Voltage Management Buyers Guide

Prepared for: UK Market

Prepared by: Voltage Optimisation Industry Council for Excellence

Edited by: Andrew Hawley

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INTRODUCTION

The Voltage Optimisation Industry has suffered a sharp decline in popularity in the UK. Savings are often short of those that were predicted, leaving many to conclude that 'VO doesn't work". The reality is that savings can be achieved by carefully reducing input voltage - the issues are linked with those that sell VO and they must now work together and agree to work together in establishing a new set of industry guidelines.

In response to a call to action by the Energy Managers Association, VOICE was formed in 2014 with the support of the majority of VO manufacturers/suppliers agreeing to sign up to a Code of Conduct that would provide consumers with increased level of confidence in the proposals that were being put forward by VOICE members.

This Buyers Guide is the first in a suite of supporting VOICE documents that will help to improve the understanding of VO and what can be achieved through its correct use.

As part of it's work, VOICE will also address any information that is made publicly available that the members believe is damaging to the industry and they will actively pursue independent testing.

Andrew Hawley
Chairman - Voltage Optimisation Council for Excellence

Statement by CEO of the Energy Managers Association (EMA), Lord Redesdale

"Voltage Optimisation has faced a number of issues over recent years, leading many Energy Managers to question whether the installation of Voltage Optimisation Equipment is the best use of limited budgets. The energy management industry is in great need of this Guide that creates a level of transparency that has until now, been missing.

I am pleased to see that VOICE has responded to the concerns raised by the Energy Managers Associations Members."

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SUMMARY

The Voltage Optimisation Industry Council for Excellence (VOICE) was established in 2014 following a call to action from members of the Energy Managers Association.

Voltage Management - the basics

Voltage Optimisation or Management is in its most basic description, the control of Voltage on a given circuit. The circuit could be providing power to any type of building or process.

There are various types of differing technologies that can achieve this, including Voltage Stabilisers, Optimisers and/or Regulators. This document focusses on a specific aspect of Voltage Management, historically referred to as Voltage Optimisation - the reduction of voltage on a circuit. It is important to note however that this is a technically complex area and that great care needs to be taken.

Whilst the technology is most commonly 3 phase in commercial environments, for simplicity - this document references single phase (240volts).

In many parts of the world, electricity is provided at a higher or lower Voltage level than is necessary. This 'over-voltage' can manifest itself through operational problems or it can often result in wasted energy.

VOICE - Our Mission Statement

To provide an unbiased consultative approach to stakeholders looking to invest in Voltage Management & Optimisation technology by:-

- Agreeing a baseline between all manufacturers for all types of equipment savings
- Establishing a written standard for proving energy savings
- Working as a group to improve the perception of VO with shared values
- To make VOICE the recognised and trusted advisor to stakeholders looking to invest in Voltage Management Technology.
- Lobby government to gain acceptance for VO technology in Government initiatives
- Promoting VM&O techniques to encourage a wider take up of the technology

VOICE - Our Vision

To establish a pro-active entity that seeks to address the concerns in the energy efficiency market and improve the reputation of the Voltage Management & Optimisation Industries.

Establish a brand & Code of Conduct that members adopt and ensure all those using the logo act in the best interests of our Clients and the Industry, this includes agreeing savings baselines, technology benefits and risks.

EQUIPMENT

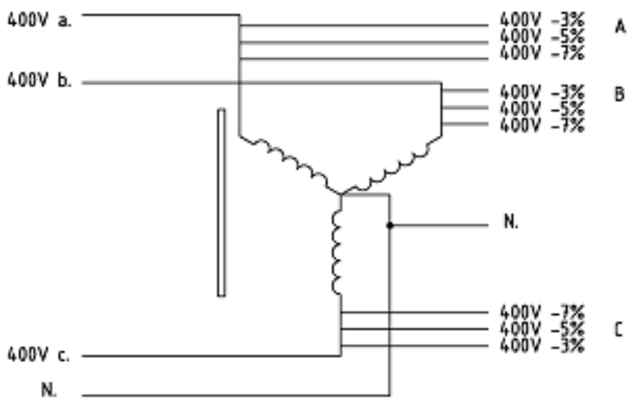
General

All equipment sold throughout the European Union are subject to all the EU's laws, standards and directives and must be CE badged where applicable. Equipment manufacturing companies should be working to BS EN ISO9001 quality management system to ensure traceability and good practice.

