Voltage Power Optimisation (VPO)®

CASE STUDY
The Tower Of London

July 2008

"We have been delighted at the Voltage Optimisation at the Tower of London. Having independently assessed the performance of the technology it was shown to have met the expected savings.

The approach of the team and the other contractors involved has been professional and responsive throughout the project. Bearing in mind the importance of the site and therefore security of supply, we can report the working of the site has been perfect. On the basis of the success at the site we are looking to Optimise our other Historic Palaces."

Tony King , Head of Maintenance and Facilities - Historic Royal Palaces

Historic Royal PALACES

power Perfector
energy saving like no other

In Summary

Description
Installation of 2 x 830kVA Voltage Power Optimisation units

Location
The Tower of London

Benefits
Reduction in electrical consumption; Increased life of electrical equipment; Protection of electrical infrastructure; Attenuation of harmonics; Balancing of the three phases
Improvement of power factor
30+ year product lifecycle

Outcomes
Savings of at least 11% in kWh consumption
Cost saving of £26,555
Reduction in CO_2 emissions of 168 Tonnes

The Tower of London:
Voltage Power Optimisation Project

Her Majesty's Royal Palace and Fortress, better known as the Tower of London, located on the north bank of the River Thames, was originally a royal palace, fortress and a prison for 'high status' prisoners, notably Edward V of England and Richard of Shrewsbury (the Princes in the Tower), and the future Queen Elizabeth I. Since 1303 it has been the home of the Crown Jewels. It has also served over the years as a place of execution and torture, a treasury, a mint and a royal menagerie, among other uses.

The use of the Tower as a strong-hold for battle ceased in 1830, when artillery made fortification obsolete. The last prisoners to be held at the Tower were the Kray twins, Reggie and Ronnie, after they failed to report for National Service.

Nowadays the Tower is a multi faceted site including, museum space, retail, offices, residential and religious facilities. In a sense it is akin to a small town and contains all the associated energy requirements.

Energy efficiency is a priority at the Tower however as a building of historical importance the impact on the buildings themselves and the long term view that is associated with any of the Historic Royal Palaces has to be taken in to account. Voltage Power Optimisation was

identified early on as a means to save significant energy at the site, with very long equipment lifecycle (30+yrs) and minimum physical impact to the infrastructure of the buildings.

Technical Overview

The main feature of a Voltage Power Optimisation unit is its ability to lower the voltage for a whole site, more efficiently than any other technology available, and therefore cut energy costs. This reduces energy bills and improves the efficiency of electrical equipment.

The declared electricity supply in the United Kingdom is now, as a result of European harmonisation, 230V with a tolerance of +10% to -6%. This means that effective voltage can be anywhere between 216V and 253V depending on local conditions. Most electrical equipment manufactured for Europe and the UK is rated at 220V and will effectively operate at voltages down to 200V.

As a result of the equipment specification and the range of voltage supply, there is an opportunity to achieve cost savings by Optimising voltage and at the same time improve the operation and the lifespan of your site's electrical infrastructure.

Barriers Overcome

The Tower of London houses some of the nation's most precious assets. Security surrounding those assets is extremely high and reliant in part on the electrical supply to the building. For any client's building shutting down the site to install Voltage Power Optimisation equipment presents challenges, however this is particularly true of the Tower.

The Tower is run from two supplies and the electrical load for the site is split between those supplies. It is possible however to run the entire site from one of the supplies. In order that the security should not be compromised during the install, the site was kept running from one supply while the installation of the Voltage Power Optimiser was completed on the other and then the same process followed for the other supply.

This required careful planning and coordination of teams from not only the suppliers / installers of the technology and the Tower's staff but also the local electricity company who were required for the shutdown, and the manufacturers of the bus bars, which connected the Voltage Power Optimisation units in to the distribution. All this was done at a time that

would cause minimum inconvenience to the operation of the Tower and allowed a period before the public arrived to test that all systems were functioning normally when the Voltage Power Optimisation units were energised. Consequently the units were installed on concurrent nights at midnight.

The Installation

The Installation of 2 x 830kVA / 1200A units was undertaken at the Tower of London at midnight on the 12th and 13th of February 2008.

As shown in the following section, the electricity consumption (kWh) in the 5 day period following the installation showed an **11%** reduction.

