ACTIVE ECO MODE IN SINGLE-PHASE UPS

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Abstract

"Environmental protection", "high efficiency" and "energy savings" are nowadays popular topics of discussion and, as they are strongly tied to the functionality of Uninterruptible Power Supplies (UPS), these have become a trendy topic as well. ECO mode represents an interesting feature in UPS technology, in particular related to small or single-phase applications with less than 10 kVA. The UPS industry has spread its use in the last few years for applications that use on-line double conversion products.

In a separate paper, the inherent ECO mode of line interactive UPS has been analyzed. However, let us now approach this operating mode and its advantages for UPS which make use of on-line double conversion technology. Its benefits, key features, trade-offs and the extra level of performance when used in Liebert® UPS products will be analyzed.

ECO Mode in Different UPS Technologies

"Environmental protection", "high efficiency" and "energy savings" are topics of very high concern for both large corporations as well as for individuals, since these aspects are part of everyday life and may generate significant cost savings in both cases. This is also valid for UPS, ranging from large units that protect substantially large data centers, to small ones with just a few kilowatts that safeguard a network or single cabinet in more modest settings.

The ECO mode (also known as "energy saving mode" or "high efficiency mode" depending on the UPS manufacturer) is currently highly discussed within the industry. The debate primarily focuses on on-line and large UPS. Nevertheless, energy savings and efficiency are also extremely important aspects in small and micro power UPS (typically from 500 VA to 10 kVA). The reasons are the same as for large power systems: significant savings on energy costs and lower environmental footprint.

Choosing a UPS in the most proper way means considering the criticality of the application that needs to be protected, as well as evaluating the energy used by the UPS to protect the load against disturbances and interruptions. In a separate paper[1], the advantages and "inherent" ECO mode in UPS which make use of line interactive technology has been explained. It is now time to explore the distinctive features of the ECO mode when used in on-line double conversion UPS.

Active ECO Mode for On-Line UPS

Firstly, we will begin with a general and basic description of on-line UPS, which will help to better understand the rest of the paper.

UPS with on-line technology include a twofold power conversion stage. In the first stage AC power at the input is converted to DC power through the rectifier or power factor correction stage. Following this, there is a second power conversion stage at the inverter, which regenerates a "clean" electrical AC power without voltage and frequency variations. Furthermore, there is also a static or maintenance bypass line that connects both input and output in case of wrong operation, overload or any other particular condition. Batteries, their charger, and the DC-to-DC converter are also part of the UPS building blocks, but they are not related to the operation in ECO mode. Fig. 1 shows the aforementioned basic building blocks.

Perhaps the first point to clarify when talking about ECO mode in on-line UPS products is the bypass mode. The bypass mode may either be determined by a faulty condition (overload, electronics, etc.) or forced by the user (i.e maintenance, etc.). In both cases, it is a transient status that finishes as soon as the particular condition that determines it is over. Users should consider that any mains failure occurring at the UPS input while the UPS is in bypass mode will drop the load.

