VOLTAGE OPTIMISATION

Is the trend of using voltage optimisation in the home justified?

Despite having a national grid, regional variations in UK supply voltages provide an opportunity for energy savings

By James Hunt

VOLTAGE OPTIMISATION (VO) is a decades-old technology, offering potential benefits in terms of power savings, reliability and total cost of ownership. Well-established in the commercial sector, VO equipment is increasingly being promoted in the domestic market. The push to sell VO into the home, coupled with the increasing number of companies selling VO equipment, makes this a particularly good time to ask: does VO work?

The best answer is a qualified 'yes', but not for all types of load, nor for all applications. Properly applied VO can result in significant savings; applied incorrectly, it can be a waste of money.

If low-voltage (LV) electrical equipment is operating at higher than its designed voltage, losses occur, resulting in more energy being consumed than necessary. Many loads may also overheat. Certain electrical appliances and machines operate more efficiently when the supply voltage is regulated and stabilised. Yet supply voltages often vary considerably from place to place and from time to time.

Electricity supply companies in the UK provide an average incoming voltage to users of 242V, but it is not uncommon for 250V to be exceeded. Moreover, 242V is higher than that required for optimum use of plant and appliances, which is specified by the Electricity Safety, Quality and Continuity Regulations (ESQCR) and the IEC 60038 at 230V ±10% This is considered a suitable voltage to ensure correct operation, and all CE-marked electrical equipment should work safely within this range.

Reduce the voltage

This voltage mismatch can cost significant amounts of money, reduce equipment life and reliability, and needlessly add to CO_2 emissions. Avoiding the mismatch is the reason for choosing to use VO, which needs little or no maintenance or monitoring. VO units optimise the voltage for maximum appliance/equipment efficiency and some may filter out spikes and harmonics to provide a smoother power supply. This provides a good operating environment for electrical equipment and enables certain loads to use less electricity. For example, a 230V lamp (depending upon the lamp technology) run at 240V typically consumes 9 per cent more energy, yet has its expected lifetime reduced by around 45 per cent.

The claim is that VO can allow electrical equipment to operate at optimum efficiency, lowering energy bills, extending equipment life, reducing maintenance and cutting the carbon footprint. Installing VO technology should allow a significant reduction in energy bills when applied to sites with well-suited loads.

How VO works

The voltage reduction is achieved in two main ways:

Fixed ratio step-down transformer. Most buildings/sites run happily at around 220V phase-to-neutral, achieved using a fixed ratio step-down transformer having pre-determined tap settings. Alternatively, the voltage tap setting on the incoming transformer can be adjusted (if not shared) to reduce the supply overvoltage.

Businesses having their own dedicated LV transformer or substation effectively have VO already, and it is only necessary >

to re-adjust the ratio between incoming and outgoing voltages. Typical voltage reductions might be in the range 3 to 12 per cent, depending on the site.

The benefits of this basic, long-established technology include better energy consumption and longer equipment life. As it is relatively cheap to buy and simple to install, the return on investment (ROI) should be between one and five years, depending upon the application. However, the disadvantage is that any change in input voltage will result in a fixed percentage change on the output, resulting in a fluctuating output voltage that does not deliver the maximum potential energy savings.

Voltage regulator. This last difficulty can be avoided by using a voltage regulator (sometimes called a 'voltage stabiliser') on the incoming supply that controls the output to an adjustable set level, while each phase is independently controlled to balance the output voltages. This is important for improving motor efficiency. The elimination of fluctuating voltages should provide extra savings, so despite a voltage regulator costing more than a simple step-down transformer, this option is often preferred where the site voltage is erratic. It can reportedly provide energy savings of 10 to 35 per cent, depending upon who you talk to.

Some voltage regulators are ferroresonant-transformer (constant voltage) based, while others are essentially electronic. They work by continually comparing the incoming voltage to that needed to drive the loads. If the supply voltage is too high, a second wave is added anti-phase to subtract exactly the necessary voltage.

If the supply voltage changes with time, fixed ratio step-down transformers and voltage regulators will behave differently; the former will provide the output according to a fixed reduction, while the latter will correct to its setpoint voltage as long as the input is within range.

Installation

VO units are typically installed in series with the mains electrical supply to a building, but note that not all VO units service all downstream electrical equipment – some may be only connected to specific circuits. This is certainly the case in many domestic applications, where some circuits are isolated from certain VO units. Generally, with domestic installation, the VO unit will be installed alongside the consumer unit or fuse box, and it will regulate the voltage to the circuits where energy savings can best be made.