Low Voltage Static or Fixed Voltage Optimisers

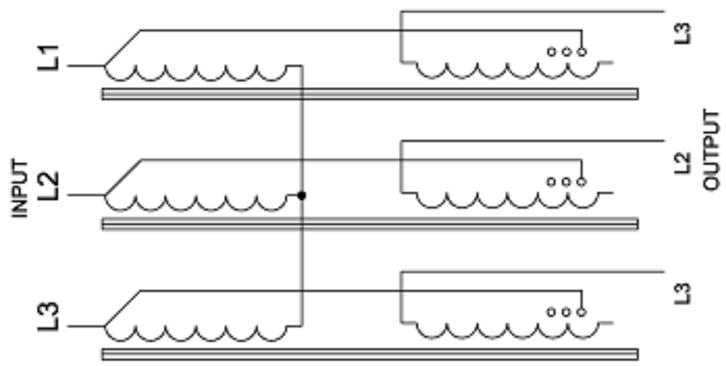
These devices give a fixed percentage reduction from their supply voltage via fixed tappings, which can only be manually changed. These can be either supplied as a single phase or a three phase device and are wired in series between the supply and load. Although the function is the same there are two design methods of achieving the required voltage reduction, the standard step-down and the anti-phase or buck transformer as it is also known.

Step-down



The step-down transformer utilizes both the phases and the neutral connections to give a step-down function of the output.

Anti-phase Transformers



The anti-phase or buck transformer relies on a voltage fed in opposition to the input voltage reduce the output. A neutral connection is not required.

Transformer Windings

Both types of transformers are dry wound auto-transformers and should be manufactured to BS EN60076-11. There are variations available with harmonic traps and zigzag interlaced windings endeavouring to balance phase voltages. However, in all cases the primary function is to step down voltages.

As with all this type of equipment there are many optional extras that can be fitted; transient and/or lightning suppression, energy metering, alarms and switchgear etc, most with their own particular standards.

Transformer Housings

The transformer would normally be housed within an enclosure that shall comply with BS EN61439-1 section 8 with a stated degree of ingress protection (IP rating) that shall adhere to BS EN60529. The enclosure’s rating label shall comply with BS EN61439-1 sections 5 & 6.1 also BS EN6007-11 section 7.1 with an appropriate unit identifier.

Anti-Phase Transformer Specification

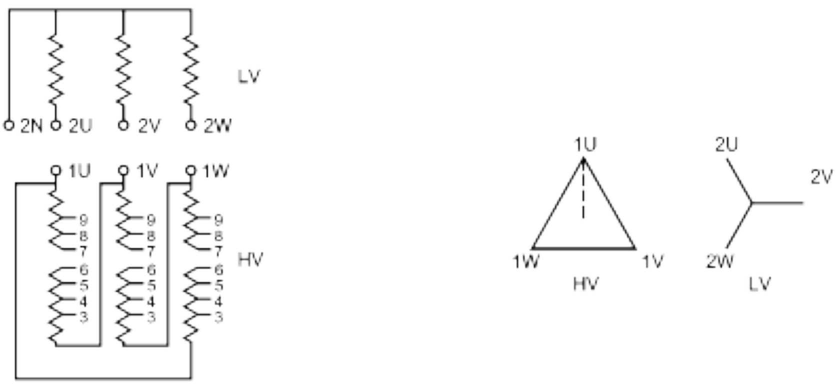
Buyers should request a minimum of the following parameters are listed.

- Input voltage range
- Phase current rating
- Available output tappings
- Operational Frequency
- Insulation Class
- Temperature Class
- Efficiency at a stated load
- Surge (over) current ratings with durations
- Operational environment
- Enclosure IP rating
- Weights and dimensions.