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SAVINGS ANALYSIS

The savings achieved by the Voltage Power Optimiser have been independently analysed by a Carbon Trust approved consultancy. The following is a summary of the savings report produced by Energy Management Solutions Ltd.

Savings Summary

Reduction in kWh consumption (for 5 days post installation)	**11%**
Reduction in average Maximum Demand	**10.5 %**
Reduction in CO2 consumption	**11%**
Projected annual savings	**168 tonnes**

Savings: Introduction

Two pP830 kVA Voltage Power Optimisation units were installed at the Tower of London, one on 12 February the other on 13 February 2008. The following is an analysis of the electricity consumption for the kWh used up to 29 February 2008. It shows the energy used in Supply point 007, meter number P01A00914, 1200010155111 and Supply point 008, meter number P01A00911, 120001015510. These two meters represent 100% of the electricity used within the Tower.

Benefits of installation:

- 11% reduction in the average Demand (kWh for the 5 days following installation of the Voltage Power Optimisers.
- 10.5% reduction in the average Maximum Demand
- 11% reduction in CO2 emissions for the site
- Protection against transients (spikes) that could damage computers and other sensitive equipment on site.

Cost of Electricity*:*
The unit cost of electricity used in this report was 6.8p / kWh. This figure includes all unit costs, standing charges and any climate change levy but is exclusive of VAT. This figure was taken from the January 2008 invoice and is fixed until October 2008.

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Data:
All half hour meter readings for the site as used in this report were provided by Team Energy.
The units were installed during half term period for school. This had the effect of increasing the energy usage in the days immediately after installation due to the increase in the number of visitors to the site. Due to this fact the analysis was carried out after the 18 February which was the last day of the half term period. Similarly all figures for 2007 were chosen away from the 2007 half term period. The energy usage in January 2007 was in general 15% lower than that of January 2008. Due to this act the 2007 figures in the third comparison have been increased by
15% to give a more accurate analysis.

Assumptions:
The report has captured as much half hour data as possible after the units were installed. This was only 5 days of data after the schools' half terms. To provide a more long term analysis it is recommended that this exercise be carried out again when a full year of half hour data is available. This will confirm not only the savings shown in this report, but will also show the savings made across the year. In all comparisons the half hour data for the two supplies have been added together to give an analysis for the whole site. The "Day" used in the comparisons is
taken as 8am to 10pm.

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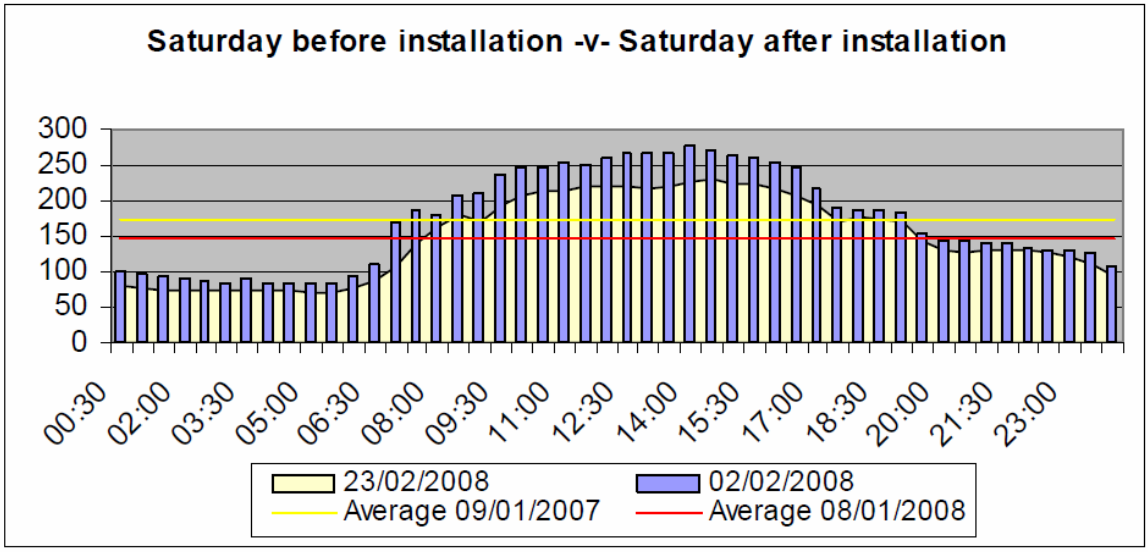
The graph below shows the comparison between Saturday 2 February 2008 (before the units were installed) and Saturday 23 February (after the units were installed).