VO benefits with load type

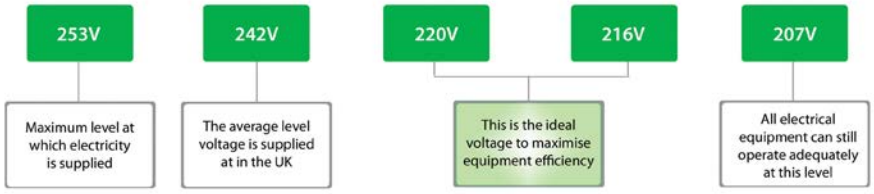
Can VO savings always be made? To quote the Carbon Trust: "prospective customers should understand the limitations as well as any potential benefits before investing in the technology." The Carbon Trust operated a very successful interest-free loan scheme for energy-saving projects a couple of years ago, and many organisations took the opportunity to install VO using this funding stream. All agreed projects had to be justified and independently verified by the Carbon Trust prior to funds being agreed.

Even so, while it is sometimes said that virtually all sites can benefit from reducing and controlling the voltage, some companies will not recommend VO for duties that offer only marginal potential savings. Unfortunately, the evidence is that VO is being promoted by some organisations as a panacea for every conceivable application; this is spoiling the market.

What are the electrical loads that matter? From a VO perspective, there are two main types: inductive and resistive. These react differently to VO, so typically benefit in different ways:

Inductive loads – Such loads include electric motors, which are often oversized so effectively operate under partial load. This reduces efficiency. Moreover, when running at 230V or over, internal losses can result in further reductions in efficiency. Such motor-driven equipment, like refrigerators, pumps and compressors, generally allows good savings with VO.

Using VO brings the following benefits for inductive loads: greater



Voltage variations and the scope for savings

CASE STUDIES

TOWN AND COUNTRY

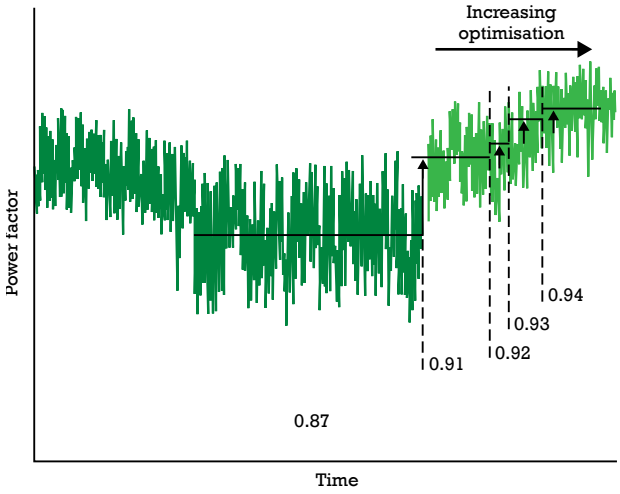
Commissioning a commercial VO system from Marshall-Tufflex

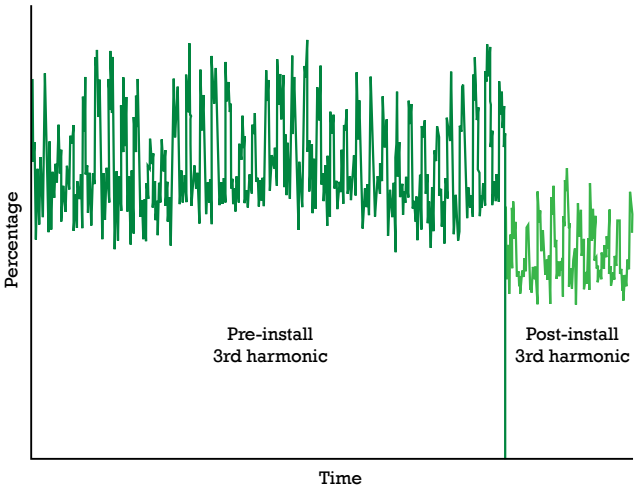
Reigate & Banstead Borough Council is addressing its carbon management programme in a number of ways, including the installation of Marshall-Tufflex Energy Management Voltis VO units. The first of these, a 300A system, has been installed in Reigate Town Hall where it is returning electricity savings of 9-10 per cent. A second 300A unit is to be installed in the Harlequin Theatre, Redhill. The council is also considering a third installation into a leisure centre.

Environmental initiatives officer Raymond Dill: "We had looked at VO previously but were uncertain whether it worked. My view now is, don't hesitate to put VO in at the first stage of any carbon reduction programme. Other initiatives such as energy saving lighting may lessen the impact of VO, but by the time you have installed them you will have already made significant savings."

