Eaton Energy Saver System versus conventional “eco-mode” UPSs

Straight talk about the technology that drives the highest-efficiency UPSs on the market

Separating hype from reality about high-efficiency or “eco-mode” UPSs

If you’ve been in the power quality industry for any length of time—whether as an analyst, specifying engineer or facilities/operations professional—no doubt you have heard plenty of hype about “high-efficiency” or “eco-mode” UPSs in the past. Those terms generally referred to UPSs that switched between standby or line-interactive and double-conversion modes to improve efficiency. This type of capability has been available on UPS products for years.

Those traditional multi-mode UPSs have their limitations. They can be ineffective against many types of power problems. They can be slow to respond to transient power conditions. They can leave the load vulnerable to high surges, downstream shorts circuits and other potential electrical system conditions.

With that history for high-efficiency UPSs, you have every right to be skeptical and ask, “What makes Energy Saver System so different? Can I entrust my most sensitive equipment and data centers to multi-mode power protection from Eaton®?”

Yes, thanks to the patented innovations that Eaton has incorporated into the industry’s most efficient UPSs. Energy Saver System works quite differently from conventional eco-mode or multi-mode UPSs in many important ways. Join us for a conversation with a cynic, a candid grouping of the questions we’ve heard from the field.

How do conventional, non-Eaton high-efficiency or “eco-mode” UPSs work?

Two basic types of high-efficiency UPSs are prevalent on the market today:

For many vendors’ models…

Under day-to-day operating conditions, the load is simply powered from a bypass power source, exposed to incoming power disturbances.

The UPS internal components—rectifier and inverter—are turned off.

When incoming power conditions are out of range, the UPS must start up internal components, magnetize a transformer, synchronize the waveform, and then close its output contactor to transfer to double-conversion mode.

Transfers can take from 20 to 3000 milliseconds. In that interval, significant disturbances can reach the load and cause problems.

Efficiency is high—as much as 98 percent under favorable conditions—but protection is low.

For other UPS models…

Under normal operating conditions, the UPS operates in line-interactive mode, which can correct for voltage variations and minor distortion on the output but not for high power surges, lightning-related transients or frequency problems.

The inverter is energized *and running* all the time, continuously consuming a portion of incoming power and reducing system efficiency.

When conditions warrant, the line interactive UPS transfers to double-conversion mode faster than the first type of UPS, because it doesn’t have to start the inverter or close an output contactor.

Efficiency is comparatively low. Under most conditions, these UPSs are hard-pressed to achieve 96–97 percent efficiency.

In short, conventional high-efficiency UPSs force a trade-off between efficiency and protection. You cannot optimize for both. And because these UPSs have a transformer, efficiency is no better than 98 percent and in reality may be much lower, depending on variables such as amount of load and the quality of the utility feed. For example, efficiency may be quite less in high or low line conditions.

How is Eaton's Energy Saver System different?

Under normal conditions, the Energy Saver System circuit provides power with surge suppression to the critical load and maintains the inverter DC input.

Because the inverter input is always charged (but the inverter is not running), and the output is always synchronized, transition time is two milliseconds or less.

A transformer-less topology enables the Energy Saver System to reach and maintain 99 percent efficiency while constantly protecting the load.

Energy Saver System intelligently adapts to incoming power conditions—first, to deliver clean power to the load; and second, to maximize efficiency. Whenever the high-speed line-detection circuitry in the UPS senses a change in condition, the system automatically changes modes accordingly:

Under normal utility conditions, when power conditions are within acceptable limits, the UPS operates as a high-efficiency, energy-saving system—providing surge protection for IT equipment and ensuring clean power is delivered to the facility.

