Measuring and publishing UPS efficiency - a dark art?

Abstract

A quick desktop survey of published energy-efficiency data for UPS machines will result in a wide variation of figures - with as much as three percentage-points of difference between the 'lowest' and the 'highest' in any given segment of the market. However this apparent disparity is difficult to explain when one looks deeper into the base technology and discovers that the internal power-topology of competing machines are similar despite the difference in published efficiency. This paper explores the issue and reaches the conclusion that, in the absence of any independent testing and certification authority, it is far too easy for OEMs to resort to one-up-man-ship in the dark art of the data-sheet 'game'.

Why has 'efficiency' advanced up the agenda?

In many parts of Europe (led by the UK) the cost of electrical energy has climbed dramatically, and if not already, then soon. At the same time the cost of IT hardware has been steadily declining to the point where, for the first time, over the typical three-year life-cycle, the energy consumption cost actually exceeds the initial purchase price.

If we consider higher capacity UPS the difference in Total Cost of Ownership (TCO) based upon a 3% delta in efficiency can lead, apparently, to a pay-back of the entire UPS hardware in less than 3 years - but only if it's realised in practice!

How can a manufacturer improve the efficiency for the data-sheet?	How can a manufacturer find the 'guaranteed' efficiency for the customer?
To publish the best possible UPS efficiency in a 'general' data-sheet certain steps can be taken to minimise the losses, each adding a small amount of improvement that makes up the final number. Some of these can be 'enhanced' and step over the line of 'ethical behaviour' but, as long as they are explained in detail to a customer, some can be justified:	To publish the 'worst case' UPS efficiency in a 'general' data-sheet can be a risky business but the information can be used to provide to the customer a 'guaranteed' figure that can be contractually relied upon:
• Supply 'nominal' voltage, or even an input-voltage that is a little on the high-side	• Supply the UPS with the 'minimum' voltage that the rectifier can accept
• Test with a resistive load and unity power-factor, although sometimes an inductive load of PF=0.9 can suit the machine better	• Test with a load that best represents the load in reality - non-linear with a slightly leading (capacitive) power factor
• Disconnect the battery, so as to eliminate any DC-bus losses	• Connect the battery, so as to take into account DC-bus losses on minimum rectifier input voltage
• Ensure that the machine starts from 'cold', is tested quickly and the cooling air is well below the 'nominal' 35°C (the colder the better)	• Ensure that the machine has reached full operating temperature before the test begin and supply with cooling air at 35°C
• Carefully select switching components, as a wide losses tolerance-band generally applies to most fast switching semi-conductors, and magnetic components	• Use switching components and magnetic components straight from the normal production line
• Only test the most basic configuration (*for example a 6-pulse rectifier without a filter on a 600kVA machine &/or disconnecting a redundant fan or power-supply to lower the parasitic losses from 'features'*) and publish the 'generic' figure	• Test the most normal configuration (*for example a 6-pulse rectifier with a 5% filter with redundant fan and power-supply to include the parasitic losses from 'features'*) and publish the 'actual' figure
• Add the maximum allowable tolerance (e.g. 10% of the total losses) and, if possible, round-up the answer to the nearest half digit at one decimal place	• Deduct the maximum allowable tolerance (e.g. 10% of the total losses) and round-down the answer to the nearest half digit at one decimal place

Comparisons?

Let us review how one, entirely white-brand, machine could have two, very different, published efficiency figures:

Test topic	Worst case	Best possible
Nominal starting value	93.50%	93.50%
Input voltage	-0.20%	0.20%
Load characteristic	-0.30%	0.10%
Battery	-0.05%	0.05%
Test temperature	-0.05%	0.10%
Optimised components	0.00%	0.10%
Base configuration	0.00%	0.25%
Sub-total	**92.90%**	**94.30%**
Losses tolerance	-0.35%	0.29%
Total with tolerance	**92.55%**	**94.59%**
Rounded & published	**92.5%**	**95%**

The most interesting feature of this type of table is that we immediately see that for any given machine we have three efficiency figures that 'could' be published:

- Guaranteed 92.5%
- Nominal, Base 93.5%
- Best Possible 95.0%

How the client, or the OEM, views these alternatives is a very subjective matter. The most important conclusion is that the efficiency can be measured and interpreted in a variety of ways (until mandatory International Standards are introduced) and each request for the data should be treated with due care and attention.

For example it is not true to say that a UPS runs all its life at minimum input voltage and maximum inlet temperature and so the 'guaranteed' figure is far too pessimistic - but it is vitally important to size the UPS cooling plant to cope with that 'disaster' scenario.

Reputable manufacturers, such as Chloride, have traditionally published the 'Guaranteed' figure, the lowest of the three, and the 'nominal' figure should be taken into account when TCO calculations are carried out - generally a full 1% higher. It is not recommended to use any 'best case' figures for TCO or plant-room heat-capacity planning.

Is that the end of the story? No. We have two issues to consider before ending:

Partial Load

Hardly any UPS systems run at 100% load and those that are in N+1 or 2(N+1) redundant configurations rarely exceed 30% load per module.

The partial load efficiency (at either 70% for most Tier I-III systems or 30% for most Tier IV systems) is the critical operating and calculation point.

The (mis)use of the phrase 'up to'

We saw that three different efficiency figures can (with some stretching of the facts) be applied to one machine. In fact there are (for most manufacturers) four efficiency figures, not three - since most series-on-line (double-conversion) machines can run in 'economy' mode with the load on the bypass and the inverter ready to have the load transferred if the mains power deteriorates. In this mode the machine efficiency is typically 97-98% and is useful for loads that require continuous voltage but not computer-grade fidelity. It also counters the off-line or line-interactive efficiency claims by correctly pointing out that efficiency must be higher when the level of protection is lower.

However, if the load can run on a line-interactive type of power system then 'up to' is perfectly permissible. Therefore, for the client, the term 'caveat emptor' applies to data-sheets that state 'efficiency up to 98%' without further qualification or explanation.

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