15 December 2010

Department of Electrical Engineering
UCT Power Laboratory

Summary Testing and Performance Report
Extracts from full Report Dated 10th December 2010

ON

Vanguards Power (VP)

PropSava SCR Voltage Optimisation System

This Summary consists of 10 (ten) pages.

Introduction:

Voltage optimisation is a turnkey energy efficiency technology which is placed in series between the municipal supply transformer and a sites main distribution board. The system operates by measuring and automatically correcting in real---time any supply voltage fluctuations above or below a voltage level set for the site. The result is that the entire site receives a stabilised and optimised voltage, allowing all electrical loads to operate at the voltage they were designed for.

A set of tests were conducted on an Vanguards Power PropSava SCR Voltage Optimisation Unit by the UCT Power Laboratory to determine the efficiency and functionality of the device. In this report the specification and the list of equipment are detailed. The results are then presented in a graphical format followed by a brief discussion about the tests conducted. Finally key observations are highlighted and conclusions are drawn.

Testing Specification:

Vanguards Power PropSava Voltage Optimisation Unit: 50KVA
Tests were conducted to determine functionality and efficiency of the unit with the output voltage set point set to 220V.

Apparatus:

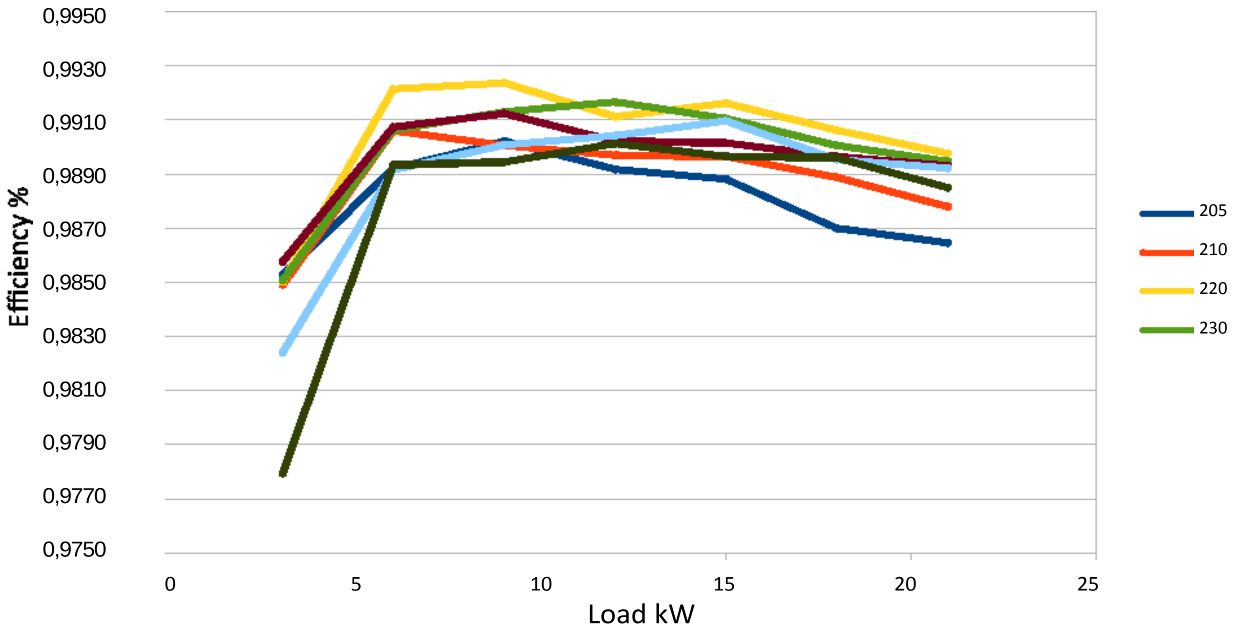
- 520kW Synchronous Machine 6600V generator set - Siemens
- 265kW 460V DC Machine - Siemens
- 250kW 500V 650A DC Drive - Veritron BBC
- 6600V Relay and switchgear - Reyrolle
- 500kW 6600V/380V Transformer - Hubert Davies
- 250 Amp Motor protection Switchgear
- 3 way load switch unit at 3kW per switch
- 21 kW Bar heater load boxes
- WT1600 Power Analyser, 5 sec update rate, single wiring - Yokogawa
- Oscilloscope - Agilent DSO 6012A
- Power Meter - Fluke 39

