



A COMPARISON OF TYPICAL UNINTERRUPTIBLE POWER SUPPLY (UPS) DESIGNS IN TODAY'S MARKETS

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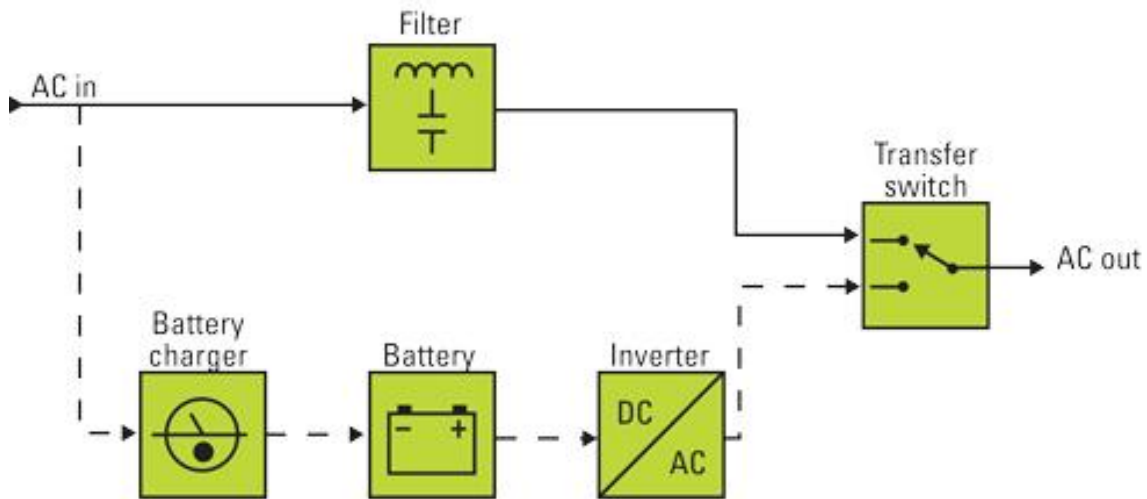
Executive Summary

At its most basic, a UPS is designed to provide backup power to support continuing operation of electrical or electronic devices in the event of a power failure. Today's UPS systems usually also provide some level of power conditioning and protection against fluctuations in voltage from the grid.

There are four types of UPS architectures in use today: Online or Double Conversion, Line Interactive, Offline and Controlled Ferro-resonant (CFR). Each has its own merits and drawbacks, depending on the application.

1. For backup applications where low cost is critical, it doesn't matter if the load loses power briefly and backup times are short, an offline solution is adequate, although it will not provide adequate protection against spikes or sags from the grid.
2. For applications that require complete isolation from any changes in grid power, such as many medical applications, a controlled ferro-resonant solution offers the best solution.
3. For applications where power losses due to inefficiencies are less of a concern and eliminating the delay from grid power available to back power is paramount, Online (also called Double Conversion) is the only solution.
4. For typical applications where power often needs conditioning but is usually available and very short transfer times from grid to backup power are acceptable, and daily energy consumption is a concern, Line Interactive is the preferred solution.

Offline



A typical offline backup power supply will continuously provide power with some filtering (typically the same as on a surge protection power strip) from the utility. When utility power fails, the device will start its internal inverter, and then mechanically transfer from utility power to inverter output. This transfer can take as long as 25 ms, which may be too long for some loads. An Offline UPS will transfer to battery backup during brownouts or surges as well. Typical offline runtimes in backup mode are from a few minutes to 20 minutes and extended runtime battery packs are rarely available.

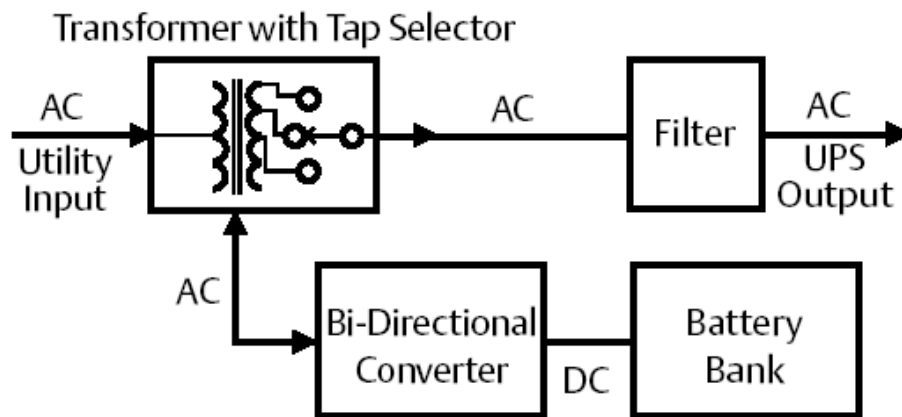
Pros

- Low cost: can be widely implemented in an organization
- Small size: unobtrusive
- Simple design: little or no training required to understand full functionality

Cons

- No power conditioning
- Slow transfer time
- Simple battery charger may shorten battery life and increase recharge time
- Limited additional functionality may not meet enterprise needs
- Short back-up time

Line Interactive



During normal operation, the Line Interactive UPS takes utility power and passes it through a transformer with various tap selections on the output. When utility power is high, the Line Interactive UPS selects a tap to lower (buck) the output voltage. Similarly, when the utility voltage is low, the UPS selects a tap to increase (boost) the output voltage.

