WHITE PAPER

UPS efficiency and its contribution to green data centres

As the spotlight has turned to the UPS's role in the PUE energy equation, manufacturers have responded with ways to improve UPS efficiency.

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The rise and continued growth of social media, the Internet of Things, and on-line transactions generally is driving demand for ever more computer processing capacity.

This growth in data centre demand highlights the critical need for efficiency in power usage. To illustrate: a 1% efficiency improvement on 2 MW power consumption will save £800,000 pa at today's electricity prices. Accordingly, this article describes how the industry uses Power Usage Effectiveness (PUE), which is a popular tool for quantifying data centre efficiency and providing a basis for improvement; it also discusses how UPS manufacturers are responding with more energy-efficient UPS solutions.

As service providers work to meet these demands, now and into the future, one result is larger-sized data centres with proportionally elevated power demands. Facilities such as Facebook's data centre in Lulea that consumes about 120 MW exist, while capacities could eventually scale much further. For example, Kolos[i], a US-Norwegian partnership, is working on a facility in a remote town north of the Arctic Circle that will eventually draw 1,000 megawatts.

PUE: An effective energy management tool – just use it correctly

PUE has become the driving force behind the improvement in energy efficiency of data centre M&E infrastructures and an integral part in the pursuit of the 'green' data centre. The metric is a measure of how efficiently power is used within a data centre. It is defined as the ratio between total amount of power consumed and the amount of power delivered to computing equipment.

$$PUE = \frac{\text{Total facility power}}{\text{IT equipment power}}$$

There are, however, some caveats in considering PUE as an energy efficiency tool. Firstly, it's important to remember that it's an annualised energy metric and not a measurement of peak power. Accordingly, peak power calculations must be performed separately to correctly size the utility and emergency generation system.

Annualising the calculation is important, as seasonal variations throughout the year will affect the heating and cooling loads, and their contribution to the PUE equation.

Another issue was flagged by the Uptime Institute in their 2014 Data Center Industry Survey[ii], and referred to in various pieces from them since then. They point out how PUE can be abused, intentionally or otherwise. For example, a PUE of one might suggest that the facility is perfectly efficient, and nothing more can be done.

However, this isn't the case, because inefficiency could be hiding within the IT equipment consumption figure. For example, TUI estimates that 20% of servers in data centers are obsolete, outdated, or unused. In fact, they launched their Server Roundup contest in 2011 to raise awareness about the removal and recycling of comatose and obsolete IT equipment and reduce data center energy use.

Apart from these considerations, PUE remains as an important and effective tool for energy management. Today, UPS efficiency contributes significantly to its results, although this hasn't always been so. A typical early-90s data centre with a critical load of around 1MVA had an N+1 UPS of probably 3x500 kVA with an efficiency of 88% and a compressor-based mechanical cooling system that maintained a tightly-controlled temperature and humidity environment. The chilled water was supplied at 6ºC and the air supplied into the under-floor plenum was around 15ºC. No 'free cooling' coils were ever considered (or available in standard equipment) and variable speed pumps and fans were still on the application horizon. Humidification and de-hum consumed energy and even the lighting was high in proportion to the load as the power density was 350-500W/m^2 from mostly mainframe hardware.

This created an infrastructure where the utility load was constant (non-seasonal) and the fully loaded PUE if known was around 2.5. However, the partial load performance was very poor – with monolithic plant (no scalability planned) and no variable speed drives – so most facilities ran at a PUE equivalent of 3.5. Hence, even at partial load, the UPS system only contributed about 0.15 to the PUE with the mechanical cooling load dominating the power demand. Energy was cheap and the load was sacrosanct and so very few people, if any, worried too much about data centre energy costs.

However, the overall facility energy landscape has changed considerably since then. The introduction of 'free-cooling' economisers and, more recently, the relaxation of the thermal envelope (temperature and humidity) by ASHRAE have drastically reduced cooling system power demand. Strict air-management, ensuring that no cooled air bypasses the load, has been established as best-practice and this has been enhanced for partial load conditions by widespread use of variable speed drives for fans and pumps. Full-load cooling coefficient of performance (CoP) has improved from 1.0 (where to move 1kW of heat from within the critical space to the external ambient takes a further 1kW of power in the cooling system) to better than 0.1 (1kW of cooling system power to remove 10kW of waste heat from the load).

To complement this contribution to a target PUE of 1.2 or better the UPS is required to offer 0.05 and the other consumers (internal and external lighting, NOC, controls, security and further functions) a further 0.05. Achieving an annualised PUE of c1.15 requires extremely efficient systems but a full load UPS efficiency of >95% is essential. Partial-load performance must also be excellent, through technology (e.g. with >94% efficiency at 30–40% load) or 'right-sizing' to keep the UPS load >70%, including the option of using modular UPS topology as described later.

