October 18, 2011

NOTICE OF PROPOSED ACTION October 7, 2011

California Energy Commission
Dockets Office, MS-4
Re: Docket No. 11-AAER-2
1516 Ninth Street
Sacramento, CA 95814-5512

ATTN: Mr. Ken Rider
krider@energy.state.ca.us

Comment of APC by Schneider Electric

Jay L. Taylor
Director, Global Standards, Codes and Environment
Jay.Taylor@schneider-electric.com
(512) 818-2073

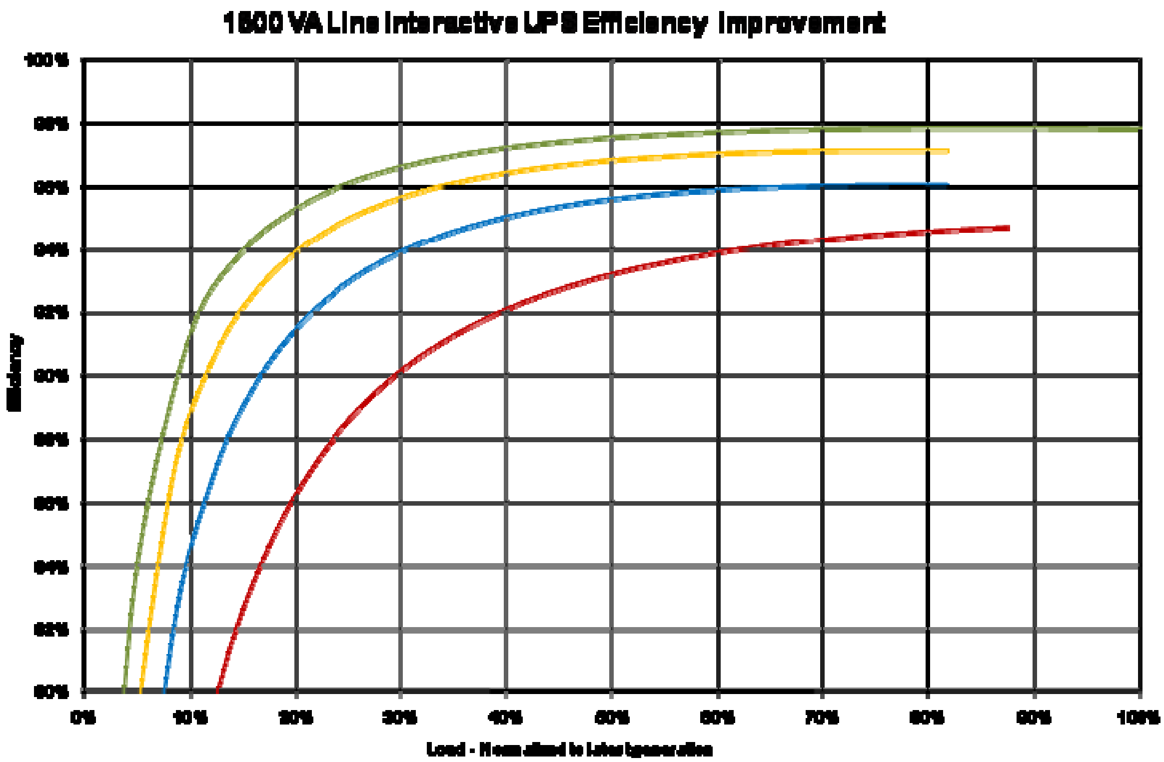
We appreciate the opportunity to express comment on the proposed rulemaking for the State of California, Docket No. 11-AAER-2. We endorse and support the recommend scope of the rulemaking for UPS systems. By focusing on VFD UPS systems you get the broadest reach for the highest volume of customer purchases.

APC by Schneider Electric is the world's largest UPS manufacturer, with significant market share in the United States and California.

We manufacture, market and install Uninterruptible Power Supply (UPS) systems world-wide with power levels from a few hundred watts to several megawatts. In 2007, Schneider Electric acquired APC and combined it with MGE UPS Systems to form Schneider Electric's Critical Power & Cooling Services Business Unit, which recorded 2008 revenue of €2.6 billion and employed 12,000 people worldwide. In addition to UPSs, our other products include precision cooling units, racks, physical security equipment and design and management software.

