# The Different Types of UPS Systems

## White Paper # 1

Legendary Reliability™

Revision 4

## Executive Summary

**There is much confusion in the marketplace about the different types of UPS systems and their characteristics. Each of these UPS types is defined, practical applications of each are discussed, and advantages and disadvantages are listed. With this information, an educated decision can be made as to the appropriate UPS topology for a given need.**

# Introduction

The varied types of UPSs and their attributes often cause confusion in the data center industry. For example, it is widely believed that there are only two types of UPS systems, namely standby UPS and on-line UPS. These two commonly used terms do not correctly describe many of the UPS systems available. Many misunderstandings about UPS systems are cleared up when the different types of UPS topologies are properly identified.

Common design approaches are reviewed here, including brief explanations about how each topology works. This will help you to properly identify and compare systems.

## UPS types

A variety of design approaches are used to implement UPS systems, each with distinct performance characteristics. The most common design approaches are as follows:

- • Standby
- • Line Interactive
- • Standby on-line hybrid
- • Standby-Ferro
- • Double Conversion On-Line
- • Delta Conversion On-Line

## The Standby UPS

The Standby UPS is the most common type used for Personal Computers. In the block diagram illustrated in Figure 1, the transfer switch is set to choose the filtered AC input as the primary power source (solid line path), and switches to the battery / inverter as the backup source should the primary source fail. When that happens, the transfer switch must operate to switch the load over to the battery / inverter backup power source (dashed path). The inverter only starts when the power fails, hence the name "Standby."

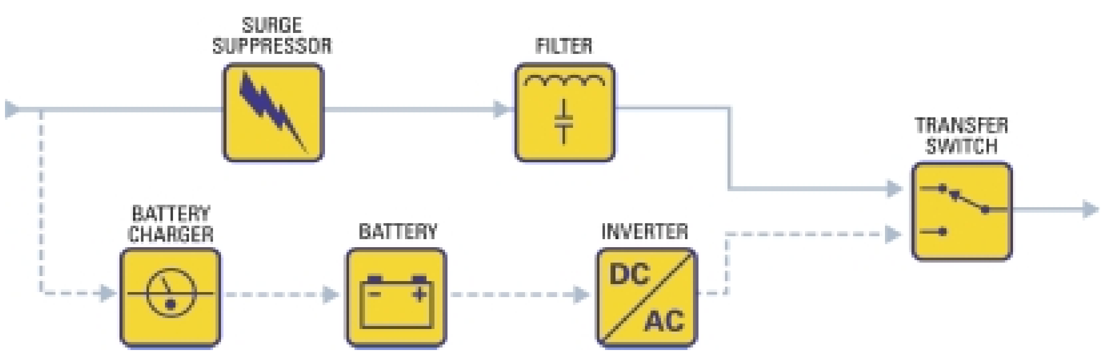


***Figure 1 --*** *Standby UPS: High efficiency, small size, and low cost are the main benefits of this design. With proper filter and surge circuitry, these systems can also provide adequate noise filtration and surge suppression.*

## The Line Interactive UPS

The Line Interactive UPS, illustrated in Figure 2, is the most common design used for small business, Web, and departmental servers. In this design, the battery-to-AC power converter (inverter) is always connected to the output of the UPS.  Operating the inverter in reverse during times when the input AC power is normal provides battery charging.

When the input power fails, the transfer switch opens and the power flows from the battery to the UPS output. With the inverter always on and connected to the output, this design provides additional filtering and yields reduced switching transients when compared with the Standby UPS topology.

In addition, the Line Interactive design usually incorporates a tap-changing transformer. This adds voltage regulation by adjusting transformer taps as the input voltage varies. Voltage regulation is an important feature when low voltage conditions exist, otherwise the UPS would transfer to battery and then eventually down the load. This more frequent battery usage can cause premature battery failure. However, the inverter can also be designed such that its failure will still permit power flow from the AC input to the output, which eliminates the potential of single point failure and effectively provides for two independent power paths. This topology is inherently very efficient which leads to high reliability while at the same time providing superior power protection.