Other case study examples

VO technology has benefited a recording studio located in the countryside, where the unstable power supply put expensive equipment valued at over £200,000 at risk. This is using a VO unit by VO4HOME to help successfully balance the power supply and improve power quality. A similar unit by the company is being used to reduce the voltage to a flat in Fulham, where overvoltage was causing expensive appliances to shut down. One farmer too has benefited; his milling machine was rendered useless because of high voltages and spikes, but the VO unit has brought the required voltage stability to the farm.





efficiency; a better power factor; and a better motor working point on the magnetic hysteresis curve (which reduces internal losses). Note that VO will not make worthwhile savings powering motors driven by inverters and variable speed drives (VSDs) – increasingly the case for motors of any significant load.

A fluorescent lighting ballast is another inductive load. It is common for building owners and facilities managers to try to save money by removing older fluorescent lighting systems and replacing them with energy-efficient HF (electronic ballast) lighting or LED lighting systems. With the right control gear, such modern lighting can save large amounts of energy. Some say that VO cannot be successfully used with modern HF lighting and many LED lighting products. However, an EA Technology report (see panel 'VO and lighting', p34) indicates that dropping the voltage to 220V provides good savings on incandescent, fluorescent, CFL and certain LED lighting – even though in some cases light levels are reduced, but not always to a noticeable level. In reality, says VO provider Marshall-Tufflex, all that the VO is doing is bringing the light level down to what the fitting was designed to run at (220 to 230V preferred supply level in the EU under the CE mark).

The best potential for saving with lighting is with older incandescent, fluorescent or discharge lighting using conventional control gear, so elderly commercial and office buildings are likely to benefit most. However, before rushing to install VO, it's important to

Interior of powerPerfector Plus commercial VO equipment

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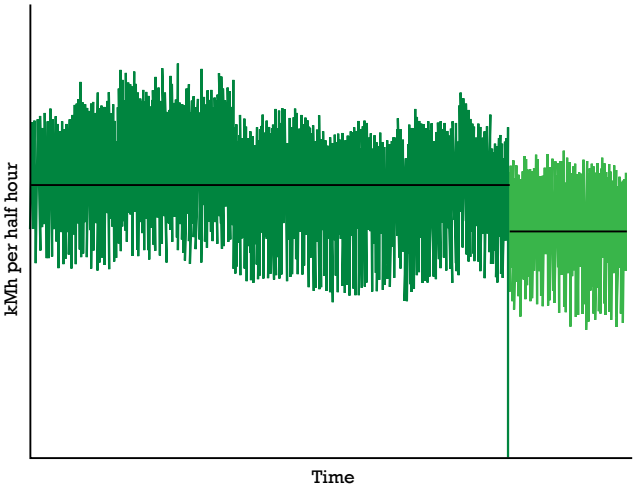


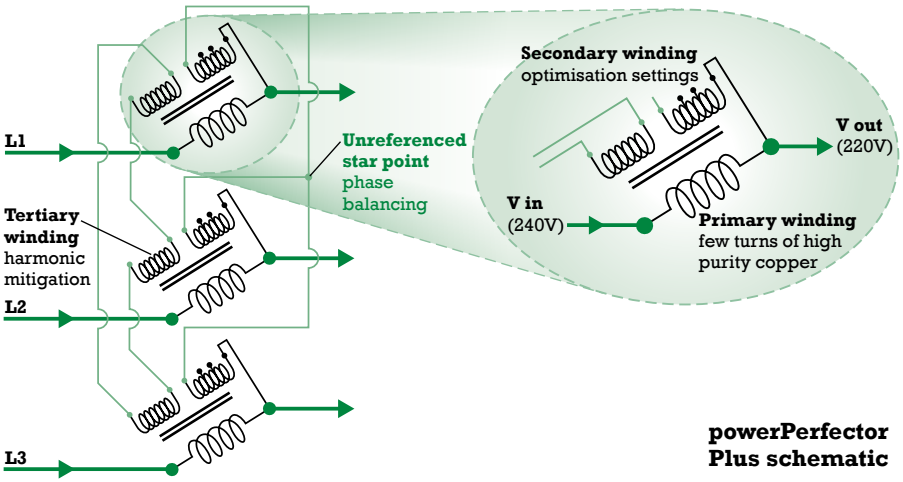
Voltage optimisation can improve power factor, reduce harmonics and save energy

determine whether switching to a more modern lighting solution might not be the more cost-effective option. Note that some VO units can filter out the high total harmonic distortion (THD) generated by HF lighting ballast and control gear, which is another consideration.

Resistive loads – This is Ohm's Law territory, with its simple linear relationship between voltage and power (Power = Voltage^2/Resistance). This is fundamentally important, as it suggests that if the voltage is reduced, the power taken will reduce as the square of the voltage. The result is a saving of energy. For an ideal, purely resistive load, dropping the voltage from 242V to 220V would give an energy saving just over 17 per cent. In the real world of non-ideal loads, savings of will be less than this – typically 11-13 per cent.