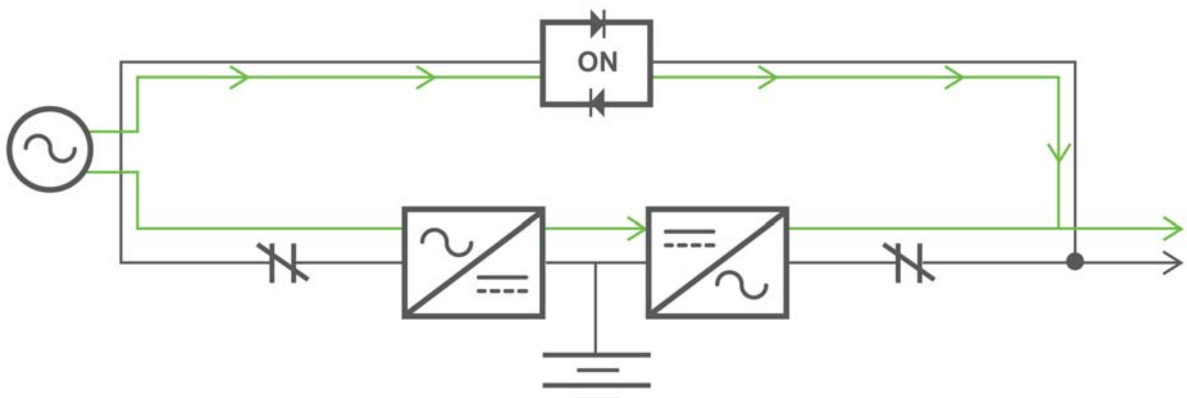

Figure 1. Active components engaged during Energy Saver System mode.

When power is erratic or during fleeting disturbances, the UPS continuously provides power to the load, while conditioning the power to eliminate any disturbances. In this mode, the UPS processes incoming power through a rectifier and inverter, completely protecting IT equipment from the incoming AC source. Reaction time to power disturbances is incredibly fast due to proprietary algorithms that disengage the continuous duty static switch in mere microseconds.

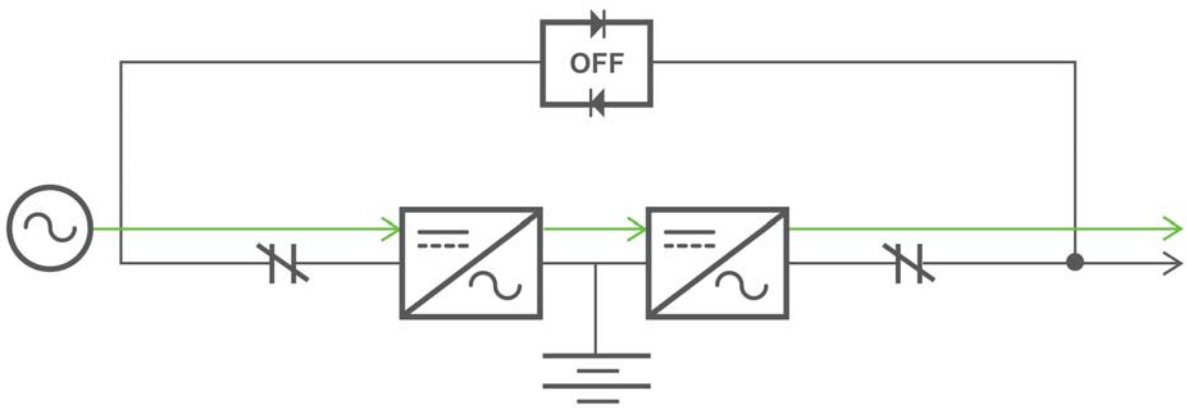

Figure 2. Active components engaged during double-conversion operation.

During a power outage or sustained power anomalies, the UPS draws power from available battery modules or other standby sources (generators, etc.). In configurations with a generator, the UPS ensures that generator power has stabilized before returning to Energy Saver System mode.