Degree day Analysis

In addition to the independent analysis carried out by Energy Management Solutions the Voltage Power Optimisation Supplier's Analysis team carried out Degree Day Analysis. This is used to show the expected level of consumption for a given temperature. In the chart below, the red points show kWh consumption per week prior to installation and the green points denote the weekly kWh consumption after installation, with all holidays excluded. They are plotted against the number of 'Degree Days' for each week for the London region.

The Degree Days are based on Met Office temperature data, and give an indication of how hard heating or cooling equipment must work to compensate for exterior temperature. The red line therefore shows the expected level of kWh consumption for a week with a given number of Degree Days. We observe that the kWh consumption is an average **9.9%** below the expected level.

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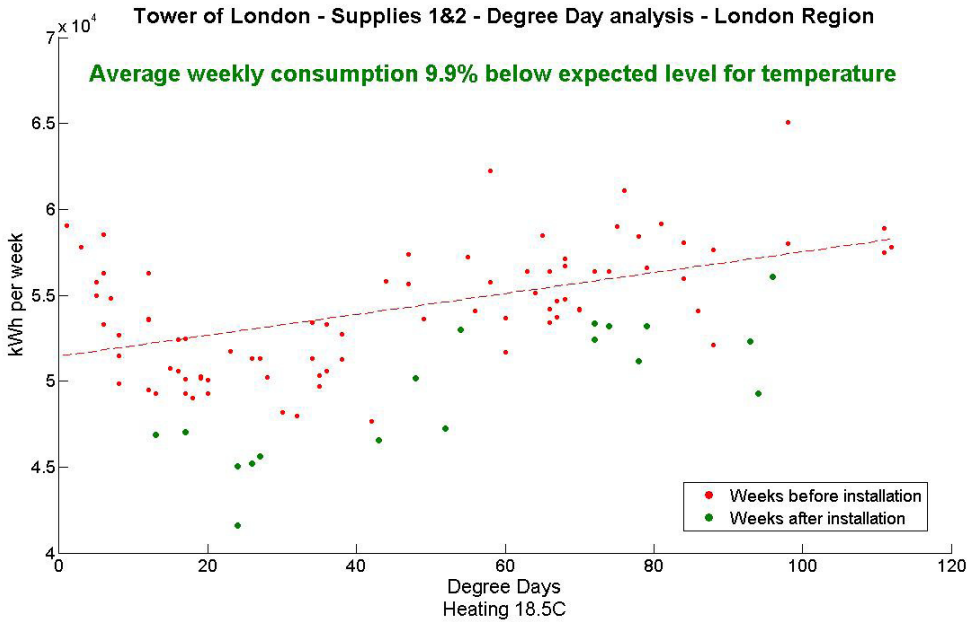

Conclusions

The installation of the Voltage Power Optimisation units at The Tower of London has demonstrated that Voltage Optimisation is a practical and very effective energy efficiency measure, as applicable in historic royal palaces as in modern offices or manufacturing sites.

In response to the success of the project, the team at the Tower of London have highlighted the installation of Voltage Power Optimisation technology as the primary energy efficiency measure that they are going to pursue in their energy reduction strategy and the technology will be rolled out across the Historic Royal Palaces estate, starting with Hampton Court Palace, where the process of evaluation for Voltage Power Optimisation is well underway.

KWh usage	**3,550,214 kWh**	**Saving**	**390,523 kWh**
CO2	**1,526 tonnes**	**Saving**	**168 tonnes**
Annual Saving £	**£ 26,555**	**Saving 5yrs**	**£ 132,775**

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Voltage Power Optimisation Additional Benefits

The ability of VPO® technology to reduce energy (kWh) consumption on a site is well documented, but the technology also provides a range of other benefits. These all contribute to creating a more efficient, robust and reliable electrical supply for your site, and provide further financial benefits on top of the reduced energy costs.

Reduced maintenance burden

- Optimising voltage with powerPerfector brings your supply voltage to the "higher efficiency" operating range of your equipment. Without this, the 'raw' supply voltage to your site is likely to be at the top end of the range of voltages your electrical equipment can tolerate. As well as reducing energy consumption, this reduces the **strain** on your equipment, and many of our clients tell us that this increases its lifespan.

