UPS systems with a high-efficiency operating mode for loads requiring continuous voltage

Abstract

The subject of energy-saving and carbon-footprint reduction has reached the critical power supply industry for both IT and manufacturing applications. The apparent delay has been imposed by the requirement for high-reliability exceeding the desire to save money or energy, or indeed both.

However, not all applications require the highest level of voltage fidelity that the classical 'computer' load has demanded in the past and opportunities have arisen for a different solution to the power supply provisioning. With the rising cost of electrical energy the pay-back period for installing high-efficiency plant has been reducing whilst the reliability of uninterruptible power systems has been steadily increasing to the point where alternatives can be considered.

This paper explores one of the possible solutions – 'eco-mode' operation of the traditional high-integrity series-on-line UPS.

Can one load have a wider tolerance to power fluctuations than another?

The classic 'computer' load requires the voltage supply to be within fine limits, as expressed in the IEEE 466 Std - 1999, notably voltage and frequency controlled to within ±1% with no break lasting for longer than 20ms. This level of power quality specification was applied to loads with embedded microprocessors.

However, today, there exists a class of critical load that is not predominately microprocessor based and does not require the high-fidelity power supply with simultaneous voltage and frequency correction. However these loads do need a continuous voltage supply for interruption-free operation. Their 'mission-critical' nature is just as important as the computer but their tolerance to voltage deviations, rather than interruptions, is wider.

A perfect example of this type of load has arisen in the recent past as data-centre power-densities have climbed beyond 4-5kW/m^2: Every Watt that is delivered to the IT load is rejected as heat into the computer room and has to be mechanically removed by close-control air-conditioning plant. At the same time the average temperature and humidity is controlled to, typically, a 22°C±1°K and 50%RH environmental specification.

Traditionally the IT load was fed by UPS and the air-conditioning plant (comprising fans, pumps and compressors etc) ran from the mains supply, both backed up by emergency standby diesel generators. When the power-density was low, e.g. 750W/m^2 in the late 90s, the rate-of-rise of ambient temperature inside the computer-room was slow and by the time the diesels had started and the air-conditioning plant had regained cooling capacity (<2mins) the actual temperature had only risen 3-4°K.

As the power-density has risen above 5kW/m^2 so the rate-of-rise of temperature has passed the critical point where the load is impacted by too high an ambient temperature before cooling can be restored – and aggravated by a rate-of-change of temperature that can induce thermal shock and, even worse, condensation.

The result has been the increasing incidence of UPS being applied to the mechanical load – first the computer-room unit fans, then the chilled-water pumps and, in the extreme, the chiller-compressors and external heat rejection fans. The load is predominately electrical motors and associated variable speed drives.

So, what is the definition of a 'less critical' load? Consider:

- The load runs perfectly well on 'normal' mains quality power, with associated breaks lasting less than 100ms and regular voltage-sags to 70%
- The load runs perfectly well on emergency genset power, with associated frequency excursions outside of ±2%Hz
- The 'mission' fails if the mains-power actually fails resulting in the cooling plant tripping off-line and taking >1min to recover by transferring to genset power
- The failure of the cooling system is equally as critical to the IT load as is the power – but the fidelity requirements are very different

Is there a problem with UPS powered cooling plant?

There is no technical problem other than making sure that any regenerative loads (from motors or four-quadrant VSDs) can be handled by the UPS system, often solved by applying a chopper converter (triggered by rising voltage) and a load–bank on the output. The reserve energy storage can be the traditional batteries (although autonomy need only be 5 minutes) or flywheels if the diesels can be started in time.

The main 'problem' is that whatever the losses in the UPS are they are higher than having no UPS at all. This seemingly retrograde step in energy efficiency is a direct result of higher power-density, so a high-efficiency data-centre is best planned with low power-density.

As an example of the impact consider that the best-in-class true on-line UPS of today (e.g. Chloride 80-NET) achieves 94% efficiency at 70% load and nominal input conditions. That produces 6% of additional losses over a mains supplied system. For a 1MW IT electrical load the mechanical cooling load will be around 400kW and the extra losses will be 36kW (including UPS cooling), or £25,500/year at the rate of £0.08/kWh. This is a substantial financial and environmental penalty to pay.

An ingenious solution

Series on-line (double conversion) UPS modules incorporate an automatic static-switch bypass that, by virtue of its very high operating speed, serves two purposes:

- A break-free transfer of the load to the reserve supply to enable maintenance to be carried out without load shut-down
- An emergency break-free transfer to the reserve supply in the event of severe overload or instantaneous loss of bus voltage

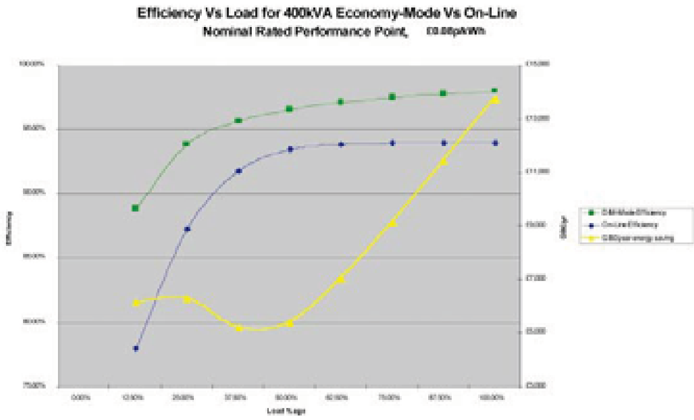
In both cases the transfer is 'break-free' and accomplished in well under 2ms. In normal operation the static-switch sits waiting for the command (manual or automatic) to 'transfer' and can then transfer the load back to the UPS inverter with the same speed and 'break-free' operation and this is the nub of the move to an energy saving solution:

Instead of being quiescent and waiting to transfer the load from the inverter to the bypass the static-switch is used to supply the load all of the time. The UPS monitors the mains supply quality and (in the reverse situation to normal) transfers the load to the inverter as soon as any deviation in the mains supply is detected.

The transfer is transparent to the load, which is always supplied with a quality of power that is better than the 'raw' mains to which it is happy to work from. The difference is that the voltage is now 'continuous'. All that is needed in the UPS is a mains-monitoring function and operational algorithm to provide the intelligent control and prevent repeated transfers in periods of mains instability.

Of course, the UPS is kept in a constant state of preparedness to accept the load and so needs control power and no-load losses to be fed but this power need only be 1.5-2% of the rated power of the UPS – an improvement of 4-4.5% over the series on-line operating mode. The highest efficiency can be obtained by provisioning the UPS cooling fans with thermostatic control so that they operate only when required.

There is an additional advantage – the lower losses from the UPS require less cooling and so the energy saving increases. In our 1MW IT load example the losses reduce dramatically from 26kW to 6kW and, with the UPS cooling saving included, the financial penalty of 'mechanical' UPS reduces from £25,500 to £5,900/year.



The chart above shows the savings relationship for a single 400kVA machine (nominal not worst case input conditions) at varying load with the cooling saving taken into account.

The saving is in energy (carbon) and in operational expenditure - financially beneficial and 'green' whilst the risk to the mechanical load (and therefore to the mission critical function) is zero.

The control feature for this 'economy' mode of operation is included as an option in the entire Chloride range of 3-phase UPS and called *Digital Interactive Mode* (DIM) to signify the interaction between UPS mode and instantaneous mains power quality.

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With over 36 years experience of writing technical articles for leading companies and institutions, Ian is a world renowned author and speaker and an expert in all aspects of critical power and building services.