VO also helps resistive loads extend equipment life. For example, some lamps are resistive, so their energy consumption is improved and operating life extended using a stabilised voltage output. This can greatly reduce lighting maintenance and lamp replacement costs. Recent tests conducted by EA Technology even showed that savings of around 8 per cent could be made on certain LED lights by dropping the voltage to 220V – with only a 1 per cent loss in lumen output.

VO is not worthwhile for certain types of heating. An example is the humble electric kettle. Any voltage reduction >



powerPerfector Plus schematic

will require the kettle to be on for longer. The same is true for thermostatically-controlled space or water heating systems.

Other loads that cannot achieve a worthwhile VO energy saving include switch-mode power supplies, typically used to drive office and domestic electronic equipment. These use the same power as previously, but will draw a slightly greater current, resulting in slightly greater cable losses and possible circuit protection device tripping. With constant power devices having a wide input voltage range, reducing the voltage increases the current, so savings are negligible.

However, equipment life is usually extended, and it is claimed that this may make it cost-effective to install a VO unit, even where the loads themselves are not conducive to energy savings On any site, the higher the ratio of inductive loads to resistive loads, the larger the potential savings will be.

Does VO work domestically?

One study ('The Effects Of Voltage Variation on the Power Consumption and Running Cost of Domestic Appliances', GK Hood, School of Science and Engineering, University of Ballarat) has examined how voltage variation affects the power consumption and energy cost of a domestic household. Various inductive, resistive and electronic domestic appliances were subjected to normal voltage variations and their power and energy measured and analysed. The results indicated that that voltage variation from the consumer's point of view has minimal effect on the cost of electrical energy. This result, if correct, would tend to suggest that for consumer use, VO might not be justified purely for saving energy.

In short, VO equipment installed at home may save a relatively small amount of energy, but may also make lighting dimmer and the electric shower a little less hot – but this is highly dependent on many factors. For example, some types of lighting will not noticeably reduce light levels, and appliances such as fridges and freezers that are constantly on and use motors, can contribute good savings. Most domestic premises whose mains voltage is currently above 240V should save between 8 and 13 per cent (depending upon the user profile). The Energy Saving Trust provides interesting figures on the typical annual cost of household appliances, some of which can and do provide savings with VO.

Note that Marshall-Tufflex, which makes VO units for commercial and domestic use, does not support installing a domestic system if the incoming supply is lower than 230V, while a few companies do not support domestic applications at all.

However, Apollo Enviro says that older domestic buildings can certainly benefit from VO energy savings, and may even have a role to play in the Green Deal, the government's flagship energy efficiency scheme. The company believes that optimisation provides a much quicker payback period and greater percentage savings on energy consumption than solar PV. However, VO has not, so far, been included in the list of technologies approved for the Green Deal. Apollo Enviro is hopeful that it will be approved at some stage, and says that the resulting increased demand would reduce VO costs.

Site survey essential

Before choosing a VO unit, it is essential to carry out a technical site survey using instrumentation attached to the incoming supply. The electricity usage data gained should ideally be combined with previous electricity usage statistics gained over a number of months, and examined in terms of other relevant site information.

VO energy savings across any site can be estimated by summing all equipment that responds to voltage reductions and power quality improvements. A site survey must aggregate the potential VO energy savings from the mixture of loads, but loads that cannot benefit must be deducted from the total to provide a realistic estimation of potential energy savings. Finally, a comprehensive report and energy usage strategy should be provided to show any realistic cost savings, so that an accurate return on investment calculation to be made.

CHALLENGING MISCONCEPTIONS

VO AND LIGHTING

LEDs are revolutionising general lighting because they improve environmental footprints and provide more colourful and dynamic lighting with an extremely long life. However, orthodoxy has it that optimisers will not deliver power savings if installed in conjunction with LED arrays. Now, though, a new study by EA Technology ('Appliance Efficacy Study', August 2012, Robert Green, Rhys Roberts & Benedict Rowton) has examined the effect of VO on fluorescent, incandescent, CFL and LED lighting, and the results are challenging this established view. Researchers looked into the effects of supply voltage on LED light output and power use, looking specifically at 220V, 230V and 245V.

EA researchers concluded that data found for LEDs suggested that there is little variation in illuminance when varying voltage. The power consumption, however, is reduced, indicating that potentially a reduction in voltage would provide reduced power consumption without affecting the illuminance experienced by the user.

This study, says VO provider Marshall-Tufflex, could challenge the commonly held misconception that optimisation will reduce efficacy and performance, while delivering only very low savings with LED lighting.