Medium voltage Static or Fixed Voltage Optimisers

These devices are direct replacements for the existing grid distribution delta/star transformers. This new design of low loss, high efficiency transformer has an increased number of tap settings offering greater control of the output voltage.

Distribution Transformers



Distribution Transformer Specifications

These types of transformers are connected directly to the grid network and therefore must accommodate input voltages from 3.3kV to 11kV and are manufactured to BS EN 60076 and must be compliant with EU Commission Regulation 548/2014 & 2009/125/EEC. The transformers are normally liquid immersed and have more than the standard 5 tap settings (-5% to +5%) for increased adjustment of the output voltage. The tap settings are changed manually, when off load.

Distribution Transformer Technical Specification

Buyers should request a minimum of the following parameters are listed.

- Input voltage
- Output voltage
- Phase current rating
- Available output tappings
- kVA
- Operational Frequency
- Insulation Class
- Impedance
- Efficiency or Losses
- Vector Symbol
- Weights and dimensions.

Low Voltage Dynamic Optimiser also known as Voltage Regulators

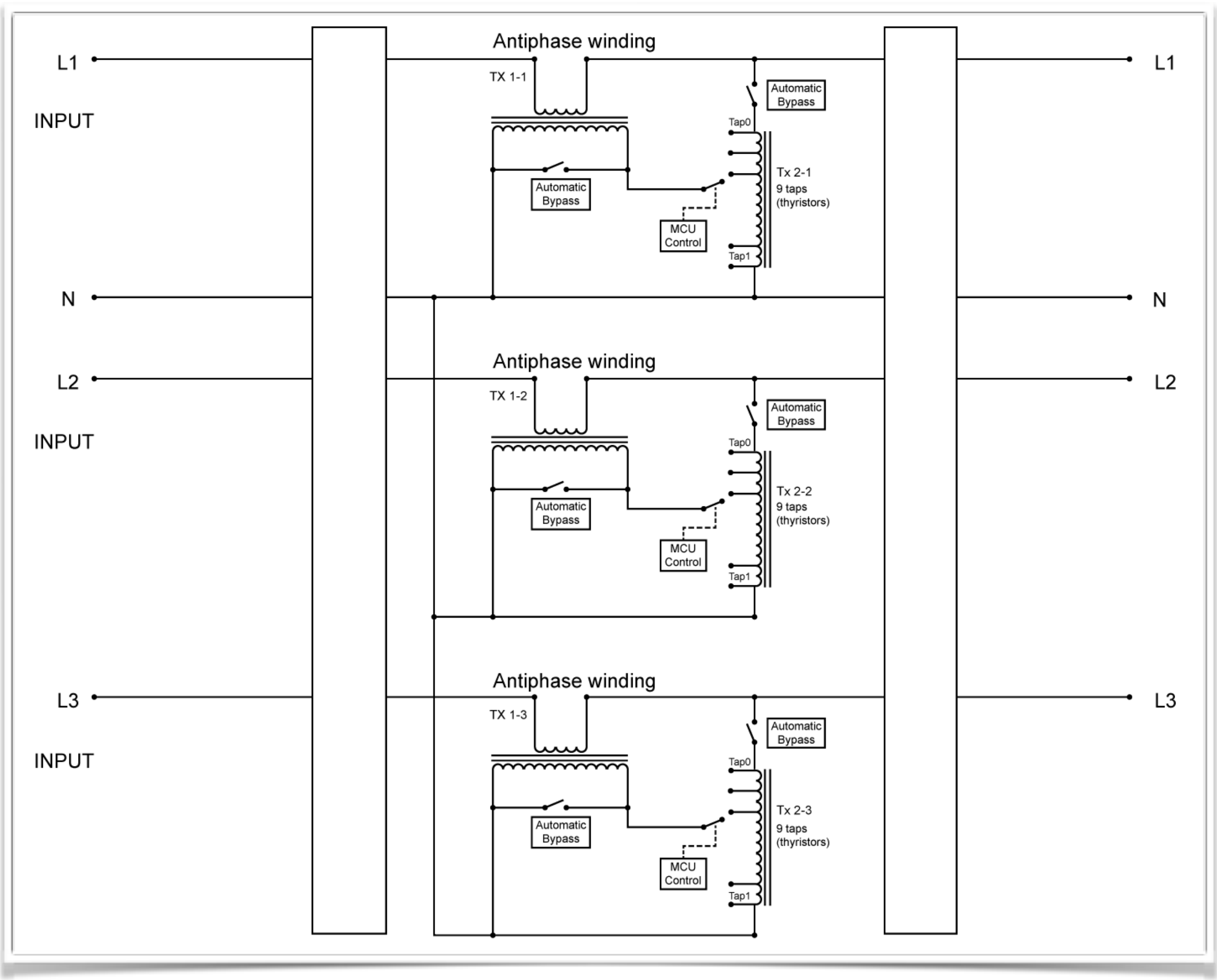
The dynamic optimiser controls the output voltage which is set to a predetermined level and maintained under the specified input conditions. This voltage can be adjusted while on line and load. These optimisers can be supplied either as a single phase or a three phase device and are wired in series between the supply and load. Although the basic function is the same there are two design methods of achieving the required voltage reduction and control.