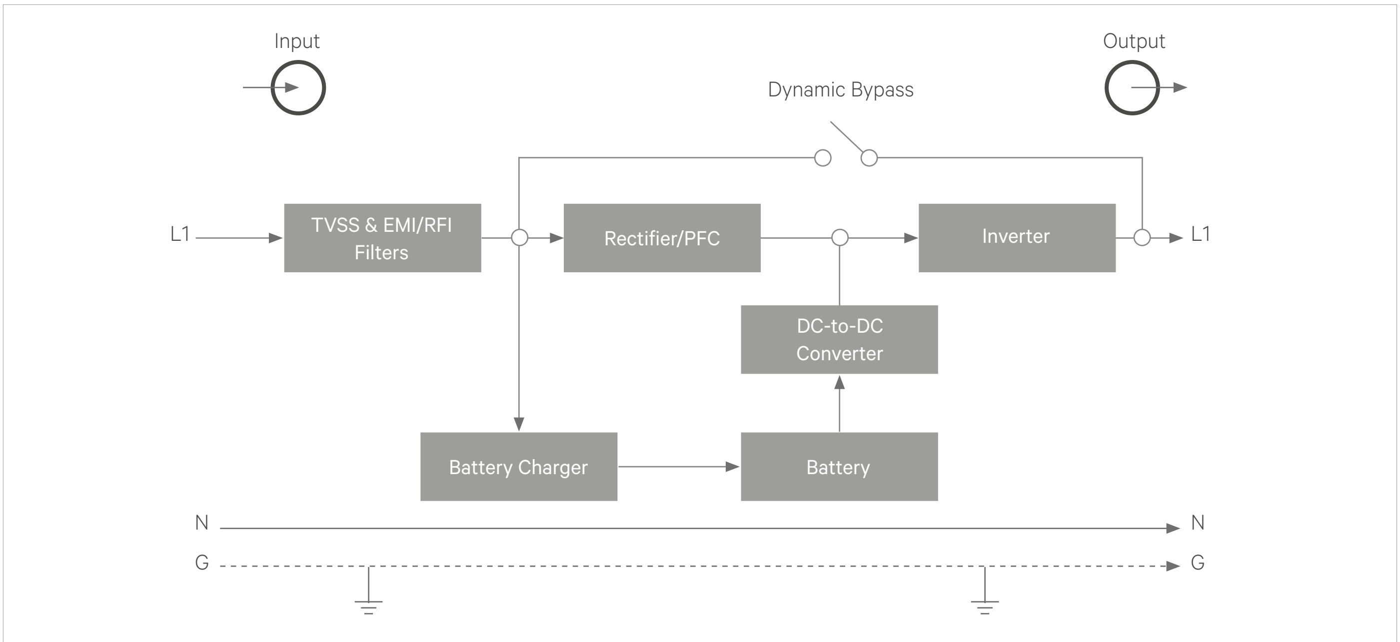

Figure 1: *On-line UPS and bypass line schematic.*

1) ECO-Friendly Choice in Single Phase UPS

On the other hand, ECO mode allows power to flow from the input to the output through the bypass line (Fig. 2), yet, it should be a quasi-permanent status. This means that the UPS will continue to operate in this mode as long as the conditions at the input remain stable without any risk to the load. Should any serious disturbance (such as swells or frequency variations) appear at the input while in ECO mode, the UPS will automatically change to on-line mode in order to continue to deliver "clean" power. Thus, it is clear that while power flows through the same path in both bypass and ECO mode, the operation and level of protection of the load is different.

This bypass line is not connected directly to the input, but through several input protection devices (Fig. 2), which are connected to the input through TVSS and EMI/RFI filter building blocks. This point of connection has two major consequences regarding protection and efficiency.

With respect to load protection, when the UPS is working in ECO mode, the availability of surge protection should also be taken into account. There are still several protection devices at the input (peak surge or over current), along with the continuous measurement and monitoring of the output current through an electronic control. This ensures that the voltage and current delivered to the load are continuously monitored by the UPS' main microprocessor, ensuring that they remain within an acceptable range – even in the case of over loads or abnormal situations. In the worst case of an internal fault (inverter, microprocessor, etc.), there is still a protection at the input that will filter or limit disturbances, so that they are not passed to the load.

The ability to reach an extremely high efficiency level is probably the best recognized and disseminated benefit of the ECO mode. It is also due to the fact that energy flows through the bypass line, allowing efficiency to reach 94-98% at full load (depending on the specific model and rating evaluated in the market) maintaining high values even at low load levels.

A user relying on the Active ECO mode should be aware of the fact that both the input rectifier and inverter power conversion stages remain operative and in stand-by operation even when the UPS functions in this mode, in order to allow a faster transfer to the on-line mode. Entirely switching-off these power blocks would save a few watts of consumption at the input and improve efficiency, but it would also have a negative effect since it would require a longer transfer time between ECO and on-line mode. This extra time is caused by the process of detection, decision, and "re-activation" of the inverter. While other UPS suppliers may prefer to save these extra watts and announce a higher level of efficiency, the continuity in power delivery and a safe load is a Vertiv™ belief. Typically, this transfer time from ECO to on-line mode (or battery mode, in a case of complete mains failure, including power problem detection and response time), will be around 4-10 ms depending on the specific model.

