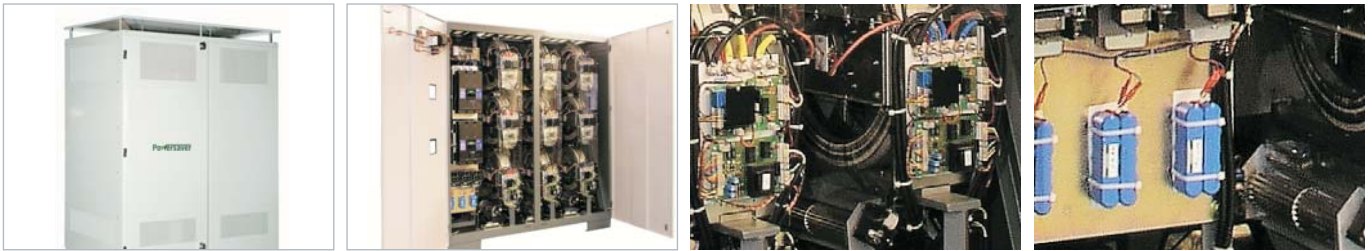


# An Introduction to Voltage Optimisation<sup>1</sup>



## Background

Nearly all your machines, lights, heaters etc. (your loads) are designed to operate at 220 volts.

However, the voltage delivered to you by the National Grid averages 242 volts and is slowly rising.

Voltage optimisation (also known as voltage stabilisation or voltage power control) is the process of reducing your incoming supply voltage from an unnecessarily high level to a new optimised level.

A saving of up to 20% (though typically around 10%) on your electricity bills can be achieved simply by reducing your incoming supply voltages from the UK average level of 242V to 220V. The exact reduction will be dependent on the loads operating on your site.

It is a relatively simple process and probably the simplest way of achieving significant energy savings on your site.

1. Also referred to as voltage stabilisation, voltage regulation, voltage reduction, voltage correction, voltage power optimisation or voltage power control.

## Benefits of voltage optimisation

The benefits of optimising your voltage include:

### Financial

- Reduces your electricity consumption and fuel bills
- Reduces peak demand and therefore capacity charges
- Extends lifetime of machinery thus reducing equipment replacement costs

### Emissions reduction

- Reduces carbon emissions

### Electrical System and Power Quality

- Helps to balance phase voltages
- Increases power transmission capacity in cables
- Increases available transformer capacity

### Motors and Appliances

- Reduces wear and tear on motors as they run cooler (inductive loads run at design voltage [220V] are operating at their design temperature)
- Provides a degree of surge protection

## Electricity savings

Typically, a commercial installation that installs voltage optimisation will reduce the electricity used by between 5% and 13%, with some sites achieving savings of over 20%. The precise amount of electricity saved depends upon a wide range of factors, including:

- The amount of electricity consumed by inductive loads in the circuits (the optimisation only works on some of the loads)
- How often these loads are in use
- The average voltage delivered to the site

## Return on investment

Return on investment depends upon the percentage optimisation achieved on each site and the costs of installation, but will vary between 18 months and three and a half years, with around two and a half years being typical.

The design life of the equipment is 20–30 years years.

As a guide, below is an estimate for a local authority.

## Installation process

The installation process involves:

1. Monitoring the electricity use on all three phases for a period of time (e.g. a week) to establish phase voltage, current, peak current, kW and power factor to determine the voltage stabilisation requirement
2. Site survey to identify critical loads and voltage measurements, site volt drop and specific installation requirements
3. Preparation of the installation site between the incomer and the main fuse board, typically between one and three days work.
4. Installation and commissioning of the voltage optimisation equipment. Installation (usually on a weekend or at night) will take several hours and will require a site shutdown.

More detail on the survey and installation process is available on request.

## Issues

Some sites, especially those with low delivered voltage or large sites with significant volt-drop within the site may need either:

- a) A step-up transformer inserted before the on-site voltage is stabilised, or
- b) Additional power factor correction within the site

Sites with a very high proportion of resistive loads will not reduce consumption as much as those with a high proportion of inductive loads.

Other loads voltage optimisation will not affect include variable-speed inverter drives, high-frequency lighting ballasts and switch-mode power supplies. This is because the voltage fed to the load is generated electronically and is not affected by the supply voltage.

Temperature-controlled heating is another category of load where no energy savings can be obtained. This is because the heater will still need to consume the same amount of energy to perform its required function, i.e. deliver heat.

### Voltage Optimisation: Example ROI

Annual kWh used	1,392,250
Annual electricity bill:	£97,458
Price paid per kWh:	£0.07
VO Installation cost:	£25,665
Voltage optimisation percentage achieved:	7%
Savings	11.5%
Annual kWh saved:	160,109
Estimated financial saving:	£11,207 per year
Estimated emissions reduction:	91 tonnes CO <sub>2</sub> per year
Payback time:	27 months
Return on investment %	42%

# Technical note

## DEFINITION

Voltage optimisation (also known as voltage stabilisation, voltage regulation, voltage reduction, voltage correction, voltage power optimisation or voltage power control) is a the process of reducing (or raising) the incoming voltage to a site to its optimum level, which in the UK is 230 volts.