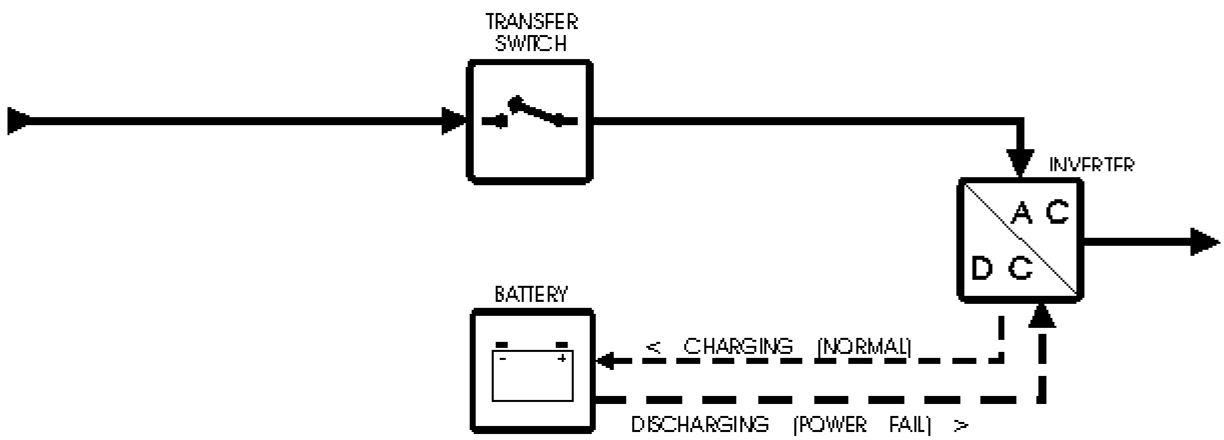


***Figure 2*** *-- Line Interactive: High efficiency, low cost, high reliability coupled with the ability to correct low or high line voltage conditions make this the dominant type of UPS in the 0.5-5kVA power range.*

## Standby On-Line Hybrid

The Standby On-Line Hybrid is the topology used for many of the UPS under 10kVA which are labeled "on-line."  The standby DC to DC converter from the battery is switched on when an AC power failure is detected, just like in a standby UPS.  The battery charger is also small, as in the standby UPS.  Due to capacitors in the DC combiner, the UPS will exhibit no transfer time during an AC power failure.  This design is sometimes fitted with an additional transfer switch for bypass during a malfunction or overload. Figure 3 illustrates this topology.

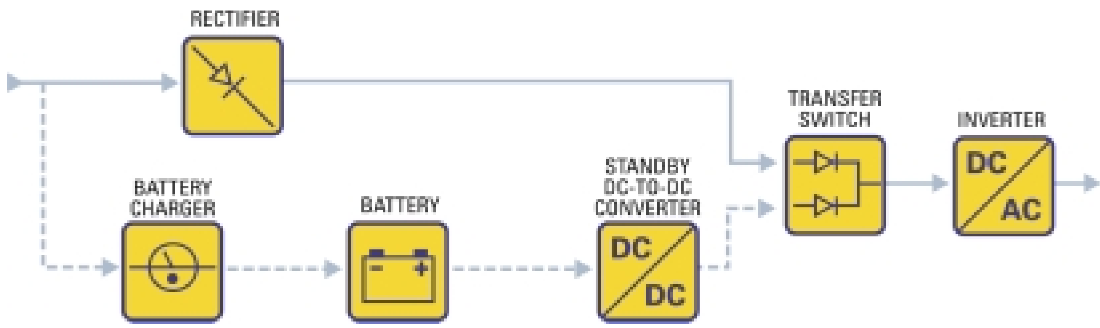


***Figure 3*** *-- Standby On-Line Hybrid: The most misunderstood part of this topology is the belief that the primary power path is always "on-line," when in fact, the power path from the battery to the output is only half "on-line" (the inverter), while the other half (the dc-dc converter) is operated in the standby mode.*

## The Standby-Ferro UPS

The Standby-Ferro UPS was once the dominant form of UPS in the 3-15kVA range. This design depends on a special saturating transformer that has three windings (power connections). The primary power path is from AC input, through a transfer switch, through the transformer, and to the output. In the case of a power failure, the transfer switch is opened, and the inverter picks up the output load.