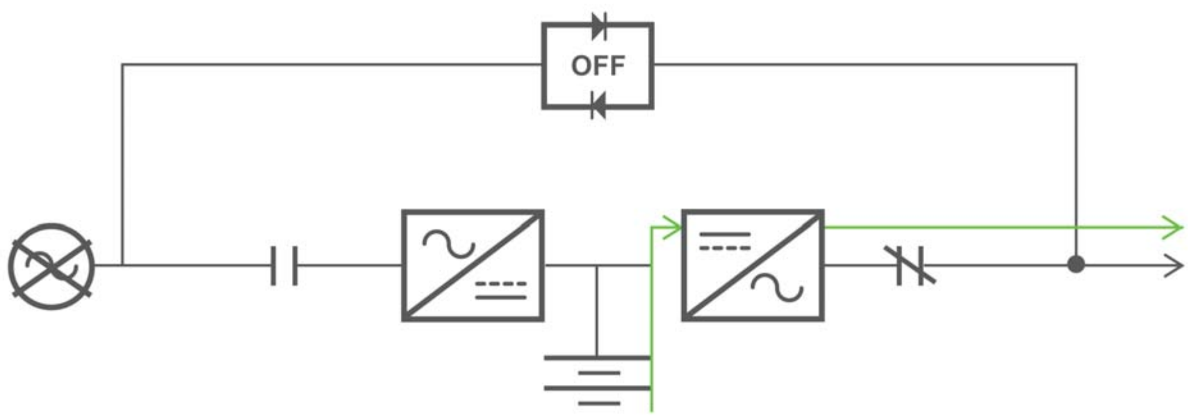

Figure 3. Active components engaged during battery backup.

This intelligent, multi-mode technology provides exactly the level of power protection needed under the conditions of the moment—optimizing for both protection and efficiency.

How does Energy Saver System offer better protection than other high-efficiency UPSs?

Many conventional eco-mode UPSs are simply running on bypass most of the time, which leaves the load exposed and vulnerable to transient power problems. Suppose a lightning strike near the facility sends a 10,000-volt spike down the line that lasts only four nanoseconds. A conventional “eco-mode” UPS running on bypass would be unable to respond quickly enough. That brief but destructive surge would pass through to the load.

In contrast, the Energy Saver System uses both the input and output filter capacitance (165 µf each) of the UPS to provide a high level of surge suppression even when operating in highest efficiency mode. The output contactor remains closed, so the surge passes through the output filter—an inductor and capacitor—which attenuates the 10,000V spike to a harmless few volts.

Surge suppression is even stronger when Energy Saver System is applied to parallel UPS configurations. For instance, an 1100 kVA UPS can be established as a line-up of four 275 kVA modules—each with its own filters—a total of four input and output filters, for much greater surge suppression (8x 165 µf).

How does Energy Saver System transfer so quickly to highest-protection mode?

Rapid transfer to highest protection mode is a function of two factors:

- How fast the UPS can turn on the inverter
- How fast it can turn off the static switch to isolate the load from the utility disturbance

Only when both activities have been accomplished is a UPS truly online in highest protection mode. Energy Saver System offers unique approaches that accelerate both processes, enabling transfer in two milliseconds or less.

Turning <u>on</u> the inverter.

With most conventional eco-mode UPSs, the inverter is turned off to maximize efficiency during normal operation. With Energy Saver System, the output contactor is constantly closed, and the inverter is in "ready state." In this mode the pulse width modulation signals are generated and synchronized to utility. The only step needed to come out of "ready state" is to gate the IGBTs, and this can be accomplished in 600 µsec. Pumpback diodes inside the rectifier keep a DC voltage on the inverter input inside the UPS, using little input power. Because DC voltage is constantly present, the inverter can start up instantaneously.

Turning <u>off</u> the static switch.

During high-efficiency mode, the UPS static switch is on, but it must be turned off to isolate the load for double-conversion operation. The semiconductors in static switches turn on instantaneously when needed, but the only way to turn them *off* is to force the current to go to zero.

The UPS could simply wait for the next zero crossing of the power line to shut off the static switch. But what if the UPS detects a big disturbance on a positive half-cycle of the power sine wave? If the static switch was still conducting, that distortion would pass directly to the load for the remainder of the half cycle. In other UPSs, the static switch has to wait for the zero crossing of the next half cycle, which could be as much as 8 ms—too long to expose critical loads to power disturbances.

Eaton has developed proprietary techniques to commutate the static switch under various conditions. Using these techniques, Energy Saver System can turn off the static switch in 600 microseconds rather than waiting potentially eight milliseconds for the next zero crossing.