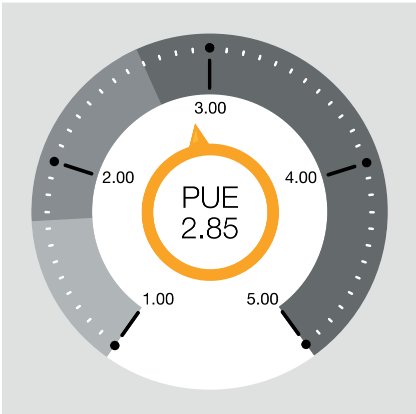


Figure 1: How can we reduce PUE?

UPS contributions to PUE – the manufacturers' response

Nine years ago, UPS efficiencies were typically around 94%. These have gradually been progressing to today's levels of up to 97%. This improvement comes from developments in the underlying UPS technology as well more specific contributions from Eco mode and Xtra VFI functions.

The most significant change has been the move from transformer-based to transformerless solutions. Some UPS designs still use transformers, but transformerless types now outnumber these by six times. Transformerless technology has been enabled by advances in power semiconductors and the introduction of the Insulated Gate Bipolar Transistor (IGBT) device. This allows a rectifier output with a much higher voltage level than previously, in turn permitting an inverter output RMS level of sufficient magnitude without needing a step-up transformer.

Transformerless technology's key advantage is improved efficiency, as shown in Figure 2 below.

These curves highlight firstly that transformerless technology yields about a 5% improvement in efficiency, but also that efficiency remains constant right down to 25% loading levels, instead of dropping off as transformer-based solutions do.

Transformerless designs also exhibit a higher power factor than transformer-based solutions; this remains consistently close to unity, irrespective of load. Higher power factors mean smaller input currents, cabling and switchgear and sometimes, reduced electricity costs. Additionally, harmonic emissions are reduced.

Transformerless designs bring a further benefit, which is indirect yet of equal significance to the efficiency gains. This relates to the considerable reductions in weight and volume achieved by eliminating the transformer and associated 12-pulse rectifier previously required to improve input THDi performance. A 120 KVA UPS, for example, can be reduced in footprint from 1.32m^2 to 0.64m^2, and in weight from 1,200 Kg to just 310 Kg.

These reductions are so important because they have led to the concept of modular UPS topology. UPSs can be built as modules small enough to slide into racks rather than demanding larger, monolithic assemblies. UPS systems can be incrementally sized to load requirements, even if they change over time. This right-sizing reduces capital cost wasted on unnecessary capacity, and can also improve efficiency when UPS loading is particularly low - a property that is exploited by Xtra VFI operation, as described below.