Combined with additional internal protection and filtering circuits, the Line Interactive UPS provides filtered and regulated power out with a minimum of internal power loss. When the utility voltage becomes out of the range that the buck/boost transformer can support, the UPS switches to battery power, usually within a few milliseconds. Since the majority of electronic equipment today is able to continue operating without power for a few ms, this does not present a problem in most applications.

Pros

- Low Cost
- Sine Wave Output
- Wider Input Range
- Buck & Boost regulation
- Efficient
- Surge Protection
- EMI/RFI/Noise Suppression

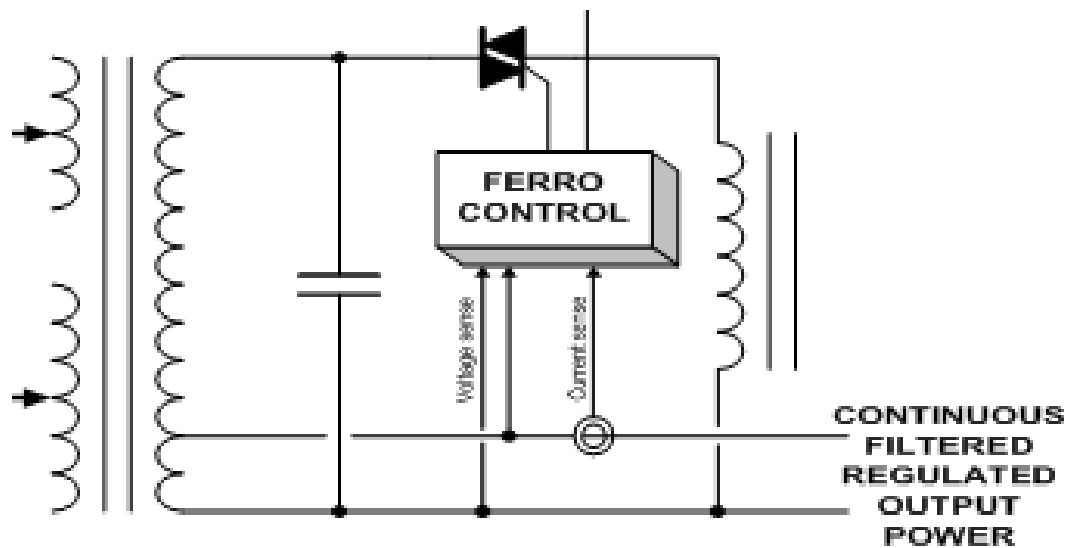


Cons

- Minimal Load Protection
- 4-6 ms transfer time
- Spike and surge protection components degrade over time

Controlled Ferro Resonant UPS

A Controlled Ferro Resonant UPS operates in the same manner as a line interactive UPS, however its transformer can hold the voltage on the load side long enough for the inverter to begin providing input power, eliminating transfer time. It also provides complete isolation from input to output, protecting against all kinds of noise. A Ferro-resonant UPS can operate over a wide range of input voltages, however due to the low frequency design of the transformer, it can be large and heavy compared with other UPS types.



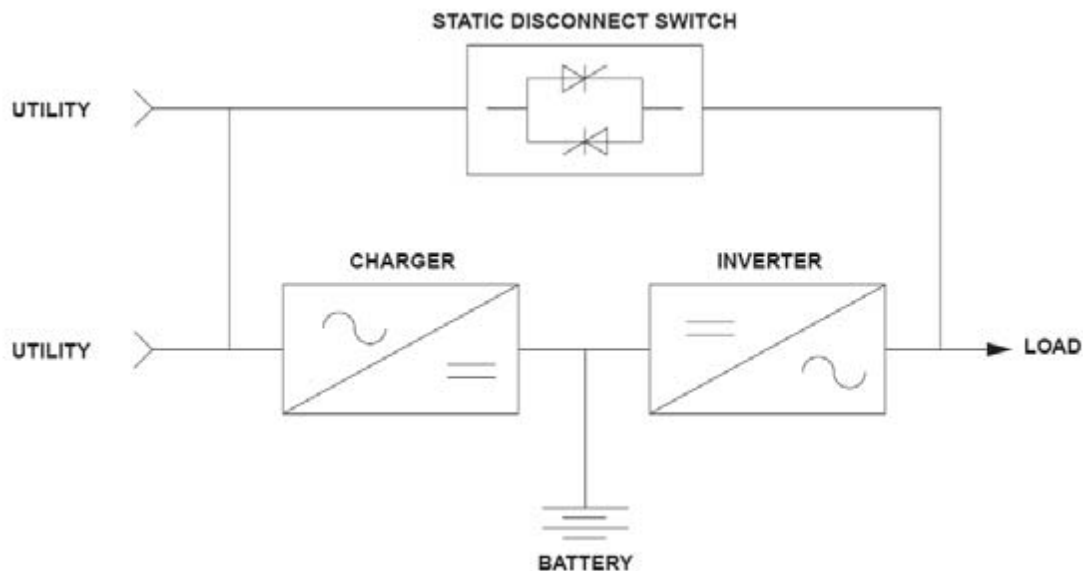
Pros

- Best spike & surge protection with complete output isolation.
- Zero transfer time
- On-Line Power
- 100% Power Conditioning
- Input Power Factor Correction
- Better Output Flexibility
- Longer Service Life Expectancy