It is also important to highlight that while the UPS is operating in Active ECO mode, there is no voltage regulation at the UPS output. As previously explained in a separate paper, the capability for output voltage regulation makes the difference when comparing line interactive UPS. These line

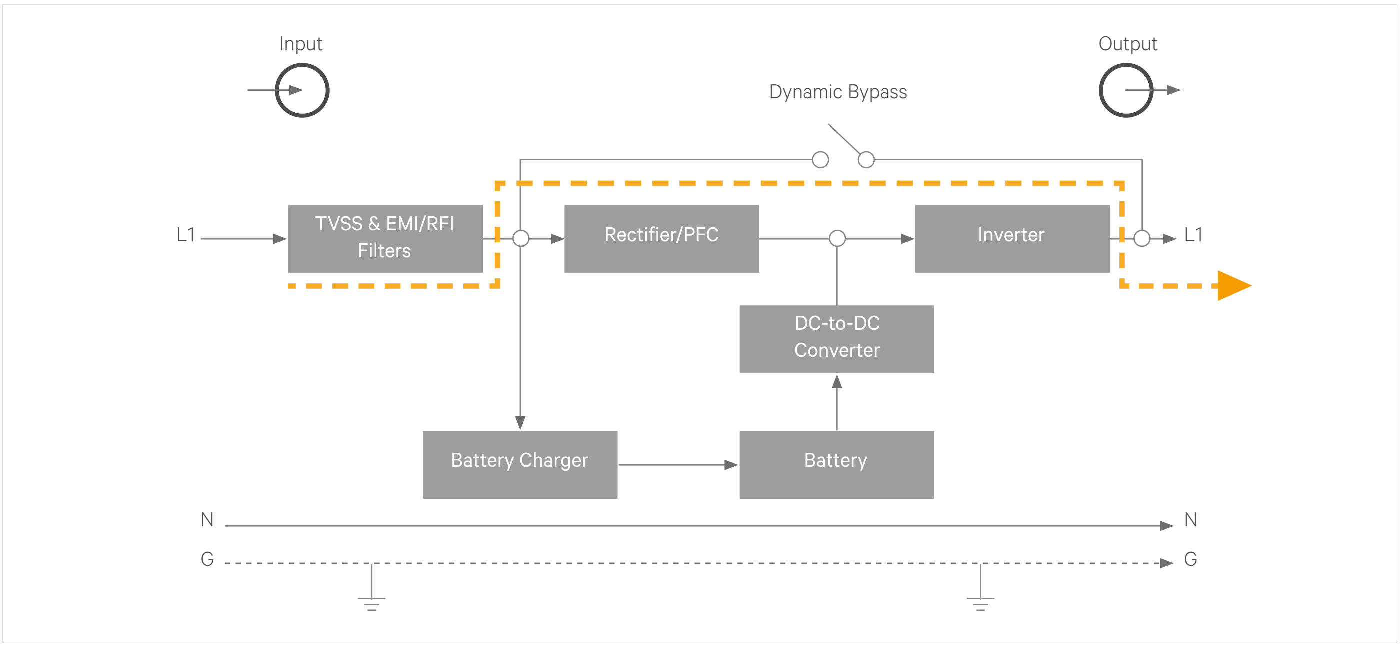

***Figure 2:** Energy flow in ECO mode operation.*

interactive UPS are able to provide high efficiency within a wider input voltage range because of the use of the Automatic Voltage Regulation (AVR) transformer - and still be able to provide some output voltage regulation. Luckily, both technologies are available in the Vertiv™ portfolio, thus it is only a matter of choosing the right one for each application.

Lastly, to fully understand when to consider the ECO mode in on-line UPS, the user should evaluate harmonics at the input. When the UPS is operating in on-line mode, whatever may be the load at the output – i.e. resistive or with high harmonics content - the input rectifier will be responsible for having a perfect sinewave input current (high input power factor with low harmonics content). This is a key point and advantage for an on-line UPS, especially when compared to UPS topologies. However, when the UPS is working in ECO mode, the harmonics content at the input will be a "mirror" of the current harmonics created by the load.