## BACKGROUND

### Supply voltage

Historically, the UK's supply voltage was a nominal 240 volts. A phased reduction to a new standard of 230V  $\pm$  10% (an effective reduction in the UK nominal supply voltage) was begun in 1995. However, full implementation of this new standard has been postponed.

Despite changes to the UK statutory supply level there has not been any reduction to our LV supply network levels and the average incoming voltage still stands at 242V. It is not unusual to see voltages in excess of 250V and some sites have recorded voltages in excess of 260V.

There are many influences on the incoming voltage level of a typical retail site (see Fig. 1.) Most of these influences are associated with I<sup>2</sup>R losses. These are not just from this site's own operational characteristics, but also from the sites around it. Figure 1 highlights the differences between day and night levels but also the weekend when other sites are nonoperational. Another aspect worth noting is the imbalance between the phase voltages, another significant cause of inefficiency.

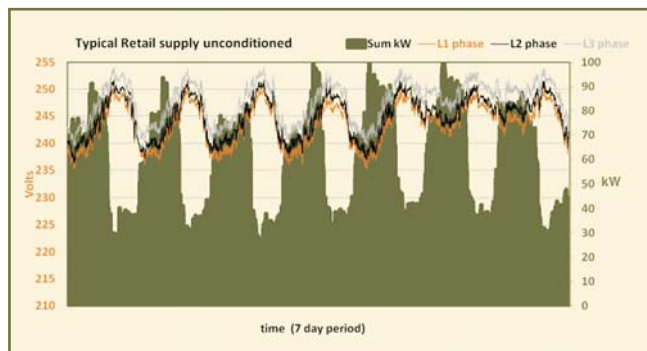


Figure 1: Incoming voltage levels on a typical retail site

### Equipment tolerance

In 1996 the Institute of Electrical Engineers (IEE) recommended that equipment manufacturers allow extend the operating parameters of equipment by an additional 4% to take into account the voltage drop across a site. This was again extended within the UK with the introduction of the new 17th edition of IEE Wiring Regulation and it is now generally considered that 230V  $\pm$  15%  $\pm$  10% (195.5V to 253.0V) is an appropriate operating range for equipment.

Manufacturers supplying into the UK and Europe markets

(CE marked) will at the very least have to ensure their equipment will function correctly at the extremes of both sets of present day statutory limits.

### The impact of over-voltage on operation

An example: a 230V rated lamp operated at 240V will consume 9% more energy than it requires. It will also only last for 55% of its design life.

## APPROACHES TO OPTIMISING VOLTAGE

The best way to correct an over-voltage situation (Fig. 1) is to reduce the voltage to the optimum voltage required to operate the equipment on the site. Most sites operate best at around 220V phase to neutral. There are several approaches to optimising voltage:

### 1. TAP DOWN THE VOLTAGE ON THE INCOMING TRANSFORMER

One approach is to adjust the tap setting on the incoming transformer, if it is not shared. However, this method is quite crude and savings are not maximised.

### 2. INSTALL A FIXED RATIO STEP-DOWN TRANSFORMER

An alternative is to fit a dedicated fixed ratio stepdown transformer (Fig. 2) with predetermined tap settings. This method has been general practice within industry for many years. The benefits of this approach are an immediate reduction in consumption and an extension of equipment life. The step-down transformer has low purchase and installation costs, typically giving 12 to 18 months return on investment. The disadvantages are obvious – there is no control, whatever appears on input a fixed percentage drop will occur on the output including voltage fluctuations and sags.

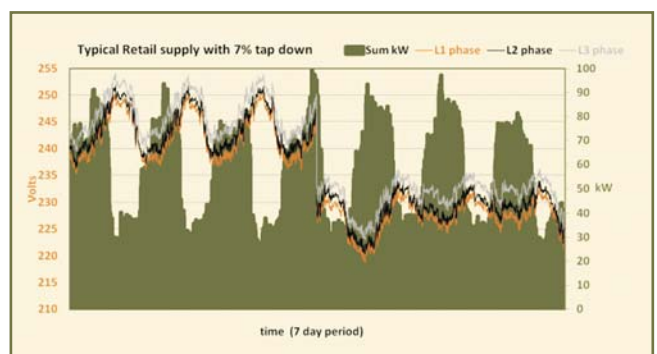


Figure 2: Supply with incoming voltage tapped down by 7%

### 3. INSTALL A VOLTAGE REGULATOR

Another method of optimising the supply voltage is by using a voltage regulator. This is an active device, again fitted to the incoming supply but with the ability to regulate the output voltages to your site (Fig.3). The benefits of this method are that the output voltages can be controlled to a pre-set level that can be adjusted online.

In addition, each phase has independent control allowing the output voltages to be balanced (known as 'phase balancing'), which improves the efficiency of the motors operating on site.

