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RUNNING UPS IN ECONOMY MODE TO SAVE ENERGY

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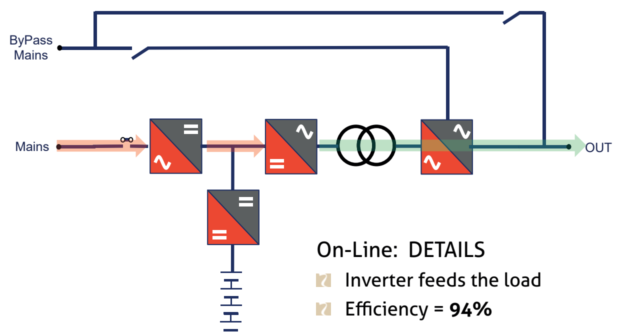
Summary

Uninterruptible power supplies can be viewed as both power quality and backup power solutions. Within the rapidly growing data center market there is a growing awareness of the potential to run on-line UPS in a less resilient power mode known as ECO-mode to reduce operating costs (electricity usage and to a degree environmental cooling) and improve power usage effectiveness (PUE). This document discusses the advantages and disadvantages of such an approach, and the longer-term implications for UPS systems within an IT environment.

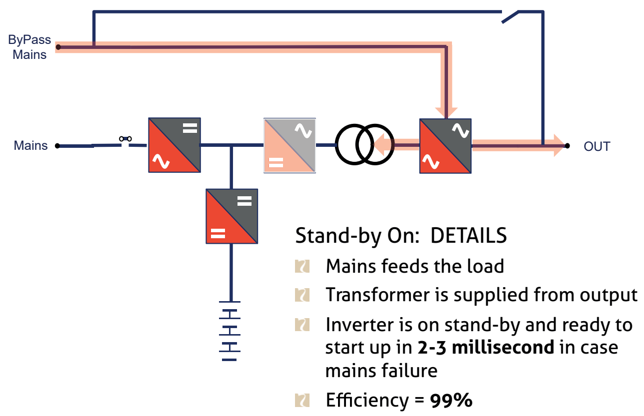
1. Introduction

In terms of power quality, a UPS system will protect a critical load from power problems present on the AC power source: whether this is mains power or an alternative source such as a standby power generator. Typical power quality problems can include spikes, surges, electrical noise, transient voltages, brownout and harmonics. The degree of power quality protection provided is dependent upon the type of AC UPS topology. These are defined in EN/IEC 62040-3:

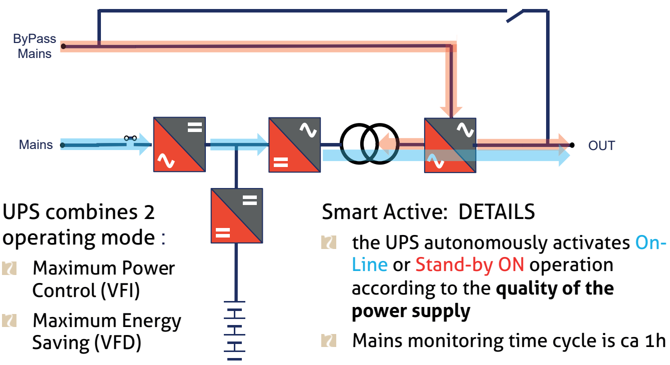
- Voltage and Frequency Independent (VFI): referred to as on-line double-conversion or on-line. Here the UPS supplies a stable output voltage and frequency to connected loads, independent of the input AC power source.



- Voltage Independent (VI): referred to as line interactive. The UPS provides a stable output voltage waveform. The UPS output frequency tracks that of the input AC waveform.



- Voltage and Frequency Dependent (VFD): referred to as standby or off-line. The output voltage and frequency are unaffected during normal operation and match those of the input AC waveform. The inverter is off-line and switches in to cover changes in voltage, frequency and availability.



Customer benefits: UPS chooses the most efficient operating mode based on the different network conditions to ensure that the supply to the load remains in optimum condition at all times

In an on-line UPS, protection is achieved through the digital generation of an AC output waveform by the UPS inverter, EMI/RFI filters, the rectifier/charger arrangement and an isolation transformer (if present). This is considered to provide the most secure, stable and electrically clean source of uninterruptible power. By comparison Standby UPS provides a backup supply only.

Within a UPS, backup power is provided by a DC source (typically a battery set), sized to provide enough time for a standby power generator to start or to cover longer interruptions in the mains power supply. For on-line UPS, alternative sources of DC power now include fuel cells, super capacitors and flywheels. These sources of standby power can help to improve overall UPS operating efficiency because they can be used instead of or with an existing battery set.