Test results have shown that Energy Saver System turns the inverter on in 600 microseconds and turns the static switch off in 600 microseconds—1.2 milliseconds total. Eaton publishes a transfer rate of two milliseconds, but in reality, the system is designed for even faster transfer.

Our IT equipment meets ITIC specifications, so is ultra-high-speed transfer really that critical?

It is true that the output of an Energy Saver System UPS will not get even remotely close to ITIC limits. For example, an ITIC-compatible power supply unit (PSU) can handle surges of 30 percent from nominal for 0.5 cycles (8–10 ms), or sags of 30 percent below nominal for 20 ms.

So this is a valid question: If the PSU can ride through disruptions of 8–20 ms, why would 2 ms transfer time be advantageous? The issue is not so much the fear of locking up IT equipment but rather two other issues:

- Minimizing the inrush current needed to recharge It equipment power supplies capacitors after a disruption
- Ensuring compatibility with downstream static switches in an A/B dual bus architecture

Faster transfer times minimize disruptive inrush current.

When first connected to an AC power source (or when powered up on an already connected source), IT equipment temporarily draws a large inrush current that can last for 2–10 ms and be as much as 10–60 times the normal operating current.

For instance, upon start-up, an HP Proliant DL 360 G4 1U server at 2.4A can draw peak inrush current of 61A for 3 ms. An IBM BladeCenter, fully loaded, normally requiring 23.7A, can draw 200A of inrush current for 4 ms. A Cisco 3825 Router can pull 50A for 10 ms.

After a power interruption, IT equipment draws a surge of energy to recharge the capacitors that provided ride-through capability. For power interruptions of less than 5 ms, surge currents typically last for half a cycle (about 10 ms) and are less than 300 percent of nominal current. For interruptions of 10-15 ms, the surge current could be 700 to more than 1000 percent of nominal current, and can last for 1.0–1.5 cycles (about 20 ms–30 ms).

If you have 1,000 servers, each with their power-hungry capacitors looking to be recharged, the cumulative demand could drag down power voltage on the power source or overload the UPS. As a result, you always want power interruptions to be as short as possible. The very fast transfer time of Energy Saver System UPSs minimizes these effects.

Faster transfer times prevent disruption to downstream static switches.

If your data center has A and B side power systems for redundancy, no doubt you have static switches in the power infrastructure to extend this A/B redundancy to single-corded loads. If an upstream UPS takes too long to change state—either from high-efficiency mode to double-conversion mode or back again—these downstream static switches could mistakenly perceive a disruption in power and switch between A and B power sources. To prevent these unwanted and unnecessary transfers from occurring, the UPS must have a faster detection/transfer time than the static switch.

Eaton has extensively tested the Energy Saver System with many different static switches at different sites and under different conditions. The fastest static switches look for an interruption of approximately 4 ms before changing state. Energy Saver System accomplishes its transfers in less than half that time, so it does not trigger an unnecessary change of state in those downstream static switches.

What if we know power will become erratic, and we want full-time double-conversion protection?

Energy Saver System has been proven reliable under prolonged and repeated power problems far greater than the typical commercial site would experience. In-service experience affirms what our testing has shown: that Energy Saver System is equal to or superior to conventional double-conversion UPSs for protecting sensitive equipment. But we understand that some data center managers and facilities managers will still feel more comfortable knowing the UPS is operating fully in double-conversion mode at times, such as during thunderstorms or rolling brownouts.

For that reason, Energy Saver System offers options for locking in double-conversion mode under user-specified conditions:

- **High-alert Mode**—The user is concerned that power may become unstable—either due to frequency or severity—and directs the UPS to stay in double-conversion mode for a pre-defined period of time, then automatically returns to high-efficiency mode.
- **Storm Detection Mode**—The UPS senses a significant number of disturbances during a short period of time and automatically switches to double-conversion mode for eight hours, then returns to highest-efficiency mode.

All modes are user-selectable from the UPS front panel, from signal inputs or remotely through serial communications.

What if we have different power conditions in different company locations?