Test description:

A total of eight load points were tested ranging from no load to 21kW. Twenty one 1 ---Kw bar heater elements were used as loads and these were switched in steps of 3kW, using a 3 way binary type load selector unit. The eight load points were tested at seven different input voltage levels ranging from 205 V rms to 255 V rms. The tests were performed using the large 500kW Genset as the input voltage supply . A set of preliminary tests were conducted using the mains supply (as per a normal installation). This supply varied from 220.89 V at full load to 227.89 V at no load. Two sets of readings were taken during each test to verify repeatability of the tests. Finally tests were conducted to determine the systems response to sudden changes in voltage and in loading.

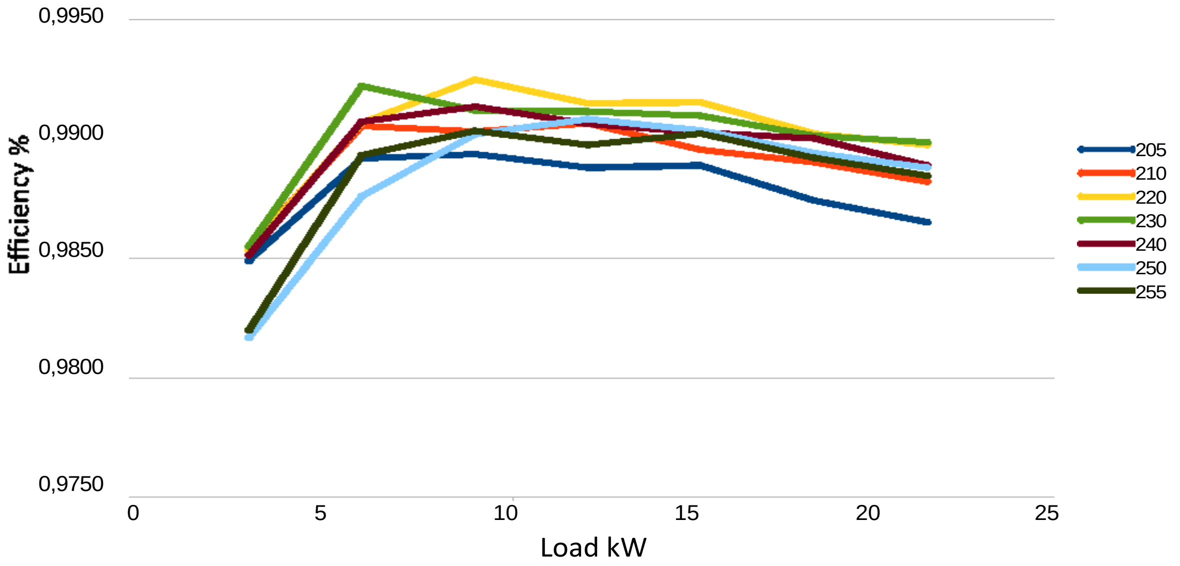
Results:

