White Paper 11 | 2010

THE GREEN APPROACH TO ELECTRICAL POWER AVAILABILITY

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INTRODUCTION

“The concept of Green is a marketing invention”. This statement more or less embodies a widespread belief that marketing is solely capable of creating or inventing necessities which do not exist. So how can such an empty concept persist for so long, mobilising governments, manufacturers and consumers?

The aim of this analysis is to clarify the environmental impacts of high-availability architectures, illustrating the basic concepts.

ALL DOWN TO THE KYOTO PROTOCOL?

The Kyoto protocol is an international treaty on global warming signed in Kyoto on 11 December 1997 by more than 160 countries. This treaty requires all signatory nations to reduce their emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride over the 2008-2012 period.

The overall objective of the treaty is to cut emissions by 5% of 1990 levels. Taking into account the sustained increase in greenhouse gas emissions over the years, this reduction amounts to around 10% of 2003 emission levels.

However, the Kyoto Protocol's sole aim is to limit global warming. The burning of hydrocarbons also produces extremely harmful and polluting substances: carbon monoxide, sulphur dioxide, nitrogen oxide and the famous PM10 (particles of less than 10 microns). These substances in the atmosphere combine with water vapour in clouds to form sulphuric acid and nitric acid, which fall back to earth in the form of acid rain.

Acid rain threatens our artistic heritage and does irreparable damage to vegetation. Causing areas that were once fertile to dry up, while rivers and lakes undergo serious biochemical alterations which kill off algae and fish. Acid rain even threatens our artistic heritage, deteriorating marble and cement and corroding metal.

To give some idea of the scale of this threat, 42% of European electricity production is derived from the combustion of fossil fuels.

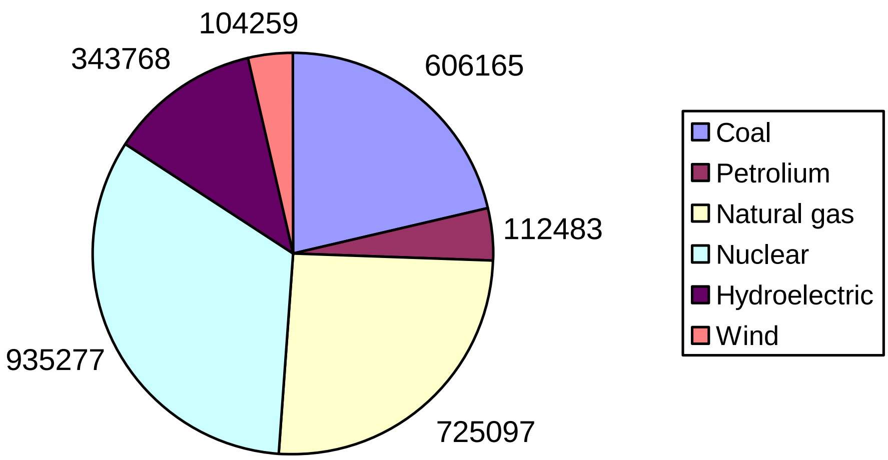

Figure 1 – Source of EU 27 Electrical Energy - 2007 [GWh]

THE EXTENT TO WHICH ELECTRICAL POWER QUALITY DETERMINES SYSTEM EFFICIENCY

In order to be considered high-quality, electrical power it must first and foremost be available, e.g. in a form that can be used by the consumer. Furthermore, physical characteristics such as the power factor and harmonic content can make the difference between a well-designed, fully-utilised system and one which is poorly designed and inefficient.

The environmental impact of an electrical system is not limited to its operating efficiency, but starts with a suitably dimensioned design and continues with regular preventative maintenance.

For example, excessively low power factors within the system, even if corrected before connection to the distribution network, entail the use of unnecessarily oversized cables and the wasting of raw materials such as copper, PVC and even the fuel needed to deliver these materials.

The following example clarifies these ideas. A conventional 6-pulse SCR rectifier draws current with 32% harmonic content and a maximum power factor of 0.9. By contrast, the latest-generation rectifiers based on IGBT and inverter topology maintain harmonic content below 3% and power factors above 0.99.

Supposing that such rectifiers supplied a 30kW three-phase load and that they in turn were supplied by 4-wire PVC cables fixed to walls, these cables would have to be 16mm^2 in diameter in the case of SCR technology, and 10mm^2 in the case of IGBT technology.