The thresholds and actions surrounding high-alert mode and storm detection mode are all user-settable parameters. For Storm Detection Mode, for instance, the default setting is to lock in double-conversion mode after three disturbances within an hour and to stay in double-conversion operation for eight hours. To match varying site conditions and requirements, users can easily change both parameters themselves—the number of triggering disturbances and the duration of double-conversion operation.

An Eaton field technician can also change the voltage deviation and frequency variation thresholds that define a “disturbance” to match specific equipment requirements and utility conditions of a given site. A good practice is to set these limits to accommodate the most sensitive piece of equipment in the load.

How does Energy Saver System handle upstream and downstream faults?

This is an important question, because other multi-mode UPSs just perceive a radical drop in voltage and switch to double-conversion mode to moderate the voltage, whether the fault is upstream or downstream of the UPS. However, if the fault is *downstream* from the UPS, such as from an equipment short to ground, you would *not* want the UPS to switch to double-conversion mode. You would want to enable the utility input source to supply enough current to open the affected circuit breaker(s) very quickly to isolate the effects of the fault.

It is therefore critical for the UPS to be able to differentiate between a source (upstream) fault or a load (downstream) fault. Is the power problem coming from the incoming utility source, or is it caused by the loads themselves, such as a short circuit, a high inrush device or an electric motor starting up?

Energy Saver System addresses this issue in the following way:

- If there is a fault *upstream* of the UPS and voltage drops to zero and the current goes to zero. Sensing both conditions, the UPS energizes the inverter to protect the connected loads.
- If there is a fault *downstream* of the UPS, voltage coming through the UPS drops to zero but current to feed the circuit will sharply increase. The UPS then remains in high-efficiency mode to enable the utility to supply sufficient current to clear downstream breakers or fuses before the critical bus can be damaged.

In short, the intelligent detection circuitry takes the appropriate action for either condition:

- **Upstream fault**—No voltage/no current through the UPS = Transfer to double-conversion mode.
- **Downstream fault**—No voltage/high current = Remain in Energy Saver System mode.

Can we expect the same reliability and service life as from a conventional UPS?

In the UPS industry, Mean Time Between Failures (MTBF) and service life are projected based on testing and monitoring of a realistic number of products over a realistic period of time. By necessity, these are theoretical calculations that are influenced by the in-service operating environment, utility conditions and maintenance that a UPS receives.

However, the intrinsic design of Energy Saver System predisposes the UPS for a high MTBF and long service life. When in Energy Saver System mode, mechanical devices such as fans are not being used. Neither are the power electronics, the big power switching transistors that provide power conversion.

An Energy Saver System could potentially go for months at a time without generating any of the heat or stress associated with running these components. Cooler operating temperatures and conservation of components is expected to extend service life, compared to conventional double-conversion UPSs where these components are running 100 percent of the time.

Do a few percentage points' gain in efficiency really matter that much?

Yes, for two key reasons:

- Even slight gains deliver significant potential savings in power and cooling.
- A vendor's stated efficiency level is often a theoretical maximum, not the in-service reality.

Even small increases in UPS efficiency can quickly translate into thousands of dollars.

In a one megawatt data center, a 10-year-old UPS is probably wasting about 150 kW of power and dissipating a lot of heat. Replacing that legacy equipment with new, high-efficiency UPSs can free up about 120 kW of that power to support new IT equipment and reduce the burden on cooling systems.

The table below shows an example for a single UPS supporting a 250 kW load. In this example, the Energy Saver System saves about $4000 per percentage point of efficiency gain, enough to recover 100 percent of the UPS cost within three to five years. The reduced carbon footprint is equivalent to pulling 29 cars off the road.

Critical Load	50 kW	125 kW	250 kW	500 kW	700 kW
Electric Costs (energy + demand)	$0.11 per kWhr				
Conventional "eco-mode" UPS efficiency	92.5 percent		93 percent		
Eaton Energy Saver System UPS efficiency	99 percent				
Three-year energy savings (MWhrs)	145	363	670	1340	1876
Three-year CO_2 savings (metric tons)	104	261	481	962	1347
Equivalent number of cars off the road	6	16	29	59	82
Three-year utility cost savings	**$15,972**	**$39,929**	**$73,715**	**$147,431**	**$206,403**

Table 1. ESS savings are significant across all load ranges and compound based on data center size.