It is worth noting that both these devices require only slight modification to convert them into voltage stabilisers. The auto-tapping transformer requires only a positive tap and the electro-mechanical requires only a change in wiring between the buck transformer primary and variable transformer, allowing both units to buck and boost the output voltage.

Auto-Tapping

The first is an auto-tapping transformer with either electro-mechanical or semiconductor switching of the output voltage between the tap positions. Each phase is controlled independently with an accuracy determined by the number of tap settings.

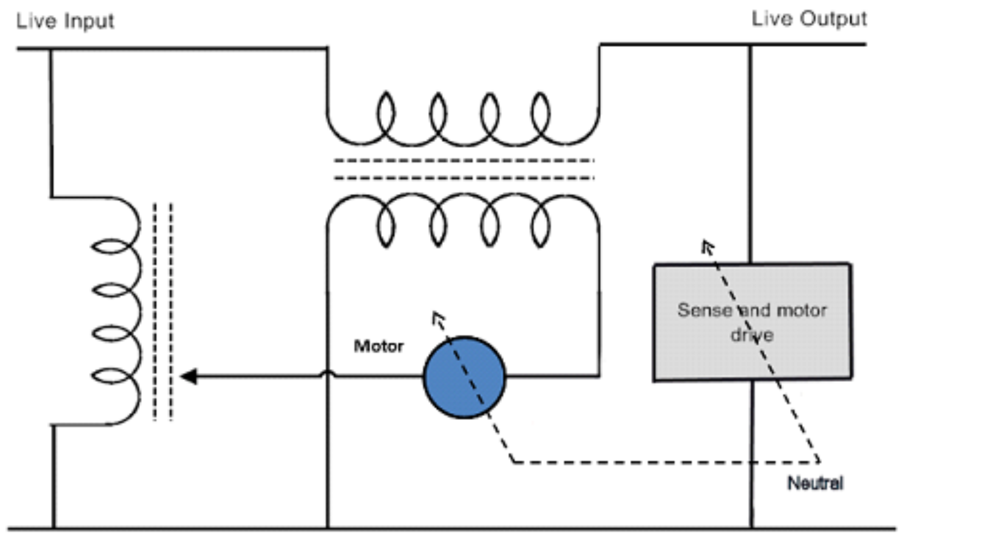
Auto-tapping regulators



Electro-Mechanical Regulators

The second method is an electro-mechanical design utilising fixed and variable transformers inter-wound in a buck system. Each phase is controlled independently with an accuracy determined by the number of windings on the variable transformer giving linear control.

Electro-Mechanical Regulator



The diagram shows a single phase of a three phase regulator. The variable transformer can be on either the input or the output side of the buck transformer.