For a 20m conduit, this difference translates into approximately 4.3kg of copper which, transported 100km by road, causes the unnecessary emission of around 1 kg of CO_2. The implications are apparent considering that a one-year old tree absorbs approximately 2kg$_{CO2/year}$.

This is without taking into account the costs of extracting and transforming or recycling the copper.

THE BENEFITS OF UNINTERRUPTIBLE POWER SUPPLY SYSTEMS

The aim of uninterruptible power supply (UPS) systems is to guarantee the quality of electrical power. Having established this, it makes sense to find a UPS which does the job efficiently without generating direct or indirect waste.

By guaranteeing the availability of electrical power to the system, modern UPS systems with an IGBT rectifier can be the best solution. These models are ideal, in that they act as a linear load with a unity power factor. Not only do they decouple the load and its electrical characteristics from the supply network, but they contribute to bringing the total power factor of the system closer to the unit (Figure 2).

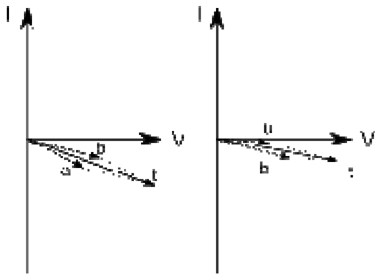

Figure 2 - Comparison between total system currents (t) in the case of both loads directly connected to the power supply (left) and with load (b) supplied by UPS with input power factor of 0.99 (right)

A further consideration is that, like all machines, UPS have their own efficiency rating which changes according to load levels. For example Figure 3 shows the efficiency curves of two different UPS. Note that given the same efficiency at full load (96%), at 50% S_n they can differ by as much as two percentage points. In the specific case this corresponds to a 37% increase in losses.

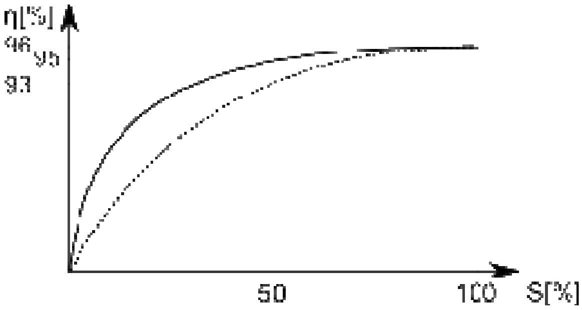

Figure 3 - Examples of UPS efficiency curves

Efficiency [%]	95		93	
	Electrical losses	Air conditioning	Electrical losses	Air conditioning
Annual losses [kWh]	13800	4600	19800	6600
CO_2 emissions [kg]	8400	2800	12000	4000
Trees needed [-]	1400	470	2000	670
Total trees[1] [-]	1870		2670	

Table 1 highlights the environmental impact of the UPS systems in Figure 3 used to supply our 30 kW load.

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Table 1 - Impact of UPS efficiency on CO_2 emissions (UPS operating 24/7, 365 years of the year)

Furthermore, due to the previously highlighted reasons linked to transportation, a compact and lightweight UPS system will have less environmental impact than one which is cumbersome and heavy.

[1] Refers to a five-year old broad-leaved tree.

THE IMPACT OF HIGH-AVAILABILITY ARCHITECTURES

When the application demands lower costs or safety risks, it is necessary to opt for redundant system architectures. For a 2N architecture, Figure 4, it can be assumed that the load of the individual UPS, due to load margins and divisions, will not exceed 30% of the nominal load.

Figure 3 once again helps us to understand that efficiency at partial loads is at least as important as full-load efficiency.