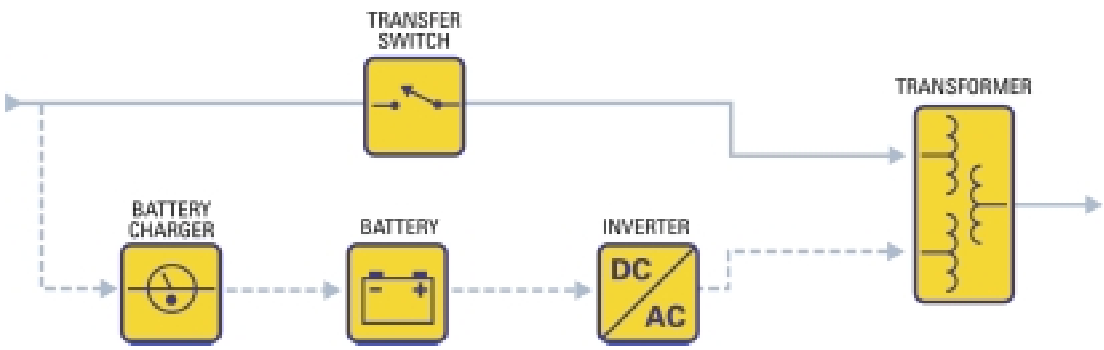


***Figure 4*** *-- Standby-Ferro: High reliability and excellent line filtering are this design's strengths. However, the design has very low efficiency combined with instability when used with some generators and newer power-factor corrected computers, causing the popularity of this design to decrease significantly.*

In the Standby-Ferro design, the inverter is in the standby mode, and is energized when the input power fails and the transfer switch is opened. The transformer has a special "Ferro-resonant" capability, which provides limited voltage regulation and output waveform "shaping". The isolation from AC power transients provided by the Ferro transformer is as good or better than any filter available. But the Ferro transformer itself creates severe output voltage distortion and transients, which can be worse than a poor AC connection. Even though it is a standby UPS by design, the Standby-Ferro generates a great deal of heat because the Ferro-resonant transformer is inherently inefficient. These transformers are also large relative to regular isolation transformers; so standby-Ferro UPS are generally quite large and heavy.

Standby-Ferro UPS systems are frequently represented as On-Line units, even though they have a transfer switch, the inverter operates in the standby mode, and they exhibit a transfer characteristic during an AC power failure. Figure 4 illustrates this Standby- Ferro topology.

The principal reason why Standby-Ferro UPS systems are no longer commonly used is that they can be fundamentally unstable when operating a modern computer power supply load. All large servers and routers use "Power Factor Corrected" power supplies which present a negative input resistance over some frequency range; when coupled with the relatively high and resonant impedance of the Ferro transformer, this can give rise to spontaneous and damaging oscillations.

## The Double Conversion On-Line UPS

This is the most common type of UPS above 10kVA. The block diagram of the Double Conversion On-Line UPS, illustrated in Figure 5, is the same as the Standby, except that the primary power path is the inverter instead of the AC main.

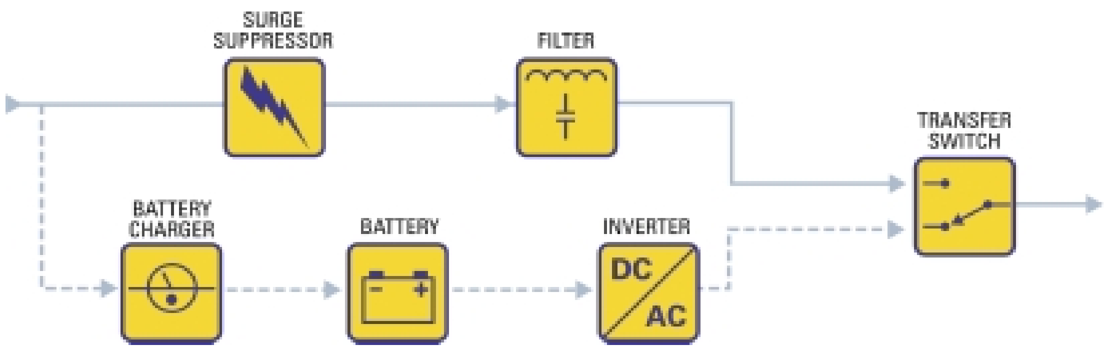


***Figure 5*** *-- Double Conversion On-Line: This UPS provides nearly ideal electrical output performance. But the constant wear on the power components reduces reliability over other designs and the energy consumed by the electrical power inefficiency is a significant part of the life-cycle cost of the UPS. Also, the input power drawn by the large battery charger is often non-linear and can interfere with building power wiring or cause problems with standby generators.*

In the Double Conversion On-Line design, failure of the input AC does not cause activation of the transfer switch, because the input AC is NOT the primary source, but is rather the backup source. Therefore, during an input AC power failure, on-line operation results in no transfer time.