For years APC has led the industry in the promotion and deployment of technologies that advance the energy efficiency of both the UPSs and the IT systems they protect. As a corporation, we have led and contributed to numerous industry consortia and standards bodies that promote efficiency and safety. Examples include: European Code of Conduct for UPS, The Green Grid and the IEC 62040 series of standards.

The chart below exemplifies APC's continuous improvement in efficiency over time.



Unlike standard battery chargers (AAA, AA), mobile phone chargers, power tool chargers and toy chargers, the UPS battery charger is designed to operate in an application where it provides longer life and higher reliability for the IT systems it protects. It must do this in an environment where the utility voltage is expected to range from 90 V to 140V and where ambient conditions of temperature can range from 0 to 40C.

In this application and environment, the battery charger function of the UPS is designed to maximize availability of the battery while minimizing the potential for premature failures due to over temperature, overcharge and undercharge. Further, the battery charger function in the UPS must operate efficiently over a wide range of input voltage in order to serve the need for fast recharge following a power event. To meet this requirement battery chargers in UPS systems are typically rated at 10-20% of the main UPS output.

While it is possible to add additional controls and independent chargers optimized for minimal power while float charging, this has historically been avoided by the industry as additional components lead to more potential failure points and an inherent decrease in reliability. We are always seeking and implementing new ways to improve efficiency (as demonstrated above) while managing the necessary safety and reliability requirements of UPS systems including, but not limited to the battery charger subsystem.

UPS Systems and Terminology

In reviewing the standard for battery chargers we have noted areas of concern. Our interest, as a company, is in delivering the most efficient UPS systems for customers that reduce operations and acquisition costs. An Uninterruptable Power Supply according to Wikipedia is defined as follows:

> *An uninterruptible power supply, also uninterruptible power source, UPS or battery/flywheel backup is an electrical apparatus that provides emergency power to a load when the input power source, typically the utility mains, fails. A UPS differs from an auxiliary or emergency power system or standby generator in that it will provide instantaneous or near-instantaneous protection from input power interruptions by means of one or more attached batteries and associated electronic circuitry for low power users, and or by means of diesel generators and flywheels for high power users. The on-battery runtime of most uninterruptible power sources is relatively short—5–15 minutes being typical for smaller units—but sufficient to allow time to bring an auxiliary power source on line, or to properly shut down the protected equipment.*

As stated above the primary purpose or function of a UPS is NOT charging batteries. Static UPS systems fall into broad topology categories, three of which are Standby, Line Interactive and Double Conversion. Each of these topologies has different baseline energy consumption. Also, none of our UPS systems currently have the capability to allow evaluation of battery charging subsystem in isolation. This is specifically due to the fact that by design battery chargers commonly share circuitry with, and provide power to, other UPS functions and subsystems. Adding battery charger isolation features would not only add cost and complexity, it could result in lower product reliability due to malfunction or misuse of these features.

UPS systems are designed for maximum reliability and near instantaneous detection and response to protect electronic equipment from many main power challenges such as: Surges, Sags, Spikes, Noise, Frequency Instability, Harmonic Distortion, and ultimately power failure. Architecturally, the circuits used in the topologies identified all consume energy when performing these basic protection functions, and cannot be separated easily, safely or in some cases at all, due to that topology.

Internal voltages present on circuits within the UPS systems (and sometimes on battery terminals) are frequently hazardous, which is why UPSs are protected and enclosed. Black box testing is therefore preferred by industry to ensure safe and uniform testing across all models, manufacturers and brands.

Observations:

- The fact is that disconnecting the load from the UPS or turning the UPS's output off does not allow for exclusive measurement of battery charger power consumption. Based on topology and other features that remain in operation, measured power consumption will be greater than that of

the battery charging circuitry alone. Examples of UPS features that typically are in continuous operation include:
   a. Serial, USB and/or network communications interfaces
   b. Power quality monitoring and data logging
   c. User interfaces such as LED and LCD displays
   d. Building wiring fault detection circuitry
   e. Line Interactive Circuitry (remains active even with output off to charge the batteries)
   f. Double Conversion Circuitry (remains active even with output off to charge the batteries)

- Even though APC by Schneider Electric products are among the most efficient in the industry today; they all would be excluded under the rules as currently proposed (based on preliminary in house testing). Our internal evaluations of competitive products indicate that our products are not unique in this regard.
- Assuming that it is possible to comply with the proposed regulations, redesigning our complete VFD product portfolio by the January 1, 2013 deadline will not be possible. The likely result of this will be the withdrawal of certain VFD products from the market, possibly driving some customers to more expensive and less efficient VI and VFI models (which are exempt from the regulations).
- Tradeoffs to UPS system design to optimize battery charger performance may cause the UPS to be less efficient with the output on, resulting in a counterproductive increase in energy consumption.