2. UPS Efficiency

Efficiency is a measure of the total output of a system as a ratio of the total inputs, expressed as a percentage. In the case of UPS electrical efficiency, the total electrical power supplied to the UPS system and its output load are considered. Advances in UPS design have seen a significant increase in UPS operating efficiency and the range of loading these can be achieved over. Typical on-line UPS system operating efficiencies have increased from 85-90% to more than 95% and over a wider loading percentage. Most UPS systems run at 80% load or less and operating efficiencies would typically reduce with lower loadings with a worst-case scenario being achieved around 25%. While EN/IEC 62040-3 defines UPS operating topologies, there is no engineering standard or guideline to define High Efficiency. The industry accepted norm is 95% or greater. However, some important players in the industry state the efficiency around 98-99% but avoid specifying that these efficiencies are only achievable in ECO-mode.

3. ECO-mode Operation

ECO is an operating mode available in most VFI-type (on-line double-conversion) UPS. It takes advantage of the automatic bypass inherent in this type of UPS design. Energy savings are achieved because the UPS is set to operate in either VI or VFD configuration (line interactive or standby) operation. This will also result in a degradation of both power quality and backup power transfer time.

Without an engineering definition for ECO-mode, UPS manufacturers are free to adopt whichever method of operating mode suits the design of their UPS system to maximize efficiency and use any marketing term they consider appropriate for this. Other terms can include: 'high efficiency mode', 'bypass mode' and 'multi-mode' or 'multi-normal-mode' UPS.

4. ECO-Mode Acceptability

When considering whether to adopt ECO-mode UPS, data center owners, operators and designers should evaluate whether the use of ECO-mode is suitable for their specific operation, assess the costs of implementation and forecast energy saving benefits.

Three factors are crucial to the effective use of ECO- mode:

1. The transfer time of the internal bypass and inverter arrangement.
2. The ride-through time of the critical IT load power supplies.
3. The quality and stability of AC mains power/standby generator power.

4.1 Transfer Time From Mains to Inverter and Inverter to Mains

Transfer time is the time taken for the UPS to transfer connected loads between the UPS output and an alternative AC power source, and vice-versa. The alternative power source can be the mains power supply, a standby power generator or another UPS (parallel/redundant configurations).

Transfer time is dependent upon the internal bypass type. Three-phase UPS designs typically incorporate a static transfer switch. Single-phase UPS tend to use static transfer switches from 3kVA up and relay-based electro-mechanical switches below.

If an external Static Transfer Switch (STS) is employed within the UPS power path, its transfer characteristics should also be evaluated. Typical STS have a transfer time of 4-6ms and when installed may require matching to the chosen UPS design, so that ECO-mode transfers are not seen as an interruption in supply.

Transfer time is also dependent upon whether the inverter and its control electronics are energized or de-energized. There may be a start-up delay if control circuitry and electronics require energizing before they can accept a load.

Transfer time can also be affected by whether the internal bypass switch continuously tracks the incoming AC power waveform and whether it is within acceptable limits for acceptance or not. Given the range of configurations it is possible to measure transfer times ranging from zero to 0.25 cycles for static transfer arrangements to as long as 500ms for electro-mechanical arrangements. Typically, zero to 2-4ms is an accepted norm for a critical IT load as this range typically sits inside the operating characteristics of a Switch Mode Power Supply-based IT server.

4.2 IT Switch Mode Power Supply Unit (PSU) Ride-through Times

Ride-through capability is a characteristic of the design of IT server PSUs. As a capacitive load, a PSU stores electrical energy as part of its operation method. This can be used to cover short-breaks in AC power, typically 10-50ms, with a minimum of 10ms as an accepted norm.

Ride-through time is typically quoted for a single power supply at full load. Dual corded power supplies (50% loaded) can have an extended ride-through capability of 50-100% greater. Energy storage capabilities within PSUs are variable between manufacturers and are typically reducing.

After a loss of AC power, a typical PSU will recover lost energy within one to two cycles. Within a large data center environment this can lead to a transient surge current, which the UPS must be capable of supporting while in ECO-mode. The surge current could lower the input supply voltage due to supply impedance. A commonly quoted guide is the ITIC (CBEMA) 2000 Power Quality curve. The 'curve' was developed for single phase ICT equipment and allowed for an interruption of up to 20ms in supply.

UPS operating within ECO-mode must be capable of providing a degree of power quality protection and a backup power profile that sits within the ITIC (CBEMA) Power Quality curve. In ECO-mode, the UPS must be capable of transferring the load within a safe margin of the ride-through capability of the PSU.