Design Standards

The design standards listed in this guide should be applied in addition to those standards EN61558-2-14 & 26 and for compliance to EMC and surge withstand capability EN61000-6-1 & 2, EN61000-4-5 and EN62041 are required.

For Installations in a domestic environment, EN6730-1 will apply.

Regulator Technical Specifications

Buyers should request a minimum of the following parameters are listed.

- Input voltage range
- Phase current rating
- Output accuracy
- Operational Frequency
- Efficiency at a stated load
- Surge (over) current ratings with durations
- Operational environment
- Enclosure IP rating
- Waveform distortion
- Weights and dimensions.

Medium Voltage Dynamic Optimiser

These devices are low loss, high efficiency transformers as in Section 3 but with additional features. There are two types of Voltage Regulating Distribution Transformer (VRDT) currently available. This type of control is particularly useful in grids where there are large numbers of decentralised feed-ins to the low-voltage range as it is capable of detecting whether current is being fed into the upstream medium voltage grid via the VRDT, subsequently adapting the control response accordingly.

A European Standard ' EN 50651 - Voltage Regulating Distribution Transformers' is currently in development and will detail the requirements for the number of steps, the range of regulation and testing of medium voltage transformers with on load voltage regulation systemsAuto-Tapping Delta/Star Transformer

Auto-Tapping Delta/Star Transformer Specification

Buyers should request a minimum of the following parameters are listed.

- Input voltage
- Output voltage
- Phase current rating
- Available output tappings
- kVA
- Operational Frequency
- Insulation Class
- Impedance
- Efficiency or Losses
- Vector Symbol
- Weights and dimensions.

Fixed Delta/Star Transformers

The second unit is a fixed delta/star transformer without any high voltage tap positions but integrating a low voltage dynamic optimiser within the output section. The transformer shall be manufactured to BS EN 60076 and also must be compliant with EU Commission Regulation 548/2014 & 2009/125/EEC. The low voltage dynamic optimiser must comply with standards in section 4.3.

Fixed Delta.Star Transformer Technical Specification

Buyers should request a minimum of the following parameters are listed.

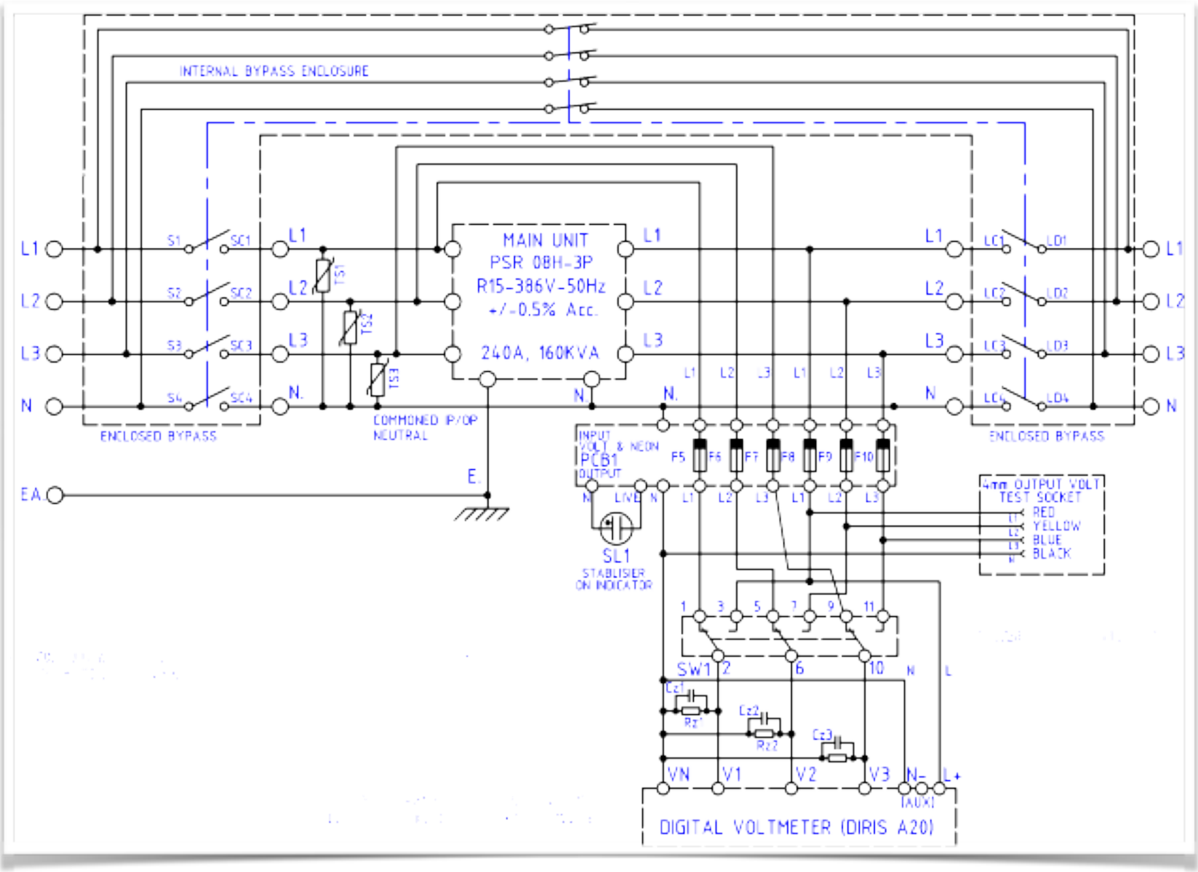
- Input voltage
- Output voltage accuracy
- kVA
- Phase current rating
- Operational Frequency
- Impedance
- Insulation Class
- Efficiency or Losses
- Surge (over) current ratings with durations
- Operational environment
- Enclosure IP rating
- Waveform distortion
- Vector Symbol
- Weights and dimensions.