- For example, a lightly-loaded **induction motor** operating at an optimum 380V instead of a 'raw' 415V experiences less heating and vibration, reducing wear on bearings and prolonging its life.

- The life of **incandescent light bulbs** is almost doubled by optimising their supply voltage.

- Most equipment benefits from the lower **'pressure'** when voltages are optimised. Other examples include Variable Speed Drives – which are particularly sensitive to over-voltage – and the capacitor banks in Power Factor Correction systems.

- When these effects are **aggregated**, the benefit to your site of extended equipment lifetimes and reduced replacement costs will be substantial. The exact saving is difficult for powerPerfector to quantify, but we estimate it to give you a 10%+ reduction of your maintenance and capital replacement costs.

Improved power factor

- Optimising supply voltages reduces the **reactance** of electrical equipment, as it prevents over-excitation of magnetic components. The effect of this is to reduce the level of wasteful **reactive power** in the electrical system. Reducing reactive power improves **power factor**, and the powerPerfector typically improves power factor by 3-10%.

- The **maximum demand** of a site is expressed in kVA (incorporating both real and reactive power). So reducing reactive power reduces the maximum demand of a site, which will lead to reduced kVA demand charges, Agreed Service Capacity (ASC), and increase spare capacity for further growth. (8% optimisation = 6%-10% reduction in MD normally)

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- Power factor **penalty charges** – which are now uncapped in the UK – can be avoided if your power factor is above 0.95. These may appear on your bill as 'reactive power charge', 'kVAr charge', 'use of system charge' or 'availability charge'. If your power factor is at around 0.9 at the moment, the powerPerfector could remove your exposure to these charges.

- In general, the strain on your electrical infrastructure is reduced if power factor is good. If your system is carrying a high proportion of reactive power, impedances and voltage-drop will be excessive, and overall **efficiency** will be low. The powerPerfector improves the electrical efficiency of your site.

- The powerPerfector yields many of the same benefits as **Power Factor Correction**, but does not use capacitors, which can be prone to failure. Instead, it helps correct the underlying cause of poor power factor, while saving energy.

Lower harmonic distortion

- The powerPerfector is able to **filter harmonics** on the mains incomer. Harmonic distortion is on the increase, leading to apparently random failures of electronic equipment.

- As the site is protected from mains-borne harmonics, disruptions to the operation of sensitive **electronic equipment** that could otherwise result from intolerance to harmonic distortion are minimised.

- By preventing harmonics from entering the secondary side of the **HV supply transformer**, the powerPerfector is able to improve the transformer's efficiency and increase its effective capacity. Customers whose utility meter is on the HV side of their transformer will see higher savings as a result.

- The threat from damaging **resonance** effects is reduced as harmonic distortion is lower, as is the risk of failure of Power Factor Correction capacitors.

- The **efficiency** of any equipment containing magnetic components is improved – contributing to energy savings – as the heating effect of harmonics is reduced. This in turn extends operating life by postponing the breakdown of insulating materials.

Reduced neutral currents

- As well as providing general harmonic filtration, the powerPerfector helps to reduce the level of **triplen harmonics** on a site, by balancing the three phase voltages.

- In addition to the benefits listed above, this leads to reduced **neutral currents** and temperatures – even though the neutral cable does not pass through the powerPerfector – as triplen harmonics accumulate on the neutral. Lower neutral currents are always desirable, and with an increasing proportion of non-linear loads generating more harmonics than ever before, undersized neutrals are a potential risk on many sites.

Improved phase voltage balance

- The operation of **three-phase equipment** – particularly induction motors – is much more efficient if the phase voltages are closely balanced. For large industrial sites that are heavily dependent upon such loads, balancing phase voltages at an optimum level with powerPerfector can yield energy savings of over 20% in motors.

Protection

- A powerPerfector makes an electrical supply more robust, and your site better protected. **Transients** – which are very brief surges in voltage from the grid – are eliminated by the powerPerfector, provided they are less than 25,000V.

- This level of protection is able to prevent transients from causing catastrophic damage to equipment, but it also prevents smaller, more common transient events that act to degrade equipment over time. This prolongs the expected life of electronic equipment.

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