The on-line mode of operation exhibits a transfer time when the power from the primary battery charger / battery / inverter power path fails. This can occur when any of the blocks in this power path fail. The inverter power can also drop out briefly, causing a transfer, if the inverter is subjected to sudden load changes or internal control problems.

Double Conversion On-Line UPS systems do exhibit a transfer time, but under different conditions than a standby or line interactive UPS. While a Standby and Line Interactive UPS will exhibit a transfer time when a blackout occurs, a double conversion on-line UPS will exhibit a transfer time when there is a large load step or inrush current. This transfer time is the result of transferring the load from the UPS inverter to the bypass line. Generally, this bypass line is built with dual Silicon Controlled Rectifiers (SCRs). These solid state switches are very fast, so similar to the Standby and Line Interactive UPS, the transfer time is very brief, usually 4-6 milliseconds.

Both the battery charger and the inverter convert the entire load power flow in this design, which causes reduced efficiency and increased heat generation.

## The Delta Conversion On-Line UPS

This UPS design, illustrated in Figure 6, is a new technology introduced to eliminate the drawbacks of the Double Conversion On-Line design and is available in the range of 5kVA to 1 MW. Similar to the Double Conversion On-Line design, the Delta Conversion On-Line UPS always has the inverter supplying the load voltage. However, the additional Delta Converter also contributes power to the inverter output. Under conditions of AC failure or disturbances, this design exhibits behavior identical to the Double Conversion On-Line.

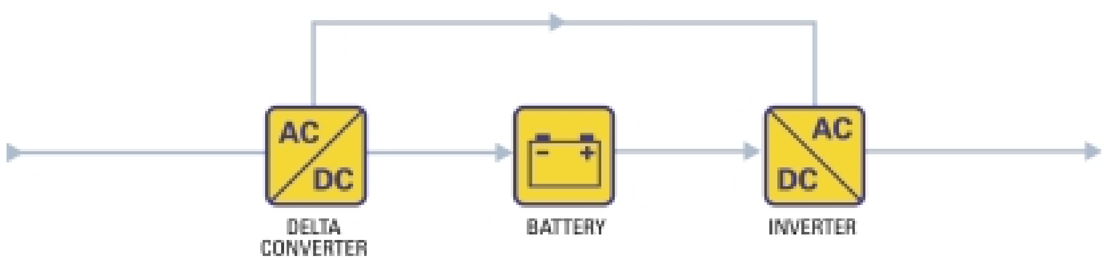


***Figure 6*** *-- Delta Conversion On-Line: During steady state conditions the Delta Converter allows the UPS to deliver power to the load with much greater efficiency than the Double Conversion design.*

A simple way to understand the energy efficiency of the delta conversion topology is to consider the energy required to deliver a package from the 4th floor to the 5th floor of a building as shown in Figure 7. Delta Conversion technology saves energy by carrying the package only the difference (delta) between the starting and ending points. The Double Conversion On-Line UPS converts the power to the battery and back again whereas the Delta Converter moves components of the power from input to the output.