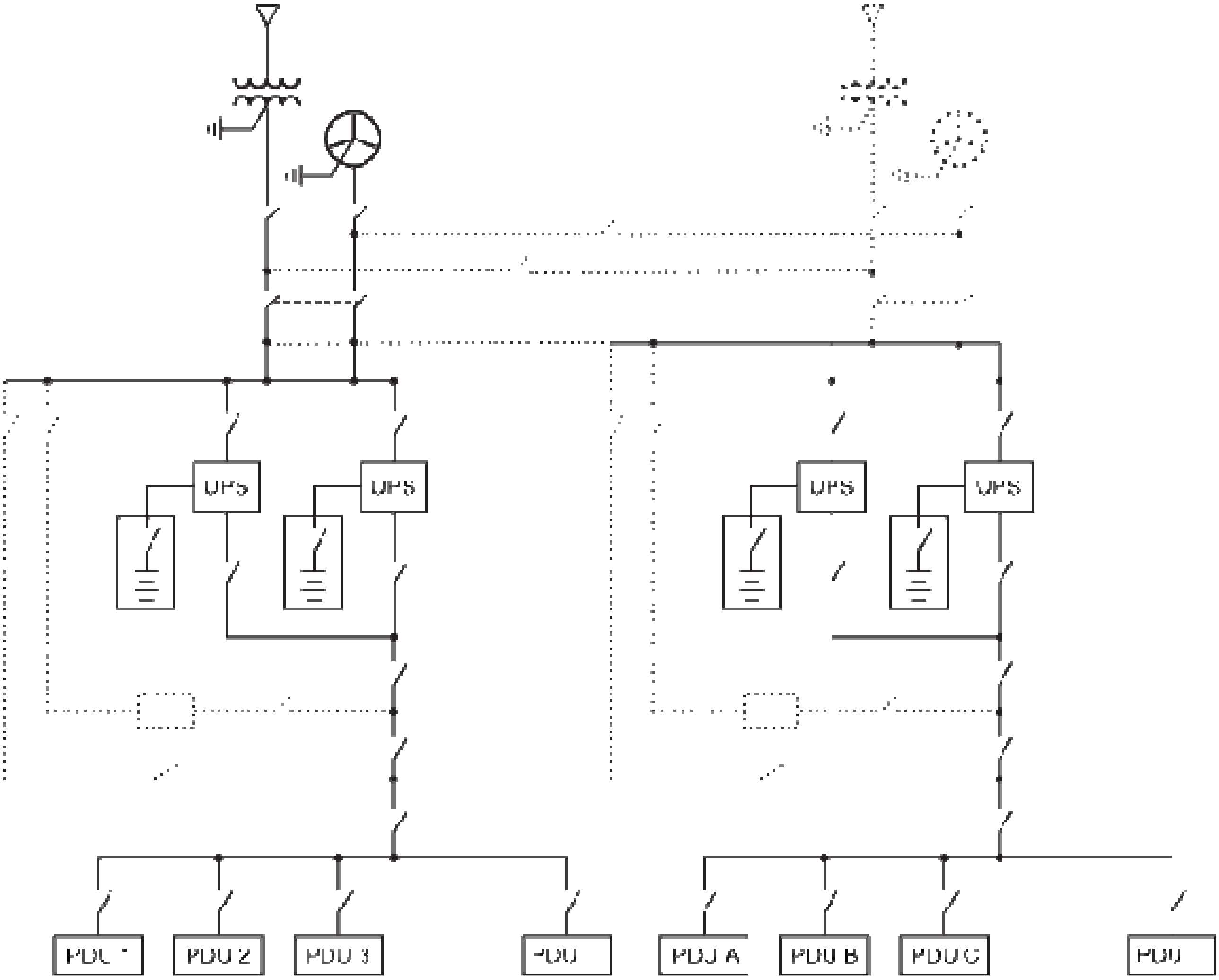

Figure 4 - 2N Architecture

ENERGY STORAGE ALSO PLAYS AN IMPORTANT ROLE

Lead-acid batteries are the means of storage most commonly used by UPS systems. Long-term exposure even to minimum quantities of lead can cause damage to the brain and kidneys and can impair the cognitive

development of children. Sulphuric acid, which is also used in lead-acid batteries, is responsible for all of the above-mentioned environmental problems linked to acid rain.

This is why old UPS and batteries should always be returned to the UPS supplier or disposed of directly by specialist recycling companies. An even better option is to install solutions that maximise the life of the accumulators. In fact battery life is linked to the ambient temperature of the installation site, Figure 5.

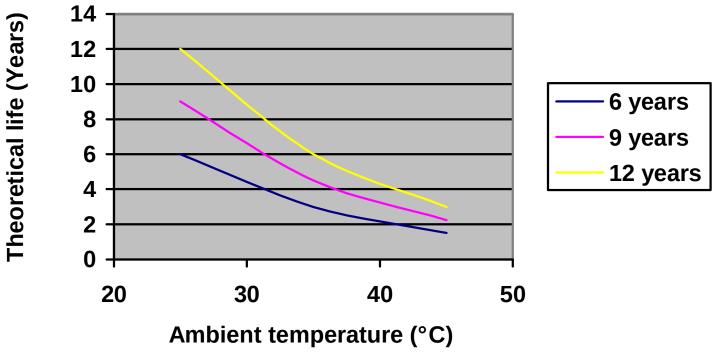

Figure 5 - Dependency of theoretical battery life on ambient temperature

Furthermore batteries are extremely sensitive to the amount and type of usage: charge and discharge cycles, discharge depth and current, charging method, etc. Therefore it is advisable to choose a UPS system with, among other things, a very stable, temperature-dependent charging current, with control systems to identify damaged elements which would cause overload of healthy elements and rectifiers with a wide input tolerance range, so that batteries are used as little as possible.