UPS Topologies

Standby topologies are used for the least expensive consumer UPSs (typically < 1,500VA). These UPS systems also offer the least performance (IEC 62040-3 VFD category); powering low criticality devices such as desktop computers, workstations and home entertainment equipment. These systems include small capacity batteries (due to low UPS output power and only 3-5 minutes of runtime at full load) with dedicated low power (typically 24-96 hour) off-line charger which combine to result in low maintenance mode power. Because many of these products already include a dedicated low power charger they are the closest to complying with the proposed regulations and will require the least circuit modifications to comply.

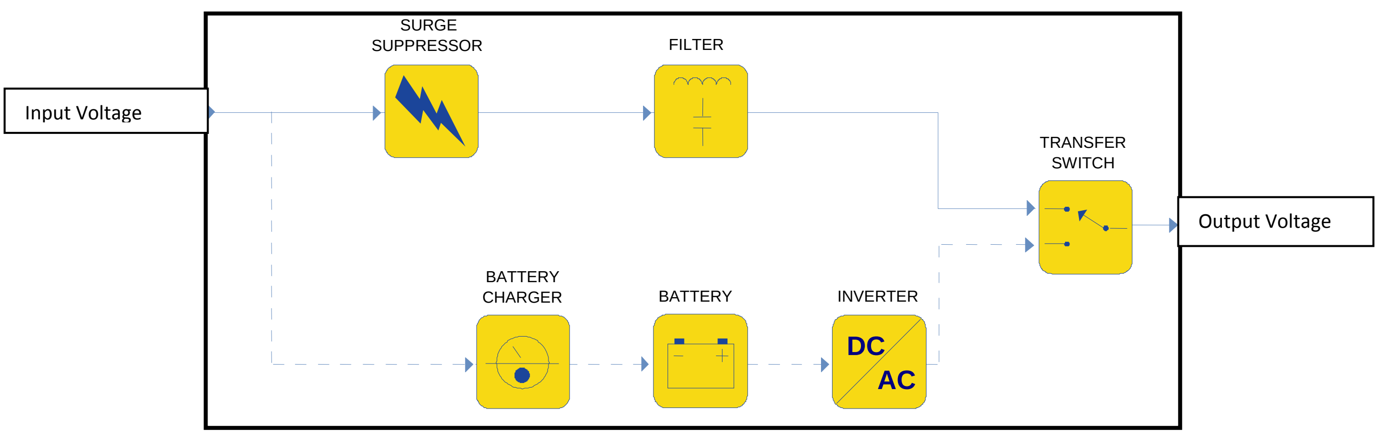


Diagram 1
Standby Topology UPS

All diagram's courtesy of Neil Rasmussen, APC White Paper Number 1.

As you can see from the diagram, the battery charger and battery circuitry is not in the direct path of power. However, other component such as filters and surge suppressors are. What this means practically is that measuring the battery charger components outside of the influence or control of other components is an unreasonable burden on the design for UPS systems.

Incorporating the IEC 62040,-3 2nd Edition reference eased but did not eliminate the concerns we have for testing or definitions. Specifically there are VFD UPSs with voltage regulating transformers capable only of correcting under-voltage. For the same reason that VI UPSs were excluded from the regulations, we recommend that VFD UPSs with transformers capable only of correcting under-voltage be excluded as well. This could also be accomplished by excluding all UPS systems with output Voltage Regulating Transformers.

Test Procedure Concerns

Specifically, and as identified previously the test procedure is not targeted at UPS systems. UPS systems are not architecturally similar to or electronically equivalent to consumer battery chargers. Many continuous processes are in place to measure and, manage power even in simple VFD Standby UPS designs.

Battery Charger Limits

A thoughtful review of available data leaves us with a crucial issue. The proposed requirements for battery chargers are not met by current UPS systems. As described above the UPS systems is NOT just a battery charger. As identified above, many continuous processes are in place. These management features are essential to the UPS performing its function. In our measurements of APC and competitive UPS systems we have not found ANY systems meeting the current criteria as established in the docket 11-AAER-2.