Voltage Optimiser Efficiency Test 1a



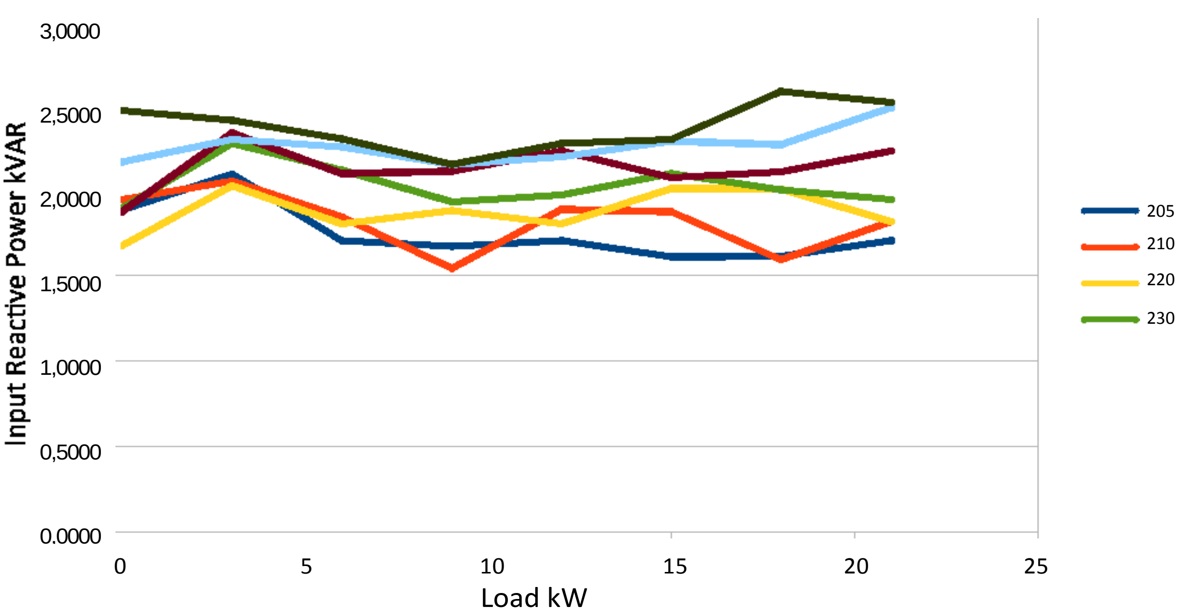
Graph 1: VP PropSava SCR Voltage Optimisation unit's efficiency as a function of loading and input voltage

Voltage Optimiser Efficiency Test 1b



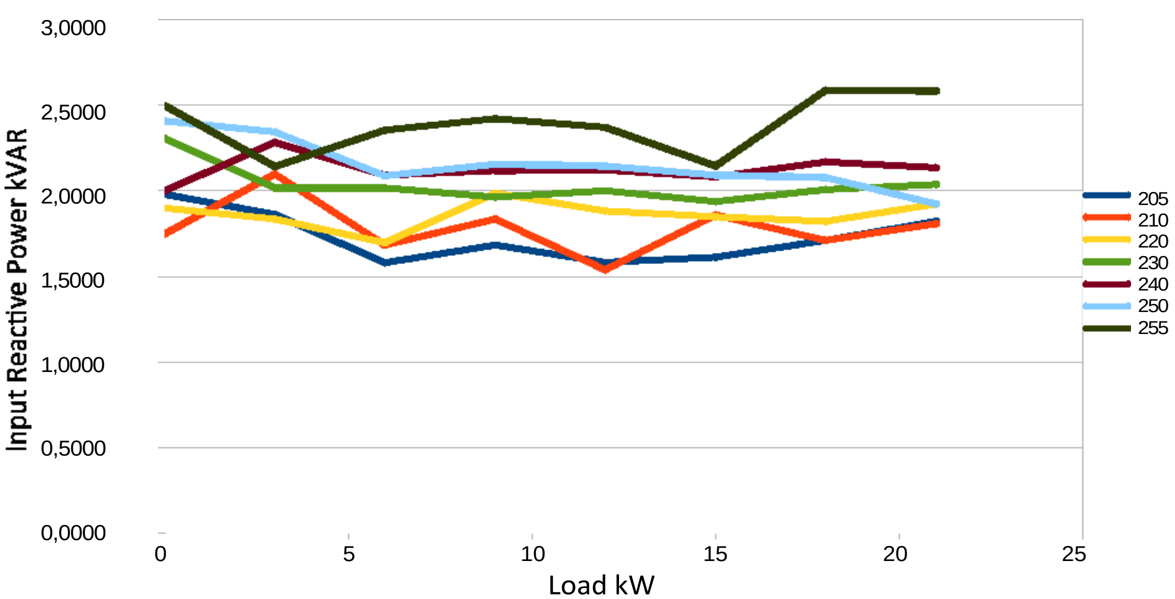
Graph 2: VP PropSava SCR Voltage Optimisation unit's efficiency as a function of loading and input voltage