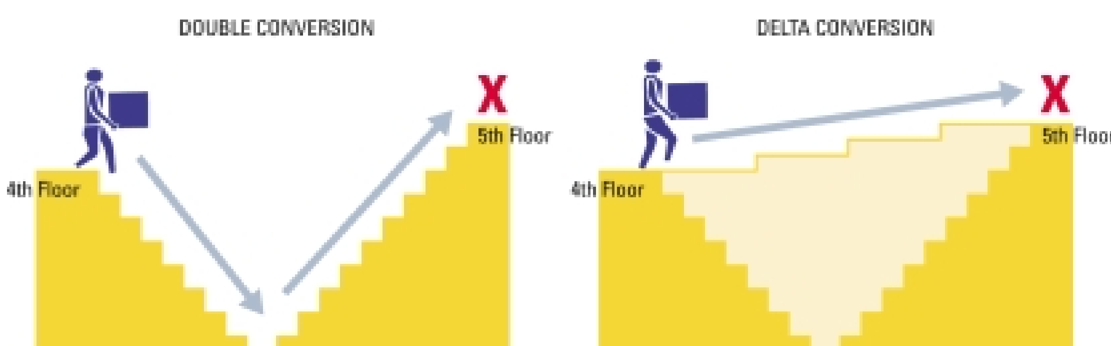


***Figure 7*** *-- Analogy of Double Conversion vs. Delta Conversion*

In the Delta Conversion On-Line design, the Delta Converter acts with dual purposes. The first is to control the input power characteristics. This active front end draws power in a sinusoidal manner, minimizing harmonics reflected onto the utility. This ensures optimal conditions for utility lines and generator systems and reduces heating and system wear in the power distribution system. The second function of the Delta Converter is to charge the battery of the UPS by drawing power and converting it to the appropriate DC charging voltage.

The Delta Conversion On-Line UPS provides the same output characteristics as the Double Conversion On-Line design. However, the input characteristics are extremely different. With full Power Factor Correction, the delta conversion on-line design provides both input power control and output power control. The most important benefit is a significant reduction in energy losses. The input power control also makes the UPS compatible with all generator sets and reduces the need for wiring and generator oversizing. Delta Conversion On-Line technology is the only core UPS technology today protected by patents and is therefore not likely to be available from a broad range of UPS suppliers.

## Summary of UPS types

The following table shows some of the characteristics of the various UPS types. Some attributes of a UPS, like efficiency, are dictated by the choice of UPS type. Since implementation and manufactured quality more strongly impact characteristics such as reliability, these factors must be evaluated in addition to these design attributes.

| | Practical Power Range (kVA) | Voltage Conditioning | Cost per VA | Efficiency | Inverter always operating |
|---|---|---|---|---|---|
| **Standby** | 0 - 0.5 | Low | Low | Very High | No |
| **Line Interactive** | 0.5 - 5 | Design Dependent | Medium | Very High | Design Dependent |
| **Standby On-Line Hybrid** | 0.5 - 5 | High | High | Low | Partially |
| **Standby Ferro** | 3 - 15 | High | High | Low | No |
| **Double Conversion On-Line** | 5 - 5000 | High | Medium | Low | Yes |
| **Delta Conversion On-Line** | 5 - 5000 | High | Medium | High | Yes |

## Use of UPS types in the industry

The current UPS industry product offering has evolved over time to include many of these designs. The different UPS types have attributes that make them more or less suitable for different applications and the APC product line reflects this diversity as shown in the table below:

| | Use in APC products | Benefits | Limitations | APCs Findings |
|---|---|---|---|---|
| **Standby** | Back-UPS | Low cost, high efficiency, compact | Uses battery during brownouts, Impractical over 2kVA | Best value for personal workstations |
| **Line Interactive** | Smart-UPS, Back-UPS Pro, and Matrix | High reliability, High efficiency, Good voltage conditioning | Impractical over 5kVA | Most popular UPS type in existence due to high reliability, ideal for rack or distributed servers and/or harsh power environments |
| **Standby On-Line Hybrid** | Not used by APC | Excellent voltage conditioning | Low efficiency, Low reliability, High cost, Impractical over 5kVA | Line Interactive provides better reliability and similar conditioning at a better value |
| **Standby Ferro** | Not used by APC | Excellent voltage Conditioning, High reliability | Low efficiency, unstable in combination with some loads and generators | Limited application because low efficiency and instability issues are a problem, and N+1 On-Line design offers even better reliability |
| **Double Conversion On-Line** | Symmetra | Excellent voltage conditioning, ease of paralleling | Low efficiency, Expensive under 5kVA | Well suited for N+1 designs |
| **Delta Conversion On-Line** | Silcon, Symmetra MW series | Excellent voltage conditioning, High efficiency | Impractical under 5kVA | High efficiency reduces the substantial life-cycle cost of energy in large installations |

# Conclusions

Different UPS types are appropriate for different applications, and that there is no single UPS type that is ideal for all applications. With the variety of UPS topologies on the market today, these guidelines will help clear confusion about how each topology operates and the advantages and disadvantages of each.

There are significant differences in UPS design between available products on the market, with theoretical and practical advantages for different approaches. Nevertheless, the basic quality of design implementation and manufactured quality are often dominant in determining the ultimate performance achieved in the customer application.