Optimisation by-pass

A method of removing optimisation from the site, without interruption of the supply to that site. The optimiser will still be connected to the supply.

System by-pass

An internal or external device that disconnects and isolates the voltage optimiser from the site's electrical supply, whilst reconnecting the site to the original incoming supply. Its operation is a break before make function. The optimiser will be fully isolated so it can be maintained.



SITE SURVEYS

Summary

Every site is different, which means the level of savings will vary, however any organisation that uses electrical equipment and lighting should consider Voltage Management as a potential route to energy savings.

The implementation of Voltage Management Equipment should always follow a reasonably consistent workflow, yet - across the leading recognised manufacturers in the market place - the recommendations do vary.

Whilst the conclusion of the project would without doubt conclude with the successful installation of the selected piece of equipment, failing to follow proper process will leave the results open to interpretation and potentially leave any installation in contravention of the relevant legislation.

We have worked hard with our members to develop an agreed process that not only ensures that equipment is installed correctly and in line with the regulations, but that the assessment of the performance of your chosen technology can be carried out with a high degree of confidence.

Survey Process

Site surveys should be carried out during typical working and electrical loading periods for the site. The site survey should be address the following points as an absolute minimum.

- Submission (and prior approval) of Site Specific Risk & Method Statements in advance of any works.
- Installation of logging equipment and obtaining spot voltage readings and any voltage drops around site (See separate section on voltage logging)
- Identification of location for any unit to be installed and obstacles etc which may be encountered as part of the installation.
- Identification of types of electrical loads on site and any required enabling works

Installation Location

As part of the survey, an overview of the potential installation location should be carried out. As well as identifying a potential physical location for any unit, other considerations such as additional electrical isolation or protection requirements would need to be checked. Particular care needs to be taken when determine if the electrical supply to site be safely isolated in house or whether the Distribution Network Operator (DNO) needs to attend to isolate at point of common coupling.

On more complex installations it is very often sensible for the installation team to carry out intrusive investigations into the main switch panel out of hours (so the power can be turned off) to confirm in detail the actual method of final inter-connection. Under no circumstances should these works be undertaken in a ‘live’ environment.