4.3 AC Power Source Quality and Stability

The quality and stability of AC mains power/standby generator power will also affect the choice of whether ECO-mode can be enabled or not. A stable electrical supply means that the voltage and frequency waveforms are stable and do not have power quality issues.

When running from a stable electrical supply, ECO-mode operation will deliver energy savings. When running from an unstable electrical supply, the UPS could 'bounce' between operating states or select to remain in on-line mode to protect the load. Therefore, in an unstable electrical environment, forecast energy savings may not be achieved.

Fault-tolerance is another related issue. A UPS in ECO-mode must be able to differentiate between AC power source and load faults if it is to protect the load. A low AC power source voltage caused by a fault condition may lead to the UPS switching to on-line mode. A low voltage condition may be within the input voltage waveform limits of the UPS to work in ECO-mode, but the UPS electronics must work harder to deliver the same output rating. Energy savings may not be achieved if the low voltage condition is long term.

A final consideration is the electrical infrastructure itself. Operating the UPS in ECO-mode may leave the critical IT load susceptible to damage from fast rising spikes and electrical surges. To protect the load, additional surge protection on the AC power supplies (UPS input and bypass) should be installed.

Due to the mix of load profiles, power quality issues can also originate within the data center itself and extended power quality monitoring should be considered for existing data centers.

In ECO-mode operation, it can be assumed that the UPS is operating in a less resilient state than full on-line mode. There may be an interruption in backup power when the mains power supply fails, and a lower level of power quality will be provided.

5. Economic Benefits of Energy Saving UPS Systems

The Green Grid Association is a non-profit organization and an open industry consortium working to improve the efficiency of IT operations and data centers around the world. The Green Grid Data Center Maturity Model (DCMM) identifies ECO-mode as an energy saving recommendation and compares its use to that of free cooling within a data center (taking advantage of low temperatures outside to cool the critical facilities). In the case of power, it means leveraging a stable mains power supply to power IT hardware that is less susceptible to mains power fluctuations and that has the capability to ride-through momentary interruptions in mains power supply.

Without a standard or industry norm, UPS manufacturers can interpret and provide ECO-mode protection in several ways:

- Standby Mode (VFD): where the load is powered through the built-in automatic bypass. The EMI/RFI filters may be in circuit or not. The inverter and its control circuitry may be energized or not. An interruption in the mains supply to critical loads, longer than 4ms, can occur when the inverter is powered up and switched in to provide backup power.
- Line Interactive (VI) Mode: where the load is powered through the automatic bypass and EMI/RFI filters to provide some protection from mains power quality problems and with the inverter 'energized' but not directly powering the load. An interruption in supply will occur between 2-4ms when the inverter is switched in to provide backup power.
- Smart-Active Mode: where the UPS chooses by itself based on predictive algorithms and mains power supply historical stability whether to operate in standby, line interactive or on-line mode.
- Emergency/Off Mode: a typical configuration for emergency lighting applications where load is powered through the Automatic Bypass directly. The UPS and filters only activate when there is a mains power failure.

Each of these modes could be considered to be ECO, and energy savings are achieved by turning off or powering down elements within the UPS including: the inverter, rectifier-charger and cooling fans. The choice is manufacturer-led and should be evaluated.

Whichever method of ECO-mode is adopted, it is reasonable to assume that the break in electrical supply will be no worse than that recommended by the ITIC (CBEMA) study. IT operators then have to rate the level of risk they are prepared to introduce to their critical loads in terms of potential interruptions in supply and lower levels of power quality.

ECO-mode can help to incur in lower electrical operating losses of the UPS because it is functioning in a lower operating state. Typical energy savings of 3-6% can be achieved between ECO-mode and line interactive (VI) operation dependent upon the data center design (best-in-class to legacy) with a corresponding saving on cooling and improvement in PUE.

Overall UPS operating efficiencies can rise to 98-99% but at reduced levels of resilience in terms of power quality and backup power availability. It is important to carefully compare the efficiency figures between UPS manufacturers to ensure they are using a similar method to achieve ECO-mode.

Based on Green Grid estimates of annual energy savings as a function of IT load (kW), savings of $82k could be achieved for a 1MW IT load up to almost $400k for a 5MW load in a legacy data center.

From a Net Prevent Value (NPV) calculation best-in-class data centers can see savings from $17k for a 100kW IT load to $950k for a 5MW IT load over ten years.

6. ECO-mode Advantages

The benefits of ECO-mode operation are essentially financial and operational and may impact corporate social responsibility. A higher operating efficiency, saving 3-6% in UPS energy consumption combined with rising electricity costs will improve Total Cost of Ownership (TCO) and Net Present Value

(NPV) figures. Specific saving calculations are dependent on the actual UPS loading (25-80%) and capital costs.