We also requested the data set information from the Federal activities be released so that we could evaluate a potentially wider field of UPSs. Unfortunately it was not available in time for this writing. We are concerned that the measurements we made on APC and competitive UPS systems are significantly higher than the proposed requirements. If the requirements are implemented as published with no functional adders as we previously proposed, then VFD Standby UPS system may not continue to be available in the California marketplace after January 1, 2013.

APC By Schneider Electric Recommendations

1. All UPSs with output Voltage Regulating Transformers or at least VFD UPSs capable only of correcting under-voltage should be excluded from the regulations.

2. We strongly recommend that in recognition of the non-battery charger functionality of UPSs, that the maintenance mode requirement for VFD UPSs without output Voltage Regulating Transformers be changed to 1.8 + 0.0021 x E_b Watts. If VFD UPSs with output Voltage Regulating Transformers are not excluded, we recommend a maintenance mode requirement of 3.8 + 0.0021 x E_b Watts for these UPSs. We believe that our proposals are achievable and that they would still remove a significant percentage of inefficient UPSs from the California market.

3. The 15 month implementation period is insufficient for manufacturers to execute a rulemaking of this magnitude, especially where we know of no UPSs systems currently in the marketplace that achieve the proposed requirements. Accordingly, we recommend that the effective date for consumer UPSs be changed to July 1, 2014.

4. To simplify testing and improve compliance, we recommend that the requirements of the initial regulations be altered as follows:

- The full test procedure should be run with the output off or on at the manufacturer's choosing to determine:
  - Recharge time
  - Battery Energy E_b
  - Maintenance Mode Power (Actually UPS standby power)
  - No Battery Mode Power (Actually UPS standby power without a battery)
- Because UPSs almost never discharge and need to keep batteries at 100% capacity at all times, they need to constantly float charge
- Therefore, the only requirement for UPSs should be that $(P_{maint} - P_{nobatt}) < A + B \times E_b$
  - A and B will have to be determined by testing some UPSs and batteries
  - Initial estimates are that A = 0.3 and B = 0.0021

Conclusion

Thank you for the opportunity to provide our evaluation and thoughts on the proposed battery regulations for the State of California, Docket No. 11-AAER-2. Our interest is providing solid, reasonable business and technical advice on a topic of critical importance to the infrastructure of the State and the industry. We are available to provide specialized guidance and technology to deliver high efficiency solutions for the state.

We need significant relief in the scope, the maintenance mode power requirements and the time allotted to comply with the proposed regulations. We are concerned that the proposed requirements are not currently achieved by any UPSs in the global marketplace, from our measurements thus far.

Your consideration of this comment is greatly appreciated.

Jay L. Taylor
Director, Global Standards, Codes and Environment
Jay.Taylor@schneider-electric.com
(512) 818-2073

The Different Types of UPS Systems

White Paper 1

Revision 7

by Neil Rasmussen

>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 appropri-

Contents

Click on a section to

Introduction

The varied types of uninterruptible power supplies (UPS) 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. UPS topology indicates the basic nature of the UPS design. Various vendors routinely produce models with similar designs, or topologies, but with very different performance characteristics.

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-ferro
- Double conversion on-line
- Delta conversion on-line

The standby UPS

The standby UPS is the most common type used for desktop 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." 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.