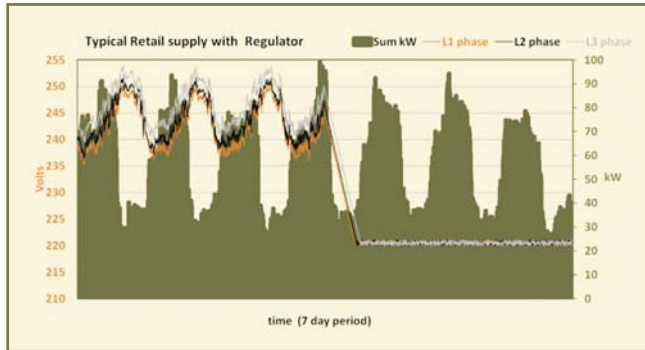


Figure 3: Supply with voltage regulated to 220 volts

### COMPARISON BETWEEN THE TWO METHODS

Although the voltage regulator is more expensive than the fixed ratio step-down transformer, the additional savings from regulation and phase balancing more than justify the additional expense. A reasonably sized site can expect a return on investment within 18 to 24 months.

As can be seen from the graph (Fig. 4) there is a substantial difference between the saving using the fixed ratio stepdown transformer and the voltage regulator.

Supply	Avg Voltage	kW	% saving
Unconditioned	246.7	57.5	None
7% tapping	229.4	53.5	6.98
Regulator	220.8	51.5	10.46

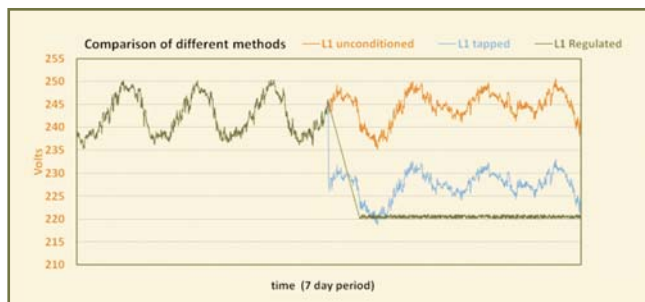


Figure 4: Comparison of different supplies: unconditioned, tapped and regulated

### FUTURE PROBLEMS WITH NETWORK SUPPLY IN THE UK

It is projected that our electricity supply in the UK will become increasingly unstable, with increased incidence of brownouts and blackouts. Alongside this, the supply will increasingly subject to sags and dips in voltage levels.

The two methods outlined above will react differently to the situation dependent upon severity of the problem. The fixed ratio transformer, as the name suggests, will

always set the output to a fixed reduction depending on its setting (Figure 5).



Figure 5: Response to a supply sag: unconditioned and fixed ratio transformers

However, the regulator will always correct to its setpoint voltage as long as the input is within its correction range (Fig. 6). The regulator correction range is determined from the unit setpoint value to a fixed percentage above to give the stated reduction. Should the input fall below the regulator lower correction range limit (Fig. 6) then the output will adjust to this lower level and the site would be no worse off than if the regulator was not fitted. An example, would be if the regulator output is set at 220V PN, then the input falls to 219V, so will the regulator's output. However, should the input exceed the upper limit then the output voltage would be reduce to the maximum percentage reduction that the regulator is capable of handling.



Figure 6: Response to a supply sag: regulator correcting voltage to target output



Figure 7: Response to variable supply: regulator correcting voltage to target output

Some sites are already suffering disruptive voltage sags and dips. In this case, we would suggest a voltage stabiliser is fitted. Unlike the regulator the stabiliser has both a positive and negative (relative to setpoint) correction range. Voltage stabilisers are used worldwide but are especially common in countries where the network infrastructure is poor and the supply inherently unstable. Although voltage optimisation is a 19th century concept, the design of modern voltage optimisers and stabilisers is constantly being refined in order to increase reliability and enhance performance.

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#### VOLTAGE OPTIMISATION: SUMMARY

Virtually all sites can benefit from optimising their voltage, but the size of the benefit will vary as conditions and loads differ from site to site. One important fact to remember: it is the loads that make the savings. The higher the ratio of inductive or 'fixed impedance' loads to resistive loads on a site, the larger the potential savings.

Fixed impedance loads that will benefit from a stable 220 volt supply include motors, compressors, refrigerators, fluorescent lighting etc., but not controlled heating processes.

An example: a 3kW kettle rated 230v will require the same energy input for the water to reach the desired temperature, therefore any reduction in voltage will require the kettle to be on for longer. However, operate that kettle at 240v and it then consumes 3.27kW and the life of the element is reduced.

Other loads that cannot achieve a saving are variable speed drives, electronic ballast lighting and devices fitted with 'Switch Mode Power Supplies' that are typically found in office equipment, PBX etc. For constant power devices that have a wide input voltage range (typically 100V – 260V) reducing the voltage will only increase the current. In this instance, the savings if any, are negligible.

However, in all cases equipment life is extended.

It is generally accepted, that even after taking into account the loads that do not make a saving (discarded loads) it is still more cost effective for a single installation to install either of the above methods of optimising voltage.

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#### SITE SURVEYS

Site surveys are essential to ascertain loads, site conditions, supply validates and usage in order to produce an accurate estimate of the savings that can be achieved by optimising voltage.