Cons

- Larger/Heavier
- Higher Heat Output
- More Expensive
- Can be problematic with power factor corrected loads¹

Online (Double Conversion)



The Online or Double Conversion UPS continuously rectifies incoming AC power to DC power to supply the internal DC bus of the UPS. The output inverter takes the DC power and produces regulated AC power to support the critical load. During an outage, the inverter continues to operate, drawing power from the batteries and the load sees no transfer time.

Due to the fact that there are two active stages of power conversion operating continuously, the online UPS is less efficient than its line interactive and CFR counterparts. It also has a shorter life expectancy due to continuous operation of all components.

Online UPS manufacturers often work to get around the inefficiency issue by increasing the DC bus voltage level. This means that the battery voltage has to increase correspondingly, resulting

¹ Power factor is the portion of power delivered to the load that is actually used. A non-power factor corrected load will draw more power than one which is power factor corrected. Most modern electronics use power factor corrected power supplies.



in a greater number of batteries and introducing a higher risk of failure due to the larger number of batteries.

Pros

- Zero transfer time
- Excellent surge and noise suppression
- Constant voltage output.
- 100% Power Conditioning
- Input Power Factor Correction

Cons

- Higher Heat Output
- More Expensive
- Lower Efficiency
- No Neutral Conditioning
- Low MTBF
- Higher battery TCO

Choosing a UPS

In choosing a UPS there are a number of considerations that will point to one design over another:

- **Efficiency.** Most security loads today are designed to withstand up to a 30 msec loss of power. High quality line interactive solutions offer transfer times as low as 3-5 msec, and operate at a much higher efficiency than online units - as much as 10% - whenever grid power is available. A 10% savings in energy over the course of a year for multiple installations can add up to a significant savings to the user. For example, at a single location, there might be up to 50 installations of 500 W loads. An online UPS will typically operate at 85% efficiency or less, so to power these loads, (50* 500 = 25 kW), the user must select online units that are drawing 15% more power: over 29 kW. Over a year assuming an average price per kWh of 10 cents, this adds up to over \$3,800 in a single year at one site. Users can realize a significant savings and reduce their carbon footprint by choosing a line interactive solution over double conversion.



- **Durability.** An Online UPS continuously converts power from AC to DC and back again, putting unnecessary stress on power conversion components all of the time. By contrast, a Line interactive unit will only use the power components to charge the batteries if necessary or when there is a power failure or extended degradation – a few times per year. Since all these components have a finite operating design life, it is reasonable to assume that a unit which uses those components less often will last longer.

Other Considerations

Regardless of the type of UPS, there are several other factors that merit consideration:

- Is the system subject to extremes of weather? A line interactive solution designed to meet -40C to +74C conditions is required by many users with outdoor backup power needs, whereas typical online solutions are designed for indoor (controlled environment) use: 0-40C is typical. Interestingly, outages occur most often during weather extremes, so it's important to make sure that the UPS is designed to operate when you need it most.
- Is the air quality poor? Electronic components that are subjected to dust and high moisture levels will fail unless they are designed to meet these conditions. A well designed cabinet combined with a system that uses extreme grade components and conformally coated boards will survive in harsh environments that leave indoor systems wanting.
- Is there easy access to the unit? If the unit is remotely installed, a UPS that requires more frequent maintenance can cost considerably more by requiring more truck rolls and unnecessary maintenance activities. While all systems require some level of maintenance, it's important to select one that minimizes maintenance.
- How long do outages last in my area? A Berkeley National Laboratory study conducted in 2004 indicates that on average in the US, events last around 1 hour and 45 minutes². Longer outages make it more important to select a UPS designed for extended runtimes and one that supports fast recharge times of batteries to ensure rapid availability of battery power after an outage.

² **Understanding the Cost of Power Interruptions to U.S. Electricity Consumers**

Kristina Hamachi LaCommare and Joseph H. Eto <http://eetd.lbl.gov/ea/EMP/EMP-pubs.html>



Conclusion

While there are a wide variety of considerations in selecting a UPS, in general a Line Interactive UPS offers the most cost effective solution for the majority of applications. Only in those applications where zero transfer time is critical, does an online UPS become the preferred choice. When choosing a UPS, key considerations include required runtime, environmental conditions and expected outage duration.