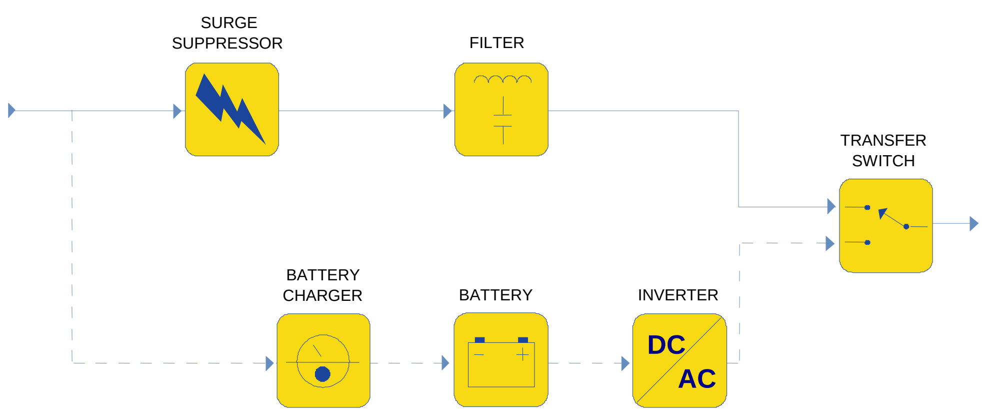


Figure 1

Standby UPS

The line interactive UPS

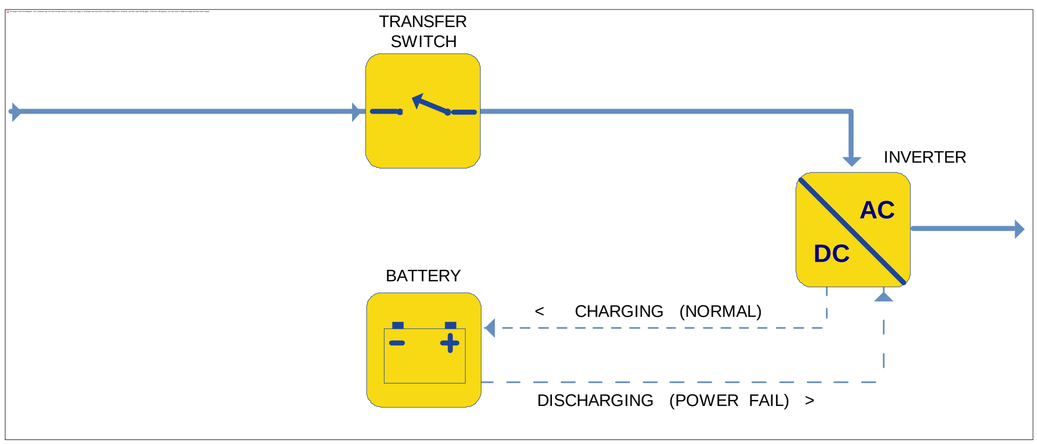
The line interactive UPS, illustrated in **Figure 2**, is the most common design used for small business, Web, and departmental servers. In this design, the battery-to-AC power converter (inverter) is always connected to the output of the UPS. Operating the inverter in reverse during times when the input 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. High efficiency, small size, low cost and high reliability coupled with the ability to correct low or high line voltage conditions make this the dominant type of UPS in the 0.5-5 kVA power range.

Figure 2

Line interactive UPS



The standby-ferro UPS

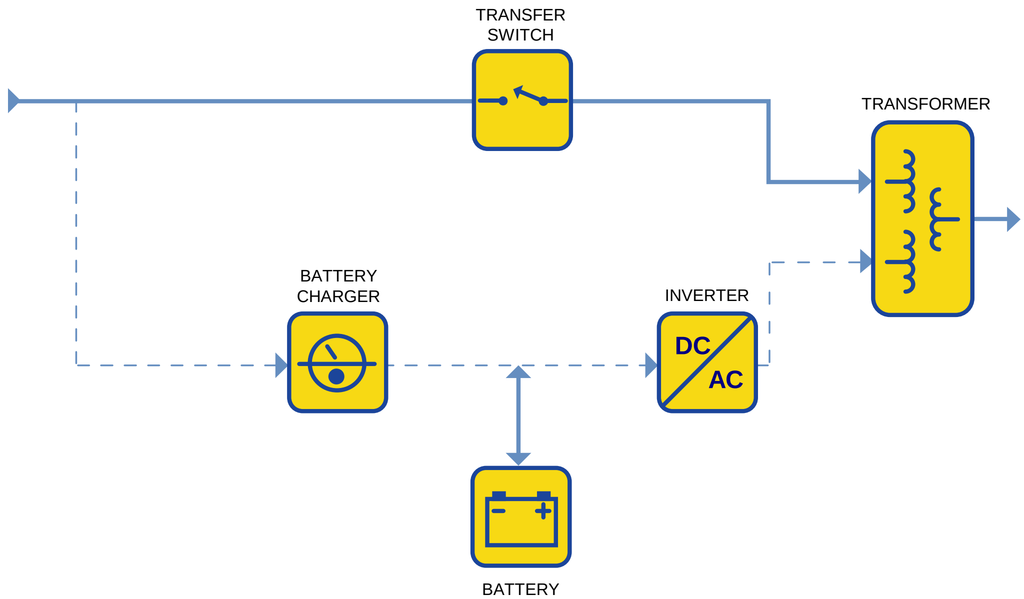
The standby-ferro UPS was once the dominant form of UPS in the 3-15 kVA range. This design depends on a special saturating transformer that has three windings (power connections). The primary power path is from AC input, through a transfer switch, through the transformer, and to the output. In the case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

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 as 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 3** illustrates this standby-ferro topology.