Harmonics are not a serious problem when using modern power supplies with an active Power Factor Correction (PFC) at the input, as is now frequently used in new servers, routers or IP telephony loads. However, it is important that a user is aware of and understands the trade-offs in order to take the right decision about which operation mode to use and reach the maximum benefit of each operating mode.

Whatever the user's decision regarding the enablement or disablement of the ECO mode in the UPS, it is clear that using this mode will result in a high efficiency for the UPS operation and a good power protection for the load. This advantage includes various savings, namely in energy, money and heat dissipation. As soon as the heat dissipated by the UPS is reduced, the cooling system in the server rack or cabinet will also diminish, resulting in a lower inner temperature for the UPS and other electronic equipment, and subsequently improving system PUE. Nevertheless, please do not forget that this minor heat dissipation will have additional advantages, as it requires less fan speed and creates less audible noise, providing more flexibility on where to install the UPS (closer or farther away from the user to avoid the audible noise), and reduce thermal stress inside the internal component (more reliable).

Several Points Make the Difference

Once the reader has understood the operational considerations of the ECO mode, differences among the UPS products in the market will consequently be more evident.

"Energy saving", ECO or "high efficiency" modes are frequently found in commercial literature. However, not all these modes are the same; neither can they provide the same level of protection and performance provided in the Active ECO mode used in Vertiv™ UPS products.

Based on the previous paragraphs, the following points should be considered:

- Efficiency achieved in ECO mode
- Input operation range in bypass mode
- Signalling and UPS status displays such status to the user (LCD or software)
- Decide the need for the UPS to operate in Bypass or ECO mode
- Transfer time
- Configurable parameters to set the operation in ECO mode (user configurable)
- Input or output protections of the UPS in ECO mode (breakers or surge protection)
- Monitoring or capability to control the operating mode remotely
- Ability to perform internal battery tests while operating in ECO mode.

The recommended set of parameters that the ECO mode should have is the ability to select or configure the input voltage range for operation in ECO mode, together with the input frequency range and the time to revert to operation in ECO mode after disturbances are detected at the input.

Considerations of the above points will help the user make the right selection. Yet, the most important point is that a user truly understands how this mode operates, choosing a leading brand that takes care in applying the above points in UPS design.

Thinking about the End-User

For a user, the ECO mode brings many advantages and additional levels of performance. This paper has attempted to show the most relevant considerations so that the user can make an optimal use of this mode, according to the specific requirements of the protected load. A user should always consider the reliability and quality of their utility power so as to decide the best usage of the UPS implementing ECO mode.

The most valuable contribution of the ECO mode is the ability to provide a higher level of UPS efficiency when there are "normal" operating conditions, while still being able to automatically switch to on-line mode when anomalies arise at the input due to peaks, brownouts, swells or complete mains loss.

This improved efficiency can be easily calculated in order to have a quick reference on energy savings, thermal dissipation improvement and reduced electrical costs. Considering a 5 kVA UPS operating at 70% load (e.g. 2800 W active load, assuming output PF=0.8), and operation during full time in ECO mode; such a load may typically be either a cabinet or small server rack, with these servers running the enterprise applications. Let us now assume that this UPS can reach an efficiency of 90% at such load, operating in on-line double conversion mode, with an estimated 98% efficiency when used in ECO mode. In this scenario, energy savings will be around 254 W, or, to state it in a different manner, 254 W of thermal losses that do not dissipate inside the cabinet. We can then proceed to do an economic analysis.

Assuming an electricity cost of 0.128 €/kWh – and by performing a rapid calculation on monetary savings for a full year – the user would get a value of about 307 € of savings per year. When this amount is multiplied by a period of 5 years, the total savings will be more than 1,500 €. Clearly, actual energy savings will depend upon the particular equipment and architecture, load and local cost of electricity. However, in case of a distributed application with 10, 50 or 100 loads across a campus, the figures above provide a good reference for these savings. Finally, the user should understand the type of load that they will protect.

As explained above, the harmonics content of the load that may affect other equipment upstream, if the load includes a modern power supply with PFC, or the type/frequency of disturbances at the input, will all help the user to decide whether or not to enable the ECO mode.

