White Paper

99% counts.

High Efficiency Mode ESS (Energy Saver System) 93PR UPS Series

Powering Business Worldwide

Required: Best possible efficiency

In UPS applications like data centers, medical labs, and industrial process controls, there continues to be a universal concern about operating costs. This results in the demand for quantifiable reductions in power usage and an emphasis on best possible efficiency in the mission-critical infrastructure. Most UPS vendors offer "eco modes," or in Eaton's case, Energy Saver System (ESS).

These operating modes offer dramatically increased efficiency, and make it easy to prove significantly reduced operating costs (OPEX) for power and cooling. However, for the traditionally risk-averse community of users and specifiers, skepticism and even trepidation remains. Their attitude is to operate the UPS the same way because it works, and for the last 40 years, UPS manufacturers encouraged this sentiment. But today, enormous pressure is being applied to manage costs. This pressure is aimed at the IT management level, and results must be visible in the c-suite. Data center operators and multi-tenant data center (MTDC) or colocation facility owners find themselves looking for a way to achieve significant cost reduction, without impacting uptime and availability. Effective management of total cost of ownership (TCO) is now a requirement, not a luxury.

In this paper, we will resolve the ongoing debate over whether or not traditional double-conversion operation is the sole path to maximum availability. We will compare the critical performance characteristics of both traditional and ESS operation, and show that ESS not only matches double conversion, offers more tangible benefits. We should note that ESS and competitors' eco mode are not identical and should not be used interchangeably when discussing performance and benefits to the user.

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Did you know?

The Green Grid has documentation stating that the typical data center should move to eco mode UPSs and use products with a broad high efficiency curve, at all load levels, by 2016.

The Green Grid, "Data Center Maturity Model" (2011)

Characteristics of double-conversion operation

Accepted characteristics

Double-conversion UPS devices operate on the same basic principle and have the following well- understood and accepted characteristics, no matter which vendor is considered.

Instantaneous response to utility power anomalies like sags, surges, transients, frequency problems and waveform distortion due to the isolation provided by converting AC to DC, then DC back to AC.
Voltage and frequency regulation within relatively tight limits. These limits are typically ±2–3 percent voltage, and ±3 Hz frequency. Modern IT equipment has a much wider tolerance range for acceptable operation.
Isolation for current and voltage distortion created by the connected load (high harmonic loads). This capability is again due to the isolation created by double-conversion operation.
No start-up or switching required at the critical moment of an incoming power disturbance. Start-up time and dependence on mechanical switching are considered potential failure points and discouraged for reliability reasons.
Synchronization with the utility is constantly maintained if the incoming frequency is within IT equipment limits.
Regeneration of the output sine wave. That is, a new sine wave is built by the UPS 24x7 to provide assurance that input power anomalies do not propagate through to the UPS output.

Undesirable characteristics

It's not all good news, however, as the following issues are related to double-conversion operation.

Low efficiency, especially at light loads and for lightly loaded UPSs is quite common, especially in redundant applications.
High input current distortion (iTHD). The UPS actually creates distortion on its own input line. This is a challenge for the UPS/generator interface, and often requires expensive oversizing of the generator. Additionally, this UPS-created distortion can be a problem for other sensitive devices onsite.
Mechanical devices required for UPS operation. This is predominantly fans, which must be operated constantly and designed for redundancy. Fan replacement is a frequent service/repair cost. Constantly running fans have a large impact on mean time between failure (MTBF) of the UPS and this impacts user availability. Motor-operated circuit breakers and contactors are another mechanical dependency that must be managed and considered in MTBF analyses.
Electrical and magnetic (EMI) noise and constant audible noise. EMI can cause disturbances in telecommunications, medical or network installations. Audible noise limits flexibility in where the UPS can be located (away from office areas, etc.).
Switching of power electronics. Modern UPSs depend on their internal power circuits to operate at enormously high speeds and handle very large currents and voltages—and do this reliably. In fact, a three-phase UPS may operate at switching speeds of 16 kHz or more. This means that its power transistors will turn on and off 276 times per 60 Hz cycle, so a modern UPS operating in double-conversion mode must perform perfect switches 54 million times per hour, 24 hours a day. If even one of these switches is not successful, the UPS will fail and the critical load must be transferred to utility bypass. Although it is a testament to the power electronics technology that UPSs can perform with this level of reliability, more switches result in more risk.