Voltage Optimiser Reactive Power Draw Test 1a



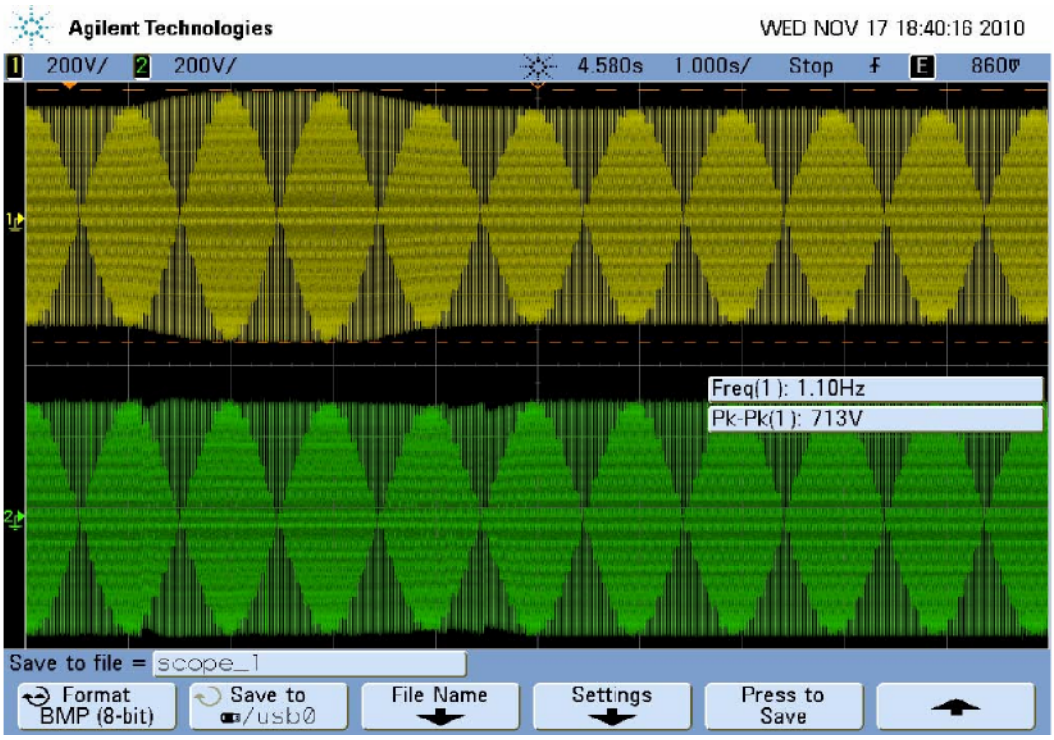
Graph 3: VP PropSava SCR Voltage Optimisation unit's reactive power draw as a function of loading and input voltage