A user should bear in mind that they are using the UPS in ECO mode. This should be highlighted on the front panel of the user's UPS as well as through remote monitoring (SNMP/webcard).

Vertiv™ is proud to offer highly reliable and quality products that implement ECO mode, such as the Liebert® GXT4™ 700 VA-10000 VA and the modular Liebert® APS 5-20 kVA, which will contribute to the energy savings of every customer's application.

For those users who are especially interested in reaching the maximum energy savings, there are additional features that may contribute to these savings.

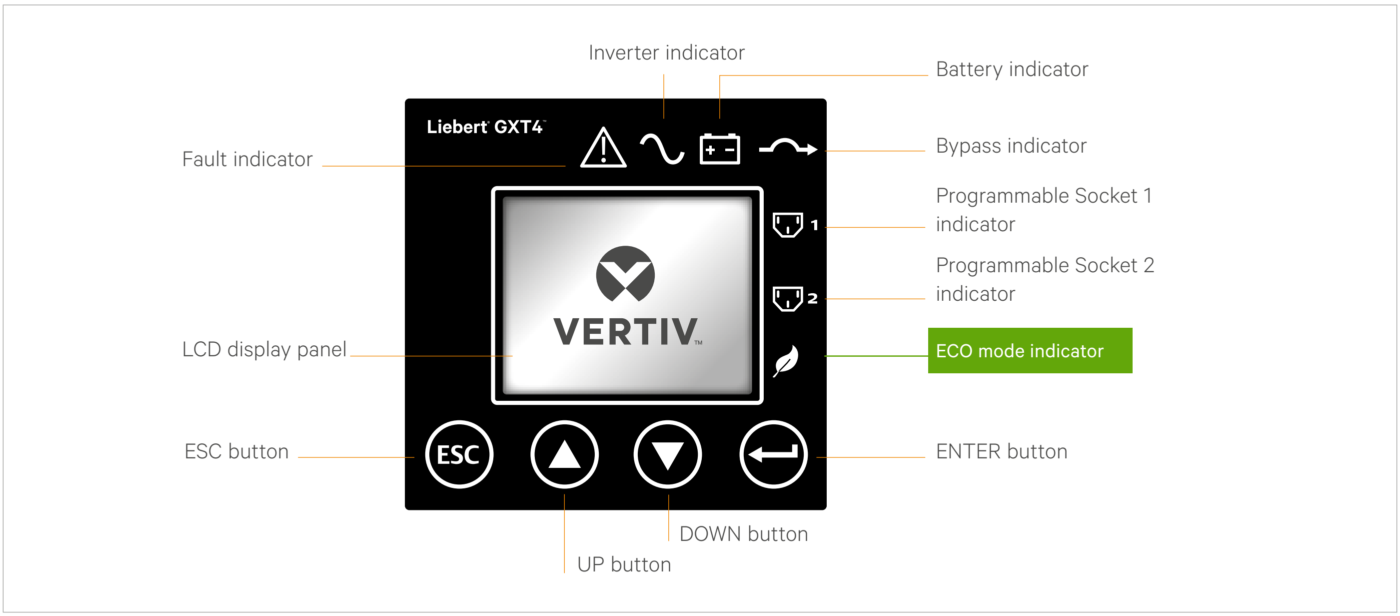

Figure 3: *Liebert GXT4 front panel LCD with ECO mode indicator.*

For example, users will be interested in the application of programmable sockets (used in the Liebert® GXT4™ Micro range). These sockets give the user the ability to switch several output power sockets on or off, so that non-critical loads may be powered-off in periods of less usage (such as the weekends).

There are many other considerations for specific applications that may require the use of parallel/ redundancy UPS, or auxiliary power systems based on gensets, which may be addressed in separate papers.

Figure 4: *Liebert GXT4 and Liebert® APS which include ECO Mode.*

Summary

This white paper has explained the advantages and operation of the ECO mode used in many on-line double conversion UPS. Even if this ECO mode is widely used in commercial literature, it is important to know the key features and trade-offs so that an end-user can make the most appropriate use for their load protection.

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