ESS characteristics

The benefits of double conversion have ensured that this mode has historically been the most trusted choice, but there are significant downsides and the most prevalent one is inefficiency. Today, the cost of power and the need to eliminate wasted resources and operate in an environmentally sustainable fashion have forced users to consider alternatives that meet cost targets without compromising reliability. Reliability translates to data center availability, which is the most important consideration of all, and it must not be sacrificed for efficiency.

ESS is a truly unique technology that doesn't just match the performance and reliability of traditional double conversion operation, but exceeds it.

ESS characteristics that match double conversion

Using the features of double conversion we already discussed, let's see how ESS stacks up.

Instantaneous response. ESS circuits respond to anomalies in typically less than two one-thousandths of a second (2 mSec). This is as fast as double-conversion circuitry can compensate and is well within the tolerance of any sensitive critical device that a UPS could be called on to support (per ITIC and NEC guidelines on IT equipment design). In fact, ESS requires much less power switching than double conversion.

Voltage regulation. The ESS system responds to voltage sags/surges changes within 2 mSec, which is one-eighth of a cycle at 60 Hz. The UPS output regulation is thus maintained.

Isolation from harmonic-rich critical load equipment. ESS can be deployed with Eaton's Harmonic Reduction System (HRS), which cancels out load harmonics so they do not appear at the UPS input terminals and cause problems in the customer's facility. Note: competitive eco modes usually do not provide this capability.

Mechanical switching. By simply leaving breakers and contactors in their closed state at all times, ESS does not require any mechanical switching during its operation. A switch that is already closed cannot fail to close. This means mechanical switching is not a part of any MTBF calculation for the ESS mode UPS and eliminates a frequent cause of concern with the reliability of "offline" eco modes.

Synchronization. Just as it would be in double-conversion mode, ESS UPS electronics and power circuit gating are always in sync with the incoming utility. The UPS does not have to wait for sync before a transition can take place.

Regenerated output. This inefficient process requires power conversion (AC/DC and DC/AC), which wastes energy. The ESS UPS constantly monitors incoming power quality, and if within limits, no regeneration is required. As a result, there is no waste. If power begins to show signs of deviation, the UPS transitions to double-conversion operation before the disturbance can impact the critical load. Patented techniques are utilized to ensure the UPS can in fact predict a power disturbance and react instantaneously to stabilize its output in 2 mSec or less.

ESS characteristics that exceed double-conversion

As evidenced by comparing the previous six items, the ESS UPS matches double-conversion performance in output power quality and protection.There are, however, the following differences in performance.

Two mSec transition times from ESS mode to or from conventional operation. Conventional UPSs can take longer to compensate for large surges or sags.

- **How fast is 2 mSec?** Well, it takes 350 mSec to blink your eyes! Another example: imagine a car race where the winner and the second place contender cross the finish line at almost 200 mph with their front bumpers one foot apart. The time clock indicates the victor won by a margin of 2 mSec.
- **Is 2 mSec fast enough to protect your critical equipment?** Standards are set by respected and impartial organizations like CBEMA and ITIC, and now more globally, IEC. These stipulate that computer equipment or sensitive lab or industrial devices be able to ride through a 20 mSec power interruption and continue to operate successfully. ESS transitions (with very rare exception) within 1/10th of that time frame. Note that other eco modes may require as much as 10 to 20 mSec for their transitions, introducing unacceptable risk to the connected devices.

Voltage and frequency regulation. ESS matches double-conversion response and may react even faster because there is no output transformer impedance between the UPS output and the critical load.

Catastrophic (lightning type) surge attenuation. ESS exceeds double-conversion capability by not requiring the UPS power electronics to compensate for ultra high-voltage surges. The ESS UPS simply uses its filter capacitor banks to attenuate the surge passively. This is something transformer-based eco modes cannot do and outperforms metal oxide varistors (MOV) suppressors by providing a surge suppression circuit that has a longer service life.