Voltage Optimiser Reactive Power Draw Test 1b



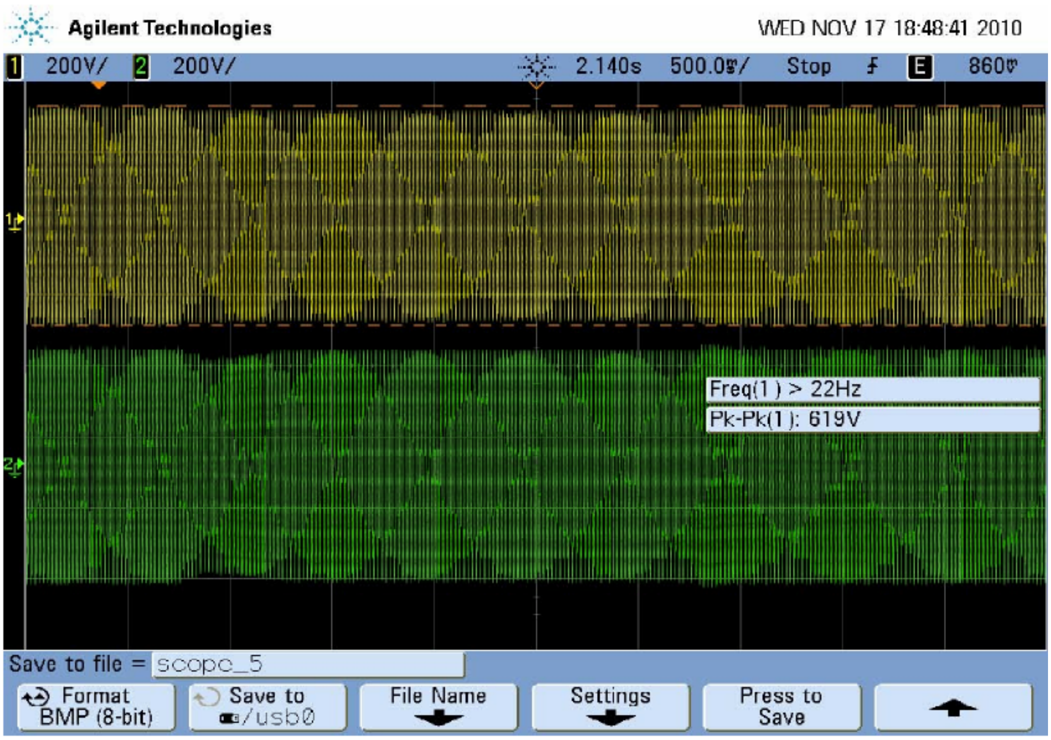
Graph 4: VP PropSava SCR Voltage Optimisation unit's reactive power draw as a function of loading and input voltage

Voltage response Test 2a



Graph 5: VP PropSava SCR Voltage Optimisation unit's response to rapid input voltage fluctuations. Yellow (top) trace represents input voltage; green (bottom) trace represents the unit's output.

Loading response Test 2b



Graph 6: VP PropSava SCR Voltage Optimisation unit's response to rapid loading fluctuations. Yellow (top) trace represents input voltage; green (bottom) trace represents the unit's output.

Discussion:

Efficiency and Functionality

The maximum efficiency of the device, in terms of input voltage occurs at 220V, and this peaks at over 99% for both tests. The efficiency drops off marginally with an increase in input voltage, to a peak of just under 99% at 255V. The lowest efficiency occurs at the lowest input voltage of 205V, where the efficiency is 98.6% at full load. The efficiency drops off at very low load but is only really noticeable at the 3kW load, where it drops to 98.5%; this loading however is not representative of a typical application of the unit. The overall output voltage stability over the load range is about 2V for each input voltage point and about 3.6V or 1.6% over the complete test.

Response Tests:

Two response tests were performed to determine the VP PropSava SCR Voltage Optimisation Unit's response to rapid voltage fluctuation and load changes.

In the first response test the input voltage to the unit was rapidly increased and then rapidly decreased. The input voltage was set at 205V and then increased to 255V for approximately 3 seconds, before being decreased back to 205V again. This is equal to a 22 % swell on the supply. The unit shows that it responds excellently to maintaining a constant output voltage, with a small initial voltage drop at the start of the swell and an overshoot at the end of the swell. The total time of this disturbance is less than a second with an output voltage change of less than 10%.