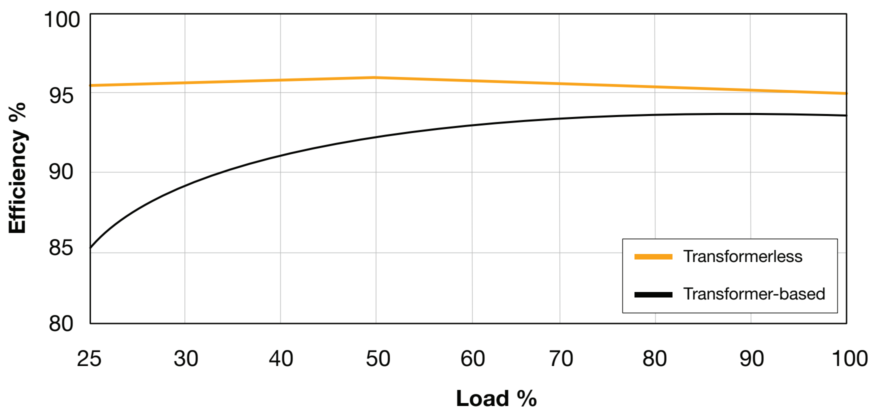


Figure 2: Transformerless and transformer-based UPS efficiencies

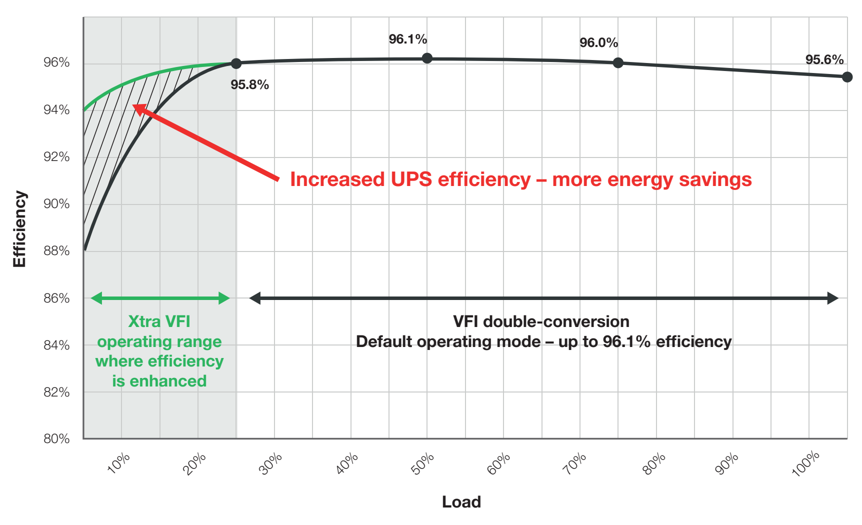
Xtra VFI mode

Severe under-utilisation is often an issue for data centres. According to Computer Communications, Volume 109, 1 September 2017[iii], a realistic data centre environment rarely reaches the network's peak capacity and the average utilisation of devices varies between 5% and 25%; most of the time, links and servers are idle and under-utilised. The paper proposes a power-aware routing algorithm that considerably reduces energy demand while negligibly affecting network performance and guaranteeing reliability.

UPSs are very much involved in this issue. While Figure 2 shows that a modern transformerless UPS exhibits a flat efficiency characteristic down to about 25% loading, its efficiency starts to drop away if loading reduces further in a facility that's under-utilised as described. However, UPS manufacturers have developed solutions such as Xtra VFI to tackle this.

A UPS such as KUPL's PowerWAVE 9500DPA can operate in Xtra VXI mode, in which it automatically adjusts the number of active modules to meet load requirements. Excess modules are switched to standby but remain in a state of readiness, primed to kick in and transfer to active mode if the load increases. The efficiency improvements achieved by this mode of operation are especially significant when the load is less than 25 percent of full UPS system capacity. In addition, Xtra rotates modules between active and standby, which extends the service life and stages aging of the UPS.

Xtra VFI provides a secure way to significantly increase efficiency in datacentres that do not run on full load



- UPS maximises the double-conversion efficiency by engaging UPS modules based on load power.
- When load is very low compared to UPS system-rated power, the over capacity is automatically switched to standby mode where modules consume much less power and thus help save energy.
- Efficiency improvement is especially significant when load is ≤25% of full UPS system capacity.

Figure 3: Xtra VXI energy savings

Active
The UPS module is operating at double conversion mode and supplying the load with the other active modules. Each module equally shares the load.

Passive
The UPS module is on standby, with the inverter switched off, ready to transfer to active double-conversion operation when the load increases.

Figure 4: 800 kW maximum load UPS example

Figure 3 shows the energy savings that can be realised by using Xtra VFI on a modular UPS system comprising ten 100 kW modules, with a total available capacity of 1 MW. Figure 4 is an example configuration for an N+2 redundant UPS supporting an 800 kW maximum load.

Example:

Maximum load = 800 kW
Redundancy = N+2
2 x 500 kW frames (10 x 100 kW)
Load power = 200 kW
No. of active modules = 4
UPS active capacity = 400 kW
UPS standby capacity = 600 kW

The system calculates the optimal percentage value for maximum efficiency, allowing for desired redundancy. The redundancy level for active capacity and the highest expected load step can be user-configured to guarantee the highest protection level.

Xtra VFI is automatically deactivated during a mains failure or alarm, with all modules switching to ‘Active’ status.

Eco mode

Many UPSs can be operated in Eco mode to achieve efficiencies up to 99%. However, this approach has the disadvantage described below as well as efficiency benefits, and is certainly unsuitable for most critical load applications.

In Eco mode, the UPS operates as an off-line system, in which raw mains power bypasses the UPS to feed the critical load directly during normal operation. Although this avoids losses related to the UPS rectifier and inverter stages, it exposes the critical load to spikes and noise arriving from the utility supply. Some installations with robust machines and stable utility supplies may find this acceptable, but any facility with sensitive IT equipment will not want to risk the damage to hardware, loss of data and ensuing reputation problems created by such exposure.

Conclusions

Efficiency in data centre equipment, including UPSs, has now become a critical concern that now influences senior executives in an organisation. As data centres, especially third-party host sites, continue to grow, the significance of every energy saving percentage point increases accordingly. More stringent government legislation, and the need to present Green credentials to customers, employees, shareholders and suppliers alike, are adding to this pressure to improve efficiency.

In understanding this, facilities managers have been using the PUE metric as a tool to measure and a basis of improvement for energy efficiency; and it's a tool that works well provided that any scope for misinterpretation is recognised and avoided.

We have seen that as other facility equipment's efficiency has improved, the spotlight has turned to UPSs and their role in the overall PUE equation. Accordingly, the article moves on to highlight the developments that have been introduced to address this increasingly critical UPS efficiency requirement; improved, transformerless modular technology, Xtra VFI and Eco-mode operation.

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