Isolation from high harmonic loads. An ESS UPS eliminates load harmonics from causing site issues or generator interface problems while providing much better efficiency than traditional double-conversion UPS models. It also uses fewer parts, which produces better overall reliability.

- **Harmonic reduction.** The Harmonics Reduction System uses the UPS power components to generate a waveform that cancels out the distortion created by the load. In fact, this feature works much like noise-cancelling headphones, just at a much higher power level.

No mechanical switching. Identical to double conversion, no mechanical switching is required for ESS operation. And since ESS mode involves fewer active electronic components, reliability is enhanced and MTBF is improved 2-3 times that of traditional operation.

Synchronization. Identical to double conversion, ESS controls constantly maintain synchronization with the utility input line, enabling the fast transition times described above.

Highest efficiency available at greater than 99 percent. ESS provides the highest efficiency available from any UPS even at very light loads when double-conversion efficiency suffers. In the Power Xpert™ 93PR UPS, ESS efficiency is more than 99 percent pover the range of 15 percent to 100 percent load. As a result, it saves money.

No input currentTHD with ESS for a more reliable generator interface it also reduces the amount of generator oversizing required, saving capital expenditure (CAPEX).

88 percent fewer fans with ESS mode. Reliability or MTBF is enhanced by the absence of power-conversion switching and the reduction in required fans. That is, about 88 percent fewer fans are needed for ESS operation vs. traditional opera- tion, saving OPEX money on repair costs and downtime for maintenance.

No EMI noise and dramatically reduced audible noise with ESS. The benefit is CAPEX savings through the flexibility in the location of the UPS.

Tangible benefits of ESS

Here are some examples of better TCO through the use of ESS.

Did you know?

The Green Grid has documentation stating that a UPS could operate in eco mode as much as 99 percent of the year.

The Green Grid, "Evaluation of Eco Mode in Uninterruptible Power Supply Systems" (2012)

High efficiency example: 96 percent vs. 99 percent efficiency

Most users understand that lightly loaded UPSs and HVAC systems operate less efficiently and this level of wasted cost is unacceptable. Occupancy rates and utilization of the data center are variables for MTDCs and enterprises as their business grows and their tenants change. This is where ESS really creates both a lower and more predictable TCO. Efficiencies in excess of 99 percent at all load levels help eliminate unplanned surprises in OPEX related to energy use. Even a 1-3 percent efficiency improvement over an alternative UPS can make the difference in which power vendor is chosen. If TCO is a gating factor, users owe it to themselves to consider the TCO difference between 96 percent efficiency and the more than 99 percent efficiency ESS affords. Add in cooling cost savings and the best solution is clear: the most efficient power infrastructure saves more money every day.

The ROI of ESS operation repays the entire cost of the UPS in two to three years. Service costs will be less due to MTBF, so mechanical components will have a longer life. UPS vendors offer easy-to-use tools that quantify the cost savings and allow "what if" scenarios to be analyzed as well. These can be customized if necessary to exactly match a client's power system design and provide a compelling tool to support their recommendation to use the highest efficiency UPS available.

A 1 MW UPS running at 96 percent efficiency wastes 4 percent of its incoming power (100-96=4). That's 40,000 watts of wasted energy, or 40 kWh. Multiply this by the cost paid for power times 24 times 365 and the result is the annual cost of this wasted energy.

So, if power costs 7 cents per kWh, then the 96 percent efficient UPS costs: 40 kWh x $0.07 x 24 hours x 365 days = $24,528 per year for every year the UPS is in service. Then add the cost to remove the heat generated by that wasted power. For comparison, substitute an ESS UPS in the previous equation: Wasted power is 1 percent (100-99=1) or 10 kWh for the 1 MW UPS. So, the same formula gives 10 kWh x $0.07 x 24 hours x 365 days = $6,132 per year. The final result is a 75 percent reduction in wasted power and a 75 percent reduction in heat created by the ESS UPS.