In the second response test the load on the unit was rapidly increased and then rapidly decreased. The load was set at 6kW and then increased to 18kW for approximately 3 seconds, before being decreased back to 6kW again. This is equal to a 300 % increase in loading. The unit again held a constant output voltage, with an initial undershoot and an overshoot of less than 10% at the points of load increase and decrease respectively. Both disturbances lasted less than 0.5 seconds.

Key observations:

- The unit functions as per its design specification when loaded from zero to full load for a large range of input voltages.
- The unit's efficiency is on average 99% with a maximum of 99.25% and a minimum of 97.8% in an extremely low loaded scenario, this suggests that it is an extremely efficient unit.
- The unit responses quickly and effectively to sudden increases and decreases on the Voltage supply.
- The unit responds quickly and effectively to sudden increases and decreases in loading.

Conclusions:

These tests give an efficiency and functionality check of the device which appears to perform well under resistive loading and typical supply conditions.

Technical Analysis of Voltage Optimisation and its Effects on different electrical loads

Introduction:

Voltage optimisation is a turnkey energy efficiency technology which is placed in series between the municipal supply transformer and a sites main distribution board. The system operates by measuring and automatically correcting in real-time any supply voltage fluctuations above or below a voltage level set for the site.

This document provides engineers and other interested parties with background information and relevant references of the response of various electrical loads to the Vanguards Power PropSava Voltage Optimisation Unit.

Specific electrical load responses to the Voltage Optimisation

A detailed analysis of how voltage optimisation generates savings in various electrical loads

Transformers

The primary mechanism of power reduction, energy conservation and power factor improvement when applying voltage optimisation to transformers is in the reduction of the no-load or core losses

Core losses are made up of two components:

1. Eddy current loss, $P_e = K_e f^2 B_m{}^2$ where K_e is a constant that depends on the core resistivity and lamination thickness, f is frequency and B_m is the magnetic flux density (Smith, 1966).

2. Hysteresis Loss, $P_h = K_h f g B_m{}^n$ where K_h and n are both constants that depend on the core material (n is often assumed to be 1.6) (Smith, 1966).

The Magnetic Flux Density, $B_m = k(V/f)$ where k is a constant, V is the voltage and f is the frequency (Smith, 1966). The reduction of V (and therefore B_m) reduces both Eddy current and Hysteresis losses and is how voltage optimization improves transformer operating efficiencies.

Operating transformers over their rated voltage significantly increases losses and also reduces power factor. Conversely, reducing transformer voltage reduces losses and improves power factor. Transformers are found throughout a typical power system, frequently in end use devices especially electronic power supplies, televisions, distributed process control systems and computers.

Electronic Power Supplies

The primary mechanism of power reduction and energy conservation using voltage optimisation in any type of electronic power supply is the reduction in the switching losses at the semi ---conductor junction. As long as the voltage is sufficient to supply the load the efficiency of the power supply will increase until the voltage supply is insufficient to supply the load.

Most power supplies are sized conservatively relative to the load they supply and are thus the perfect candidates for increased efficiency using voltage optimisation. Many power su pplies also include transformers and reactors that perform more efficiently at lower voltage as discussed above.

Lighting

The savings derived by voltage optimisation in lighting systems depends on the type of lighting load.

Incandescent

The mechanism for energy savings in incandescent lighting is one of the easiest to understand. Incandescent bulbs generate light by heating their elements until they become white hot. This is achieved by the resistance of the element. Power, P = VI is a function of voltage and current and in a simple light bulb (where Ohms law applies) V = IR. Therefore, $P = V^2/R$ and the power savings are proportional to the difference between the voltages before and after voltage optimisation. The light output will be reduced at lower voltages, but as long as voltages remain within reasonable limits this loss in light output is not noticeable.

The life of incandescent bulbs is also significantly reduced with a bulb operating a 5% over rated voltage only reaching 50% of its rated life (Cowern, 2010)

Fluorescent

Fluorescent lighting can be broken down into three categories.