Dependent upon the size and age of the data center, a saving of 3-6% may improve the overall Power Usage Effectiveness (PUE) ratio. The lower the existing PUE ratio, the greater the impact from running in energy saving mode. Within the data center environment, the same applies to savings in cooling, as a more efficient UPS operation will generate less heat into the critical facility. The UPS manufacturer may be able to offer resilient parallel configurations where one or more UPS are set to run in ECO-mode.

7. ECO-mode Disadvantages

The disadvantages of ECO-mode introduce further complexity into power continuity planning for electrical engineers, facilities managers and ICT operators.

ECO-mode may not be suitable for all locations and load types. This energy saving mode relies on a clean and stable mains power supply, and low harmonic generating loads. In ECO-mode, additional expenses and considerations may have to be given to surge, spike, harmonic suppression and the electrical switchgear and its monitoring.

ECO-mode introduces a lower level of resilience into critical load environments. In a Tier 1 installation (Uptime Institute), a single UPS is available but with backup power transfer delay. It is not instantaneous, and the level of power quality protection provided is weaker, leaving the potential for critical load hardware damage and operation disruption.

In Smart line interactive Mode, the UPS selects whether to operate in line interactive or on-line mode dependent upon the state of the local mains power supply. The selection depends upon a period of power stability and monitoring by the UPS sensing circuits to prevent 'bouncing' between operating states. In dynamic, industrial or remote environments ECO-mode may not always be available as an operating option.

To prevent hunting and poor generator synchronization, ECO-mode may not be available or suited to supplying loads with leading power factors such as Blade servers. In full on-line mode, a UPS will protect upstream loads and distribution elements from harmonics. In ECO-mode, these could pass through the bypass and pollute the supply to other critical systems within the distribution infrastructure.

8. Measuring UPS Efficiency In Practice

UPS can provide an array of operating data including input and output voltages and frequencies, load Amps, kW, KVA, battery charge percentage and runtime available. More advanced systems provide kWh measurements which can be used to calculate PUE ratios. Where the load is connected directly to the UPS output or there is no intelligent reporting at the connected PDU level, these more sophisticated UPS provide this in situ monitoring at no extra cost.

The operating efficiency figures quoted on UPS manufacturer datasheets are often generated during R&D work or within laboratory test conditions. They may not actually be achievable within 'real world' conditions, and especially if the test conditions were optimized through the use of a stable load profile, stable mains supply, near unity power factors and true sinewave voltage and current waveforms. Other aspects that can affect recorded figures include the battery charge state (fully charged or discharged or even connected) and room temperature; which will affect fan speed.

9. Energy Star Mark

Energy Star is an international standard for energy efficient products, originating from the US Environmental Protection Agency. The Energy Star mark covers consumer products and those awarded the mark should be able to show 20-30% less energy usage compared to federal US standards.

Computer products and peripherals are covered within the Energy Star standard, including UPS and it does identify ECO-mode as a potential energy saving operation, describing it as a multi-normal-mode UPS.

12. Conclusion

ECO is a badge that all hardware suppliers to high-energy usage environments have tried to apply – to both their companies and products. As a rapidly emerging trend, there are few standards, guidelines and accepted norms (if any) to help users assess and compare eco-badged systems. This applies to UPS systems as much as to other critical systems within a data center environment.

The ETL does provide some indication as to the overall energy efficiency of a UPS but whether such a system can achieve its published efficiency levels is dependent upon the test conditions and the real-world environment it is operating within.

While ECO-mode can lead to higher energy savings and lower Total Costs of Ownership, its usage will introduce a lower level of resilience into a critical IT environment in terms of the transfer time to backup power and an inferior level of power quality for connected loads.

Where ECO-mode may be acceptable as an operating mode is within an N+x parallel or redundant system configuration. Here one UPS would operate in on-line mode as the master UPS and additional UPS modules are allowed to run in ECO-mode or allowed to even drop into a higher energy-saving sleep state until called upon to actively support the load.

These advanced systems may also be able to increase their efficiency through cyclic charging of their batteries, allowing the battery charge to degrade to a set level over a time period before a recharge is applied. The use of alternative DC backup power sources may also improve energy efficiency and extend the overall Total Cost of Ownership. These can include flywheels, fuel cells and super capacitors.

ECO-mode may be comparable to free cooling in data center air conditioning but not directly, as it introduces a greater level of operational risk. When making any financial assessment, this risk should be factored in.

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