Figure 3

Standby-ferro UPS



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.

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 draw only sinusoidal current from the utility, much like an incandescent bulb. This smooth current draw is achieved using capacitors, devices which 'lead' the applied voltage, ferro resonant UPS system utilize heavy core transformers which have an inductive characteristic, meaning that the current 'lags' the voltage. The combination of these two items form what is referred to as a 'tank' circuit. Resonance or 'ringing' in a tank circuit can cause high currents, which jeopardize the connected load.

The double conversion on-line UPS

This is the most common type of UPS above 10 kVA. The block diagram of the double conversion on-line UPS, illustrated in **Figure 4**, is the same as the standby, except that the primary power path is the inverter instead of the AC main.

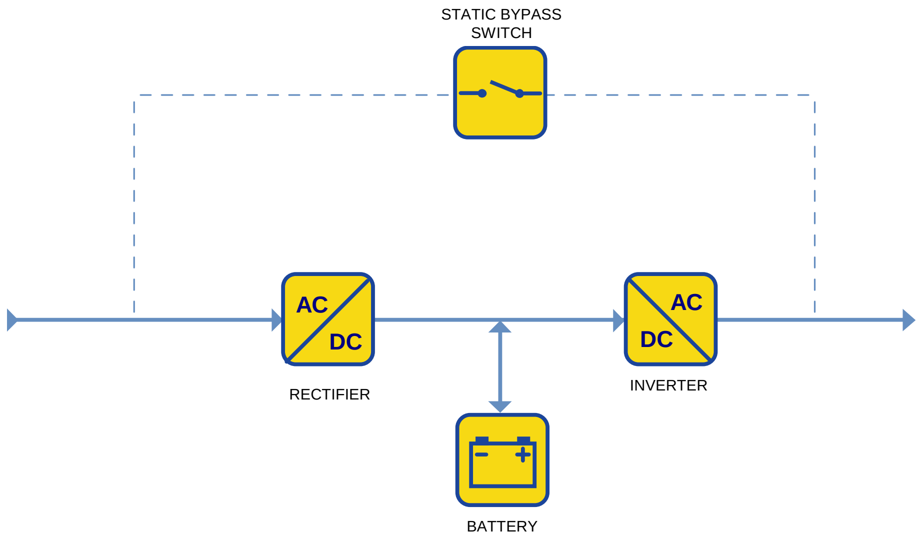


Figure 4

Double conversion on-line UPS

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 charging the backup battery source which provides power to the output inverter. Therefore, during an input AC power failure, on-line operation results in no transfer time. Both the battery charger and the inverter convert the entire load power flow in this design.

This UPS provides nearly ideal electrical output performance. But the constant wear on the power components reduces reliability over other designs. Also, the input power drawn by the large battery charger may be non-linear which can interfere with building power wiring or cause problems with standby generators.

The delta conversion on-line UPS

This UPS design, illustrated in **Figure 5**, is a newer, 10 year old technology introduced to eliminate the drawbacks of the double conversion on-line design and is available in sizes ranging from 5 kVA to 1.6 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.