1. Magnetic Ballast – The energy conservation mechanism from voltage optimisation is the same as the conservation from transformers discussed above. Testing on some magnetic ballast fluorescent lamps indicates that the performance index (lumen output) of the lamp improves as the voltage is reduced (M S Chen, 1981)
2. Electronic ballast – The energy conservation mechanism from voltage optimisation is the same as the conservation from electronic power supplies.
3. HID – Depending on the type of ballast, savings will occur from either the same mechanism as transformers or electronic power supplies.

LED

With LED lights requiring a DC voltage supply, savings are generated via the same mechanism as electronic power supplies.

AC Motors

AC motors typically offer a large proportion of energy savings at any given site. The energy conservation available from AC motors using voltage optimisation depends on the application, the motor type, size, design and on the speed and torque characteristics of the driven load.

a) In general if a motor is operating at its fully rated mechanical load, then it is most efficient at full name plate voltage. At mechanical loads under the rated load, efficiency increases as the voltage is reduced. In an environment where engineers typically spec motors larger than required for the mechanical loads they drive, in order to prevent mechanical failure, there is a huge opportunity for energy savings via voltage optimisation.

b) In all cases reactive power input decreases as the voltage is reduced and power factor improves with lower voltage and drops sharply with high voltage (M S Chen, 1981).

c) In an application where motor speed is not feedback controlled, reducing the terminal voltage will reduce the output torque. The slip will increase and the speed will decrease. In applications such as the fans used in air conditioning plants the driven load will decrease as a function of the cube of the motor speed thereby further increasing energy savings.

d) In general the percentage efficiency improvement for small motors is greater than for large motors and high efficiency motors will not increase efficiency as much as standard motors (Cowern, 2010).

AC Motors Cont

e) For motors operated by VSDs, energy savings are attainable via voltage optimisation in the isolation transformer and in the electronic power supplies.

f) Over-voltage can drive up amperage and temperature even on lightly loaded motors. Thus, motor life can be shortened by high voltage.

DC Motors

g) The energy savings achievable by voltage optimisation are primarily via the isolation transformers and electronic power supplies.

Computers

h) All computers are supplied via electronic power supplies. These provide savings as discussed above.

Heating

i) No savings are achievable using voltage optimisation in thermostatically controlled heating loads other than any savings in pumps or other machines built into the system. Any space heating will offer savings proportional to the difference in the square of the voltages before and after voltage optimisation; however this does not represent an increase in efficiency but rather a reduction in heat output.

Overall power factor of the electrical system

j) High voltages tend to reduce power factor within an electrical system due primarily to the over---excitation of transformers, motors and other inductive elements. Voltage optimisation tends to improve overall system power factor which results in additional energy savings.

Conclusion

k) Voltage optimisation develops energy savings in the majority of typical electrical loads. The savings developed are via different mechanisms in different load types, with some loads offering higher saving opportunities than others. With a stabilised voltage supply all electrical loads benefit from not operating in an over or under voltage situation. For many loads this benefit means not only that they run more efficiently but also that they operate at a higher power factor and accrue an increased useful lifespan over the long term. With a voltage supply in many parts of the world which can and does fluctuate between 207 and 253 volts; voltage optimisation is a turnkey solution which allows all loads to run at a stable and optimised level.

References

Smith, R. J. (1966). *Circuits, Devices and Systems A First Course in Electrical Engineering (517---518).* New York: John Wiley and Sons.

Cowern, E. (2010). *Electric Motors and Voltage.* From The Cowern Papers: http://motorsanddrives.com/cowern/motorterms12.html

M S Chen, R. R. (1981). Effects of Reduced Voltage on the Operation and Efficiency of Electric Loads. 3-–157.

Toomas Vinnal, Lauri Kütt and Heljut Kalda of Tallinn University of Technology.