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Voltage Power Optimisation (VPO)®
The Hidden Cost of Over-Voltage

Most energy efficiency measures have focused on reducing demand at the point of consumption. A wealth of new, more efficient drives and motor controllers, low energy lighting and building management systems means the choice for end users seeking to manage their electricity consumption has never been greater explains Alex Rathmell, head of analysis at **powerPerfector** Implementing the disparate measures mentioned above and sustaining the energy savings can be a challenge for energy managers in a complex workplace, with many control-based energy saving measures relying on goodwill or good behaviour from the workforce to keep them effective, and many measures posing the threat of serious disruption to the working day, or complex technical challenges in implementation.

In this context, the effect of poor power quality is often overlooked both as a problem and an opportunity. Until recently, power quality was not considered to be a major source of inefficiency in electrical equipment, as the UK had historically enjoyed a relatively clean power supply compared to many countries. Now though, several factors have conspired to make tackling power quality an attractive energy saving measure, and one of the quickest and easiest wins in the energy manager's tool kit. By cleaning up the supply, energy savings are immediate, permanent and transparent - that is they are achieved without affecting daily operations and without being dependent on the vagaries of human behaviour.

The breakthrough has come with the recognition that the UK's power supply is no longer optimal. Generally when we plug in to the mains supply we don't give a second thought as to how the voltage level might affect the efficiency of the electrical equipment we connect. We know that in the extreme, when the voltage is far too high, light bulbs glow brightly and blow with alarming regularity; whilst with very low voltages, TVs flicker and motors over-heat. Yet there is a broad band in between these extremes where the effects are more subtle, though very significant in terms of energy efficiency and the longevity of equipment.

Following European harmonisation in 1995, the declared electricity supply in the UK became 230V nominal, +10% to -6%, so supply voltage could be anywhere between 216V and 253V depending on local conditions. The European standard covering the UK (EN 50160:2007) now says that the permissible range is 230±10%, making 207V the minimum level at which UK equipment must operate. Most electrical equipment, designed to work for the whole European market, actually has an optimum operating level of 220V, as this was the nominal supply level prior to 1995. Yet in practice over 90% of sites in the UK continue to receive voltage at the historic average level of 242V - and will continue to do so because the design of the supply infrastructure cannot easily be changed.

The grid is designed to accommodate a certain degree of ‘volt drop' across a geographical area, so a small percentage of consumers connected to remote or dense parts of the network are already operating towards the lower end of the permissible range. Unilaterally reducing voltages could therefore take these consumers below the minimum level. The only solution is for the vast majority of users to be supplied at the upper end of the range (an approach that also minimises I2R system losses), so we routinely supply our equipment at over 20V higher than its optimum supply level, wasting huge amounts of energy in operating plant and equipment. In addition to this grid design limitation the connection of various new renewable resources such as wind to comparatively weak points in the grid is expected to have the effect of increasing voltages locally even further. So at a time when an increasing proportion of our equipment needs a lower voltage, our commitment to renewable power may actually elevate voltage and inadvertently increase energy use.

The only real way to address this issue is to optimise the voltage locally, to ensure site-by-site that energy using equipment is receiving the correct voltage, maximising its efficiency and its lifespan. Of course, customers with their own HV transformer have a certain degree of control - they can typically adjust their voltage by up to ±5% by altering their transformer's tap settings - but this doesn't constitute optimisation in any meaningful sense of the word. Reducing a 242V supply by 5% gives us 230V, still 10V higher than the optimum level so there is a substantial missed opportunity for savings.

Just as average voltage levels remain high or creep upwards, other factors are contributing to a deteriorating power quality picture in the UK to which engineers are having to adjust. As well as potentially increasing average voltage levels, the introduction of diverse but intermittent generating sources into the mix leads to more switching on the grid, increasing incidents of ‘transient' voltages and other distortions that can damage sensitive electronic equipment and cause nuisance tripping. Levels of harmonic distortion are also at historically high levels, not least due to the ongoing replacement of older linear equipment with more efficient non-linear loads such as high frequency electronic ballast lighting, and huge numbers of inverter drives. These technologies should be applauded, but raising levels of harmonic distortion dramatically increases losses in a power system.

However these new realities do not mean tackling the UK's most prevalent power quality issues need be a formidable technical challenge. While serious or unusual problems should always be dealt with using bespoke solutions, a ‘common sense' approach to power quality can be applied to any site where energy savings are needed. This approach is to optimise the voltage at the source of the building's power supply, to ensure it is well matched to the electrical equipment, while taking the opportunity to protect the site from grid-borne transient distortions and reduce losses by filtering harmonic distortion and improving power factor.

Fortunately, these twin pressures of deteriorating power quality and the need to improve energy efficiency have been experienced before - in Japan, nearly twenty years ago. At the time, Japan had the same pressures on fuel and energy prices that we have today, as they have to import all of their fuel requirements and rely on expensive nuclear generation. As a result attention was focused on the incoming supply to a building, on its voltage level and quality, as a way of achieving further incremental energy savings in a country where the need for efficiency is deeply embedded in working culture. Technology known as ‘Voltage Power Optimisation' (or ‘VPO') was developed specifically to save energy by optimising supply quality, dealing with the most prevalent power quality problems in a device that can be fitted ubiquitously, as a permanent part of every site's electrical supply infrastructure. The technology must add neither risk nor additional energy use to the site, so total reliability and extremely high efficiency are key elements of the design of VPO equipment. These requirements, as well as the need for additional power quality improvements, mean that conventional automatic voltage regulator technology with its reliance on moving parts and electronic control systems is not appropriate for at-source applications - the development of VPO represents a new approach.

There is an even greater opportunity for VPO technology in the UK than in its home country of Japan, because the voltage supply parameters there are 90-110V, which is adjusted by -2%, -4% and -6% by the implementation of VPO. This approach - essentially correcting for local problems on the grid and targeting the voltage at the optimum level for equipment operation - has saved millions over a period of many years. In the UK, meanwhile, our institutional problem with over-voltage means that not only can a higher proportion of sites benefit from optimisation, but the savings delivered in each case are substantially higher than those seen in Japan. Even on an efficient site with modern lighting and inverters fitted to its motors, savings of 4-8% are typical, while a site with a high proportion of older equipment is likely to experience 10-15% savings in many cases. This means the technology will pay for itself in 2-4 years, making it a popular choice for energy managers confronted with CRCEES obligations and the looming threat of widely-predicted energy price increases.

Optimising power supply at source is a way of harvesting a number of different opportunities for savings across a diverse range of plant and equipment. The savings seen on the main meter are an aggregate of a range of different effects - some dramatic, some subtle - across the whole site. Technically, most savings are realised in induction motors and lighting equipment. Optimising the voltage to a motor essentially means giving it a supply that is appropriate for its loading point. An average motor is both over-specified (and therefore lightly loaded) and, in the UK at least, supplied at an over-voltage. So losses can be reduced by bringing the site voltage to a lower level without affecting the motor's operation. Lighting benefits by being returned to its 'design' voltage and brightness, so both current and power is reduced and lamp life is increased substantially. In fact, almost all equipment will benefit from extended lifespan if provided with an optimised power supply, adding a tangible maintenance cost reduction benefit to the available savings.

Increasingly, energy managers are finding that addressing power quality issues at source is one of the highest performing and lowest impact tools at their disposal, and the take up by major retail, governmental and public sector organisations confirm that VPO is among the most attractive energy saving measures on the market. This reflects the growing realisation that poor power quality is wasteful, and its correction presents an invaluable opportunity for energy savings.