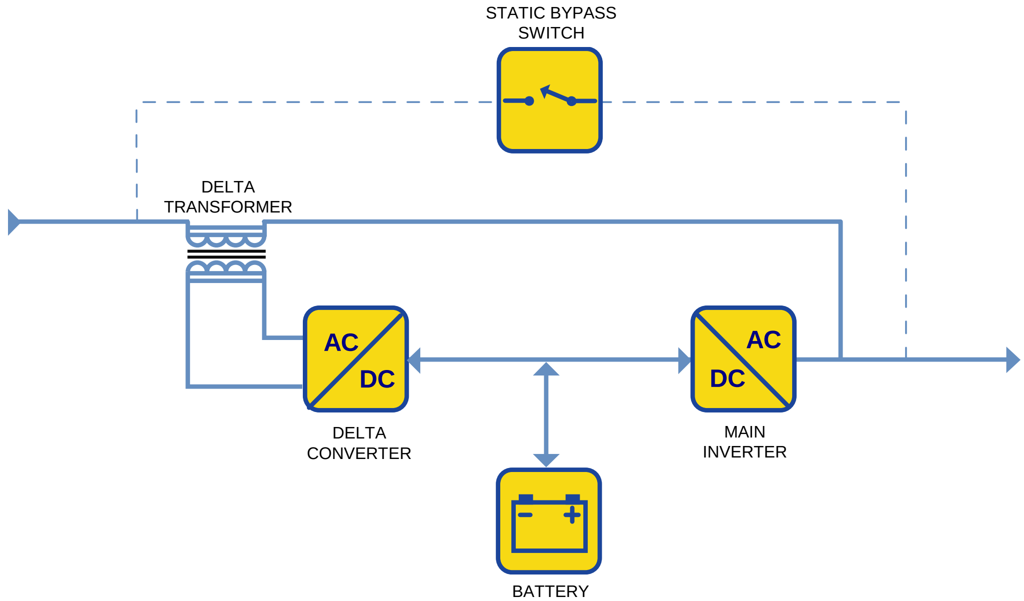


Figure 5

Delta conversion on-line UPS

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 6**. 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.

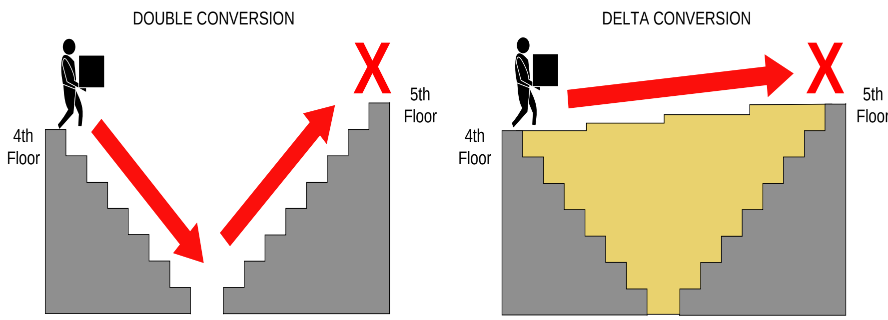


Figure 6

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 utility and generator system compatibility, reducing heating and system wear in the power distribution system. The second function of the delta converter is to control input current in order to regulate charging of the battery system.

The delta conversion on-line UPS provides the same output characteristics as the double conversion on-line design. However, the input characteristics are often different. Delta conversion on-line designs provide dynamically-controlled, power factor corrected input, without the inefficient use of filter banks associated with traditional solutions. 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.

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.

Summary of UPS types

Table 1 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.

Table 1

UPS characteristics

	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-ferro	3-15	High	High	Low - Medium	No
Double conversion on-line	5-5000	High	Medium	Low - Medium	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 by Schneider Electric product line reflects this diversity as shown in **Table 2**.

Table 2

UPS architecture characteristics

	Commercial products	Benefits	Limitations	APC's findings
Standby	APC Back-UPS Tripp-Lite Internet Office	Low cost, high efficiency, compact	Uses battery during brownouts, impractical over 2kVA	Best value for personal workstations
Line interactive	APC Smart-UPS Powerware 5125	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-ferro	Commercial product availability limited	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	APC Smart-UPS On-Line APC Smart-UPS VT APC Symmetra[1] MGE Galaxy MGE EPS Liebert NX	Excellent voltage conditioning, ease of paralleling	Lower efficiency with older models, expensive under 5kVA	Well suited for N+1 designs
Delta conversion on-line	APC Symmetra MW	Excellent voltage conditioning, high efficiency	Impractical under 5kVA	High efficiency reduces the substantial life-cycle cost of energy in large installations

[1] All Symmetra UPS models are on-line double-conversion except for the Symmetra MW which is on-line delta conversion.

Conclusion

Various UPS types are appropriate for different uses, and no single UPS type is ideal for all applications. The intent of this paper is to contrast the advantages and disadvantages of the various UPS topologies on the market today.

Significant differences in UPS designs offer theoretical and practical advantages for different purposes. Nevertheless, the basic quality of design implementation and manufactured quality are often dominant in determining the ultimate performance achieved in the customer application.

About the au-

Neil Rasmussen is the Senior VP of Innovation for APC, which is the IT Business Unit of Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 14 patents related to high efficiency and high density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

Resources

Click on icon to link to resource

APC White Paper Library
whitepapers.apc.com

APC TradeOff Tools™
tools.apc.com

Contact us

For feedback and comments about the content of this white paper:

Data Center Science Center, APC by Schneider Electric
DCSC@Schneider-Electric.com

If you are a customer and have questions specific to your