Average efficiency in the real world can be quite different from stated maximum efficiency.

Manufacturers usually state UPS efficiency ratings at full load, but most of today's UPSs are markedly less efficient under lighter loads, which is how they are likely to be used. Since so many IT systems use dual bus architecture for redundancy, the typical data center loads each bus (and UPS) at less than 50 percent capacity, often as little as 20 to 40 percent.

As a result, it is important to understand UPS efficiency across the entire load range, not just under theoretical ideal UPS operating conditions. While other UPSs drop off markedly in their efficiency, UPSs with the Energy Saver System sustain 99 percent efficiency even when lightly loaded—as much as 15 percentage points better than a traditional UPS.

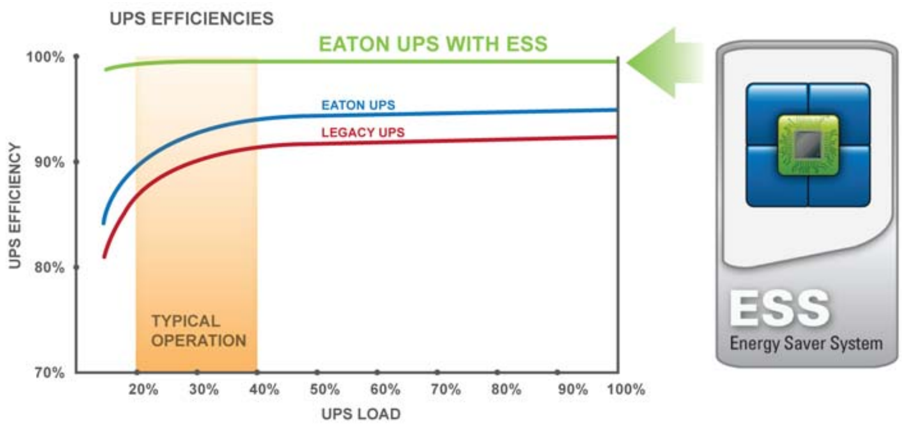

Figure 4. **ESS UPSs maintain 99 percent efficiency no matter how big or small the load—as much as 15 percentage points better than traditional UPSs in the typical operating load range.**

Closing thoughts

In the developed world, utility power is well within ITIC specifications 99.99x percent of the time. Complete power conditioning is needed only rarely, yet traditional double-conversion UPS process utility power through an inverter and rectifier every millisecond of the day, converting it from AC to DC and back to AC again—dissipating heat and wasting power at every stage.

With energy costs now representing such a huge percentage of operating costs, doesn't it make sense to activate the highest protective levels only when needed? That is the premise behind high-efficiency, multi-mode UPSs.

However, until recently, there were trade-offs. Specifying engineers had to choose a "high-efficiency" UPS based on mutually exclusive merits. One type of UPS offered highest efficiency but without comprehensive power protection. Another offered highest protection, but at lower efficiency.

Energy Saver System eliminates those trade-offs by providing:

- **Premium power quality**—Fault detection and transfer to double-conversion mode in 2 ms or less
- **Highest efficiency across all load ranges**—99 percent efficiency in normal operation
- **User-configurable modes**—Forced, full-time double-conversion mode when desired
- **Intelligent fault detection**—Differentiated treatment for upstream or downstream faults

With a more efficient allocation of power, you not only reduce utility bills and total operating cost, but also achieve more with available backup power and cooling systems—delaying the point where those systems would have to be upgraded to accommodate data center expansion. With its low carbon footprint, relative to legacy UPSs, Energy Saver System also contributes to corporate sustainability initiatives.

If you already have an Eaton 9390 or 9395 UPS, you may be able to upgrade to Energy Saver System quickly and easily with a visit from an Eaton field technician. If you are in the market for a new UPS, look seriously at the industry's most effective, efficient and environmentally responsible choice.

Sources

1. Underlying figures from *The Invisible Crisis in the Data Center: The Economic Meltdown of Moore's Law,* Uptime Institute, 2007