With regard to the heat calculation, note that every 1 kW of heat loss is equivalent to 3,412 BTUs. In our example, the 96 percent efficient UPS loses 40 kW of heat constantly and 40 x 3,412 = 136,480 BTUs emitted by that UPS that must now be removed by the HVAC system, resulting in increased OPEX cost. In comparison, the ESS UPS only emits 10 kW of heat, or 10 kW x 3,412 = 34,120 BTUs. Again, the highest efficiency UPS produces 75 percent less heat.

As can be seen above, the basic calculations are quite simple, yet the results are tangible and provable. The benefit is ESS power and cooling savings will repay the cost of the UPS itself within two to three 3 years of operation.

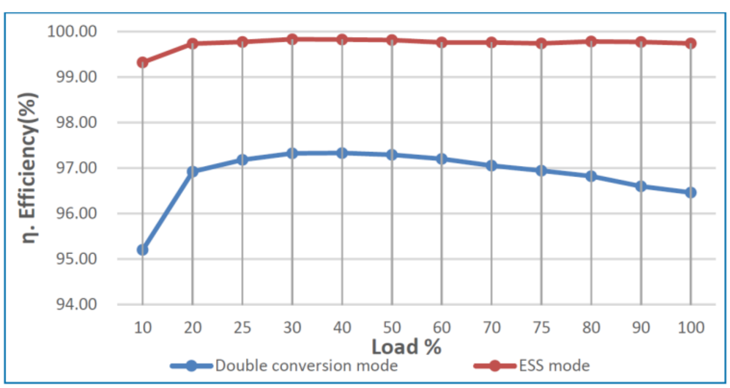

Figure 1. Efficiency comparison – Double conversion mode vs ESS mode

MTBF improvement for ESS; the benefit is lower maintenance costs

As shown earlier, a UPS operating in ESS mode is not switching its power electronics 54 million times per hour. It uses 88 percent fewer fans for better reliability of mechanical components, delivers lower stress on semiconductors and produces less ripple on power capacitors. A comparison of MTBF calculations using MIL HDBK 217 shows the expected improvement in MTBF for an ESS UPS over traditional double-conversion products: a UPS operating in ESS mode provides two to three times greater MTBF than a traditional double-conversion product. This is a significant benefit for anyone with a mission- critical enterprise. MTBF information may be shared upon request. The benefit to the user is lower repair and maintenance costs due to fewer fan, contactor and capacitor failures.

Additional operating mode; the benefit is lower downtime costs

A dual-fed UPS operating in ESS mode can survive a power loss to its rectifier input without using its battery for support. Compare this design with a traditional UPS that drops to battery whenever rectifier input is lost. The benefit is lower battery stress and less risk of a weak battery causing UPS failure.

Superior surge suppression vs. MOV-based suppressors

UPS designs that depend on internal MOVs or external surge suppressors for protection from voltage transients are placed at increasing risk as more and more transients are suppressed. The ESS UPS, however, uses its power capacitors for transient attenuation and can survive a much higher quantity of transients without risk of wearing out or failure.

Utility incentives

Monetary incentives are available from local utility companies for being able to operate these large facilities at a significant power savings. Almost all utility companies in the U.S. offer these incentives that are paid either quarterly, annually or on a one-time basis. All these savings drop directly to the user's bottom line, as shown in Table 1 below.

Critical load	50 kW	125 kW	250 kW	500 kW	700 kW
Electric costs	$0.11	$0.11	$0.11	$0.11	$0.11
Legacy UPS efficiency	92.5%	92.5%	93%	93%	93%
Eaton ESS UPS efficiency	99%	99%	99%	99%	99%
3-year energy savings	145 MWhr	363 MWhr	670 MWhr	1340 MWhr	1876 MWhr
3-year CO2 savings	104 metric tons	261 metric tons	481 metric tons	962 metric tons	1347 metric tons
Cars off the road	6 cars	16 cars	29 cars	59 cars	82 cars
3-year electric cost savings	$15,972	$39,929	$73,715	$147,431	$206,403

Table 1. Three-year power cost savings for different sized UPS installations

High quality of output;