Currently the greenest and most industrially available alternative to batteries is the flywheel.

A flywheel caused to rotate about its own axis without translation stores energy according to the formula:

$$E = \frac{1}{2} I\omega^2$$

where:

- E is the energy stored by the rotating body;

- I is the inertia, which depends on the form and linearly on the mass of the body;

- ω is the angular velocity.

It can therefore be affirmed that energy is linearly proportional to mass and proportional to the square of rotation speed.

this means that twice the mass corresponds to double the energy stored and that twice the speed makes for four times the energy stored.

There are basically two types of flywheel on the market: those for which energy

storage is based on mass and those for which it is based on speed.

They can respectively provide 1-2 MW and 1 MW of back-up power for up to 30 seconds.

Typically the efficiency of high-speed flywheels is higher since the bearings supporting the flywheel, due to its limited weight, are magnetic rather than mechanical and because the flywheel rotates in a vacuum cylinder, thus reducing friction and viscous damping. In all cases, the absence of mechanical bearings noticeably reduces the need for maintenance.

Flywheels are useful when the UPS is required to provide enough ride-through time for a generator to

transfer, or to eliminate severe harmonic pollution from the electrical power supply.

One of the benefits of flywheels over batteries is that they are eco-compatible.

Battery life is noticeably reduced by the memory effect, long-term capacity loss and sensitivity to ambient temperature. These issues do not affect flywheels, which means that they are particularly suited to "green" applications.

As well as the ecological benefits, there is also the advantage of increased energy availability, since flywheels recharge in minutes whereas batteries typically require hours to fully recharge.

In addition, flywheels are characterised by high power density, as shown in Figure 6..

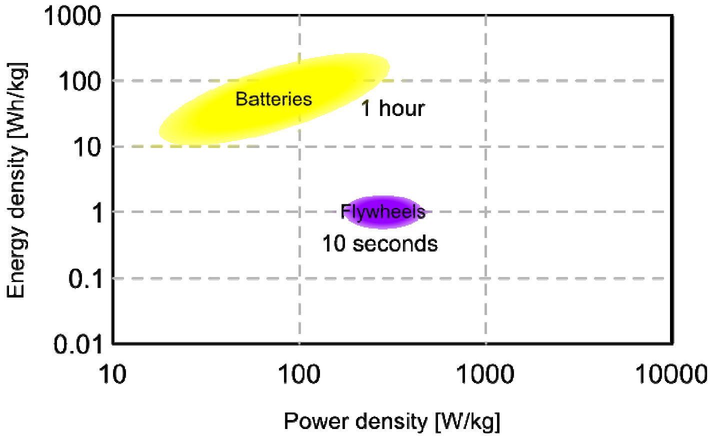

Figure 6 - Energy comparison between batteries and flywheels

Last but not least, flywheels can be installed in place of batteries or even in parallel with

them on the DC BUS.

The advantage of a hybrid battery/flywheel energy storage system is that in the event of micro-interruptions

the flywheel is able to supply the energy needed by the system, whereas the batteries are only required for outages lasting longer than 10 seconds, thereby extending the life of the accumulators.

THE BEST CHOICE

A well-designed system is one that achieves the best compromise between cost and benefit, based on an effective exchange of information between buyer and supplier.

Before choosing an UPS and system architecture it makes sense to consider downtime costs and the environmental impact that your system may have.

In practical terms, if estimated downtime costs linked to the useful life of the system exceed costs derived from the complexity of the system, it's worth asking yourself whether you are making the right choice. Even the European Code of Conduct for Data Centres advises that 2N architectures should only be utilised when strictly necessary.

Ultimately, however, the decision of whether or not to go green is determined by personal preference and operating cost savings.

In both cases, the UPS supplier will aid the right decision based on the needs and requirements specified.

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White Paper – 11/2010

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