Identification Of Electrical Loads On Site

The most important objective of the site survey is to identify the types of load and their relative impact on potential energy savings on site. It is well known and documented that differing loads offer different potential savings opportunities it is the detailed evaluation of this information following the survey that will form the basis of any savings predictions. All manufacturers of voltage management equipment will have their own figures for this.

It is of the upmost importance therefore that the person carrying out the survey has access to good levels of information regarding what is installed on site. Part of this should undoubtedly be a thorough a walk around of the site as a great deal of information can be gained by talking to someone who thoroughly knows and understands the site and its processes and (where available) assets registers.

It should be understood that any identification of any load type is only a snapshot of the site at the time it is carried out, any site must be considered dynamic in terms of the loading types and therefore the potential savings achievable. With the correct information available at the time of the survey, there should be no reason why accurate predictions of overall savings should not be possible. Post installation analysis of energy consumption will (where data is available in sufficient detail) always reveals differences in energy reduction on different days or at different times of day.

As part of the survey, identification of any loads which may not be suitable for optimised voltage operation, in reality these are generally few in number and tend to be based around older equipment designed for 440V nominal voltage. Where equipment is known not to operate correctly at the reduced voltage rather than abandon the complete project consideration should be given to managing the voltage at the equipment through the use of step up transformers, or by applying small increases in the voltage set point until the equipment operates correctly although it should be noted that this will impact on the overall energy reductions through Voltage Management.

VOLTAGE LOGGING

Spot Voltage Readings

Spot voltage readings should be obtained from various points around the building including points close to the main supply, furthest point and areas of heavy loading, these may be taken using calibrated conventional multi meters (preferably RMS) or readily available plug in type power meters, these values should be used to identify any voltage drops on site and should form part of the process of defining the ideal site voltage when specifying and also commissioning any Voltage Management equipment.

Installation of Data logging equipment

A voltage profile of any site considering the installation of VO equipment should be sought. There are many different factors which will play a part in the best method to suit a site's needs, each type of logging equipment is briefly outlined below and the type of site or load which it is best suited towards. The duration of logging periods would need to include a typical loading cycle, in general this should be a minimum of 1 working week, which may be less than 1 calendar week.

Single Phase Voltage Plug in Recorder

This type of logger is the most common type of recording equipment used for logging the voltage profile of a site and offers the distinct advantage of being small and portable, and does not require invasive access to install. This type of equipment is most suitable for sites where there is a single incoming low voltage supply to site which is generally electrically balanced and does not suffer from any harmonic issues.

Differing models of this type of device are available, some units record an instantaneous value at a programmable pre-defined time interval, other units record a minimum, maximum and average value for each time interval, where this is the case as part of the proposal process consideration should always be given to all the data available.

Where single phase voltage only recording is used for recording data, load checks using either on site sub metering or hand held current clamps should be used to confirm individual phase current loadings, as any significant current imbalances will not be visible from other data.

Portable three phase power logging

Three phase logging should be carried out over a typical operational period to give the most realistic information possible (as with the single phase outlined previously). Portable three phase data logging equipment can be broken down into two distinct variants, the first and most common type directly measures & records the voltage and current consumption of an electrical supply. When the device is downloaded to a computer this data is then used by the software to calculate further values such as Power factor, apparent power (kVA) and true power (kW) and kWh consumption.

Three phase data logging would benefit sites with a more complicated electrical networks, such as sites where there are either two High Voltage (HV) or Low Voltage (LV) Electrical supplies via one Fiscal Meter (MPAN), where the load through each supply needs to be apportioned or where significant load imbalance exists across one single supply.

The main drawback with three phase logging equipment, is the more intrusive nature of the installation - very often with access being required to potentially live electrical connections as part of the equipment installation. However with the correct planning and equipment this issue can nearly always be overcome.

Portable Three Phase Power and Harmonic Recorder / Analyser

These devices offer further benefits for sites with known issues of harmonics or are subject to internment grid or load side power quality issues. These recorders will give the added benefit of recording more detailed data including total and individual voltage and current harmonics, usually recording minimum, maximum and average data points for each time period. The additional information recorded is useful in issues with harmonics or other power quality problems which may be dealt with separately.

