floats on the system and takes over the DC loads in the event of power failure (or failure of charging equipment). This approach is known as float charging. The other type of charging where a high rate of charging current has to be used to bring up the battery to full charge after it has been completely discharged is called Boost or equalizing charge. Charging equipment is normally designed for performing a specific type of charging and is called either as float charger or as boost charger depending on the function. In some cases, a charger can be designed to perform either function (one at a time). Redundant battery and charger configurations with single function chargers are normally used in DC supply systems to provide reliable power output. In UPS systems, it is usual however, to have a single charger perform both types of charging. The actual current and voltage for carrying out battery charging will depend on the type and construction of the battery and has to be done in accordance with the manufacturer'' recommendations.

The discharging of a battery can be done at different rates. The higher the rate, the lower will be the output energy from the battery. In other words, the energy output from the battery during its discharge cycle starting from the fully charged to the fully discharged state is a function of the discharge rate. The maximum value of output is when a battery is discharged at constant rates for a period of 10 hours or more. The electrolyte temperature too has an effect on the output of the battery during the discharge cycle. We will cover these issues in a separate chapter on charging and discharging requirements of batteries.

## 1.10 Selection and sizing of batteries

A battery has to be selected based on the load it is expected to supply and the environment in which it functions. Certain batteries may be more suitable for a given application (say standby service) than others. In some cases, site requirements may be a predominant factor. For example, in a location where acidic fumes are not desirable, one will have to select a battery that is fully sealed. In some cases, long battery life would be a decisive selection factor, whereas in others it could be predictability of failure that is important. Certain batteries which can perform well under frequent charging and discharging conditions may be best suited for traction applications (such as platform/forklift trucks).

Having selected the type of battery, the next step will be to select the rating of the battery. Rating is expressed in different ways, such as ampere-hour (Ah) or kW/cell by different manufacturers.

The battery rating depends mainly on the following factors:

- DC voltage required
- Load requirements
- Backup load cycle
- End cell voltage
- De-rating factors for ambient conditions

Rating calculations are to be carried out based on well-known standards such as IEEE: 485 or manufacturer’s recommendations for sizing using the criteria cited above. The standards indicate the values for derating under different ambient and design conditions. The calculations are done using battery data in the form of battery characteristic curves or rating charts supplied by the manufacturers for each specific type of battery in their manufacturing range. We will review the methods of calculation of battery rating with examples in a separate chapter.

### 1.11 Maintenance and disposal of batteries

A battery needs proper upkeep like any other system. This includes the sealed type of batteries (which are often referred to as ‘Maintenance free’ quite erroneously). Regular inspection and preventive maintenance will go a long way in ensuring that a battery can last its specified life and can function to its full capacity. Since battery is usually the last line of defense against power interruptions, any unexpected failure of a battery can prove catastrophic. We will discuss in the concluding chapter, the reasons and modes of failure of batteries and how we can perform tests to predict the remaining life of a battery so that, timely replacement can be done without waiting till failure occurs.

In particularly critical applications, continuous on-line monitoring of batteries can provide an excellent solution to obtain an indication of problems as they develop. Such systems are now available and can be used to advantage in not only predicting but also avoiding failures by timely corrective measures.

Once the useful life of a battery is over, it should be properly disposed. Batteries contain toxic metals such as lead or cadmium and cannot be treated as other general industrial scrap. It is therefore a normal practice to hand over the spent battery back to the manufacturer (or other specialized agencies), who can recycle/recover usable material from the battery

## 1.12 Summary

In this chapter, we had a quick overview of the contents of this manual and will now go on to a more detailed discussion on the various aspects outlined in the above sections.