In ESS mode, UPS output satisfies class 1 condition of IEC 62040-3

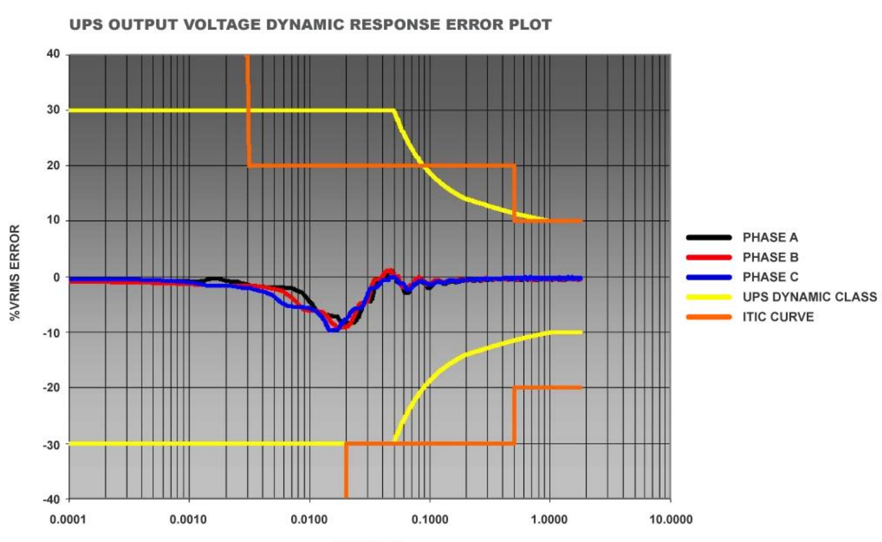

Figure 2. ESS Response Example – 100% Outage

Conclusion

In the UPS market, confusion may exist around the performance and capabilities of different eco modes. False vendor claims often confuse the market further with statements comparing eco modes to bypass operation. At Eaton, our position is clear: ESS works incredibly well and we have many satisfied users. Figure 3 below quantifies our user base and defines results of ESS usage around the world.