On Site sub metering with data export

Many sites now benefit from the installation of sub metering equipment. The complexity and information available from these systems vary considerably site to site, however, where the information is recorded digitally, large amounts of data could be available without the need to install portable equipment as you may already have critical information such as the Voltage profile, kWh per data period ideally half hour per electrical supply.

Any additional sub metering on specific sub circuits such as lighting, chillers or small power can prove useful. Data should be available for a period of at least 12 months. Data should be available in either excel, CSV or txt format for spreadsheet manipulation.

SAVINGS PREDICTIONS

Why does Voltage need to be managed

Until 1995, the statutory supply specification in the UK was 415/240V ±6% (i.e. phase voltage (Vp) within the range 226-254V) & the vast majority of the electrical distribution network was designed to deliver electricity within this range. VOICE members have found that single phase voltage in the UK is around 242volts.

Historically the supply voltage in mainland Europe has been 380/220 volts with a typical tolerance of ±6%. Steps to harmonise voltage levels were taken in 1995 when the statutory supply specification in the UK changed to 400/230V+10% -6%. This remains the current UK position today.

To simplify the market for electrical equipment further, the European Union introduced the Low Voltage Directive (LVD) 2006/95/EC to regulate the normal operating voltage in Europe. Equipment that meets this standard bears the mark and is designed to operate with a nominal supply of 230V.

Electricity Quality and Supply Regulations (EQS) will harmonise supply voltages across Europe at 400/230V ±10%, i.e. Vp within the range 207–253V. This means any piece of equipment with the CE mark can be safely operated on the local electricity supply anywhere in Europe.

How are savings calculated

There are many mathematical processes and procedures that can be used to determine the beneficial effects of Voltage Management. Whilst these can provide some indication of the savings that are being achieved, they are (to some degree) flawed and buyers should take great care in how these calculations are applied and that they are being carried out by a true independent.

Regression Analysis/IPMVP

Regression analysis and/or IPMVP takes data from a period after any equipment was installed and calculates savings mathematically by comparing historical trends and seasonal data. This can include adjustments for degree days and trading levels/footfall. Applied correctly the resulting outputs can be useful but the process can be open to manipulation.

Where regression analysis is relied upon, the chosen supplier should provide fully detailed explanations, formulas, data sources and justifications for any adjustments that are made. This will enable the information to be assessed by an independent third party if required.

External Bypass or ‘Switch-off’

Whilst not always practical, it is possible to determine the level of savings by measuring the energy (kWH) to a site with the original voltage and then again at the lower voltage over a similar period. A degree of care needs to be applied if this approach is taken and it should only be done by a competent person/Electrician.

POTENTIAL EQUIPMENT SAVINGS

A Standard Savings Guideline

Whilst the true savings on any installation will determined by a thorough site survey as discussed elsewhere within this document, the following table describes a benchmark of savings in a typical scenario.

The following information assumes that average incoming voltage is running at a constant 242volts and a reduced/managed output voltage of 220volts.

It is important to stress that these figures are indicative and whilst the following can be used as a guide, they should not be used as a basis for calculating return on investment.

Lighting	Potential Savings
Filament Lamp	25%
T8 Lighting (switch start)	19.5%
T5	12.5%
Low Voltage Halogen	15.5%
Tungsten Lamp	14.6%
LED (with IC based Driver)	0%

Other	Potential Savings
Pedestal Fan	9.8%
Desk Fan	2.3%
Large Drinks Cooler	3.7%
Domestic Fridge	3.1%
CRT Monitor	0%
Vacuum Cleaner	16.8%
TV	0.9%
Desktop PC	0%
2.5kW Electric Heater (not thermostatically controlled)	16.6%
Clarke Air Compressor (DOL)	17.1%
Cassette Type HEVAC	8.8%

Voltage Optimisation Industry Council for Excellence
Unit 6, The Tannery Business Centre
Northowram, Halifax, HX3 7HR
t: 0844 585 3043
e: info@voice-vostandards.com
w: www.voice-vostandards.com

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