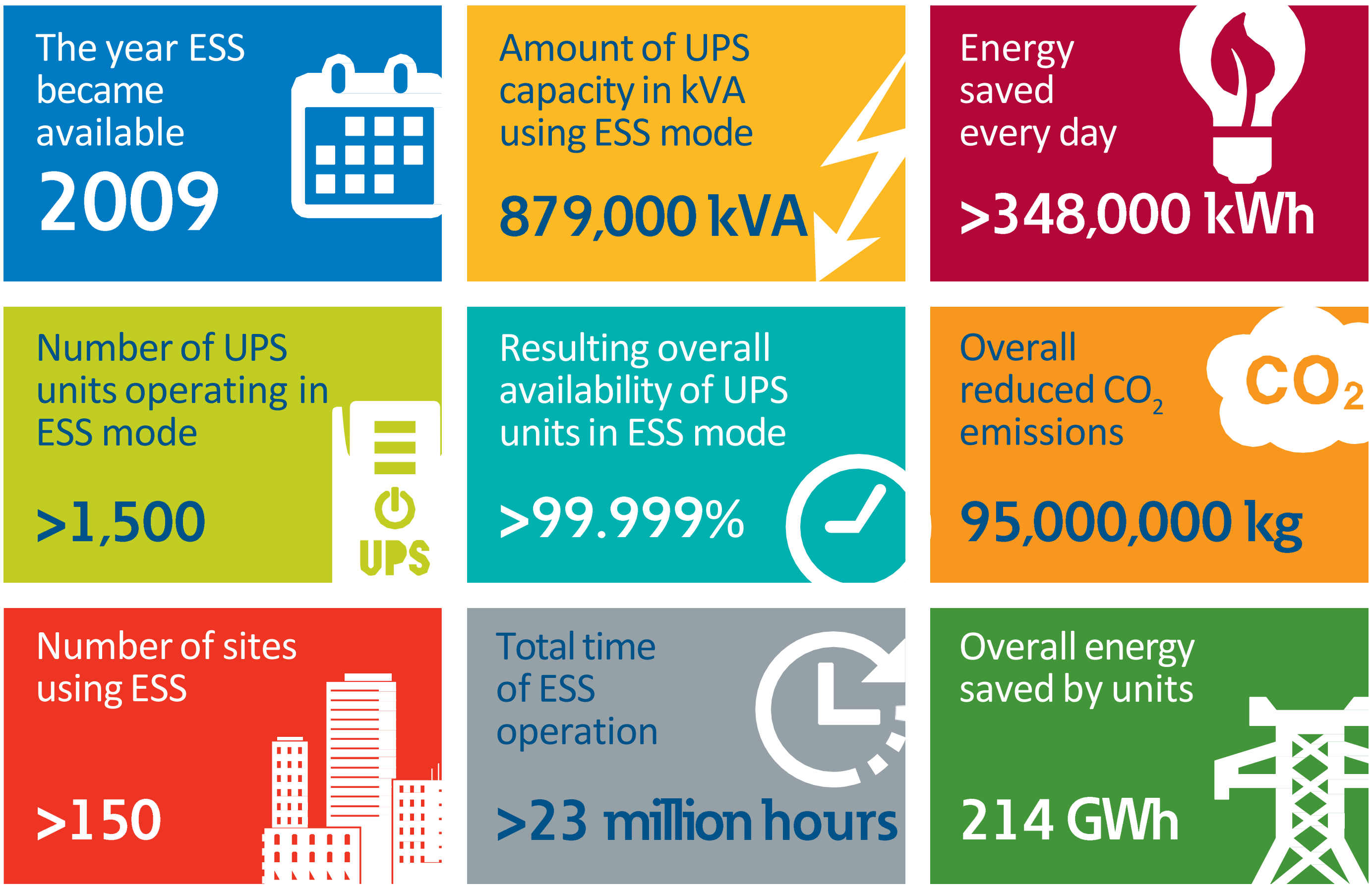

Figure 3. The proven performance of ESS

Most large enterprise and MTDC operators have serious concerns about their effect on the environment and are making investments that show the public, their customers, and their shareholders this is a top priority. Improved power efficiency and lower cooling requirements save valuable energy and also reduce water usage, allowing data centers to provide real evidence that they are good neighbors and assets to the community.

Data center operators today are universally focused on total costs over time, and they are constantly questioning their ROI. The upfront cost of hardware and commissioning are only a part of the decision on infrastructure design and deployment. Service costs, battery maintenance/ replacement and power costs are evaluated over the complete service life of the equipment, usually 15 to 20 years.

Eaton's patented ESS should not be equated with other vendors' eco modes. It provides all the benefits of double conversion while ensuring improved quality, reliability, and significant cost savings, all without impacting the availability of the mission-critical application. ESS performance surpasses eco modes in the following ways:

1) **Faster transition time to and from high efficiency mode.** ESS transition times are almost always sub-2 mSec. Eco modes may be as slow as 12 mSec, six times slower than ESS, which introduces a risk that IT equipment may be affected by a break in power continuity.

2) **Fault detection.** In ESS or eco mode, it is critical that the UPS be able to handle short circuit conditions, and instantly distinguish whether the fault occurs upstream or downstream of the UPS. For example, the eco mode UPS reacts to a sensed loss of voltage by turning on its inverter, but if the fault is downstream of the UPS, this could easily result in a load loss due to overload. The patented ESS mode detects the location of the fault and reacts appropriately to protect the critical IT load.

3) **Transient suppression.** ESS mode UPSs can suppress lightning-type surges effectively without using MOV-based suppressors, which have a limited life. Eco mode products often cannot make this claim, and depend on external surge suppression devices that may have been rendered ineffective by previous surge events.

4) **Patented static switch commutation.** ESS can commutate (turn off) its static switch in less than ½ mSec. This is required to quickly isolate the critical load from incoming power disturbances. Competitive eco modes may take as much as 8 mSec to disconnect a failing utility source from the UPS load.

5) **Correction of load harmonics.** ESS has the ability to use its power converters to correct for undesirable harmonics created by the user's IT devices on UPS output. Eco modes cannot correct this issue, which may cause iTHD issues onsite.

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