Treatment of voltage optimisers/reducers in SAP

From Bruce Young, BRE, 27 October 2011

1) Introduction

A voltage optimiser is an item of equipment installed to change the voltage delivered to electrical fittings and outlets on some, or all, of the electrical circuits within a building. Questions arise as to what is the optimal voltage, how that affects the "efficacy" of services delivered (ie, the useful service obtained relative to power consumed), how it affects longer term electricity consumption for the services required by the building occupants, and the electrical overhead in running the voltage optimiser itself. Some thought must be given to these questions to determine how energy savings arise and how they should be evaluated and credited in SAP.

2) Optimal voltage

The standard voltage in domestic premises in the UK has historically been 240V, but a European Directive has set a European standard of 230V. The purpose of the Directive is to facilitate the common market for electrical goods in Europe. The allowable margin set by the Directive is ±10%, whereas in the UK the margin was previously ±5%. The effect of the wider margin is that no changes are necessary in the UK because 240V±5% (ie, 228-252V) is contained within the range 230V±10% (ie, 207-253V), and it is believed that no actual changes have been introduced; ie, the nominal voltage in the UK remains at 240 in most if not all premises. The actual voltage in buildings varies, of course, depending on the electricity distribution network and loading conditions.

As a consequence of the Directive it is expected that manufacturers of electrical products for the European market have now designed them for optimal performance at 230V. A voltage optimiser, if it regulates the voltage to 230, can take advantage of this.

3) Optimisers or reducers?

Some items of equipment described as voltage optimisers regulate their output to less than 230V. These should be called voltage reducers, rather than optimisers, as there is no reason to suppose a voltage other than 230 is optimal for power delivery to the range of available domestic electrical products. The power dissipated falls further and further as the voltage is reduced to zero; there is no "optimum", and the benefit or drawback of any particular lower voltage must be judged on the basis of the *service delivered* relative to the *power consumed*. This is termed efficacy (not efficiency) and will vary greatly according to the function and type of electrical product or appliance.

4) Efficacy of services delivered by electrical equipment

Efficacy (rather than efficiency) is the term used to describe useful output relative to power consumed. This is already well understood in lighting, where figures for luminous efficacy are readily available, but the concept applies to all electrical products. Unlike efficiency (which is a dimensionless ratio), efficacy has units – such as lumens/watt in the case of lighting. If efficacy can be raised by altering the voltage then there is an opportunity to save energy, as the same level of service can be provided for less power.

5) Evaluation for the purposes of SAP

SAP estimates the energy requirements for the provision of heating, hot water, ventilation, and lighting in dwellings. Electrical appliances are not regarded as part of the building and are not assessed individually. Nevertheless a typical figure is included for their annual energy consumption, related to floor area, in an occupied dwelling.

The purpose of SAP is to compare *buildings*, and one of the principles is that they should be compared on the basis of standard occupancy and equal service levels. If the effect of a voltage optimiser or reducer were to reduce service levels below requirements that would not be considered as an energy saving. A saving only occurs where the same service level can be provided with a smaller amount of energy; ie, with greater efficacy.

To establish the extent of savings it would be necessary to define a representative range of domestic electrical equipment and lighting, identify the useful functions it performs, and test it as described in sections (9) and (10). For all types of electrical equipment a method of measuring the critical output must be found, so that efficacy at different voltages can be determined. As the range of electrical products and appliances is very large it would be sensible to restrict testing to those whose efficacy is believed to be higher at a lower voltage (category (c) in section (6)). An assessment would then be made of what proportion they constitute.

Thermostatically controlled heating equipment need not be tested as it may be presumed lower instantaneous heat output is compensated by longer operating cycles. Thermostatically controlled cooling equipment (eg, refrigerators) may well behave the same way, and if it is to be tested the test period must be long enough to allow for the possibility of longer operating cycles needed to achieve the same cooling service.

Finally, electrical losses from the voltage optimiser/reducer equipment itself under the full range of loading conditions needs to be measured and an estimate of annual consumption prepared.

Uncontrolled field trials in dwellings are not an acceptable method of testing voltage optimisers/reducers because there are many reasons for day-to-day changes in the electricity consumption. They mask, and are likely to overwhelm, the effect of the optimiser/reducer. Only very large field trials, conducted with many participants over a long period, can reduce this inherent variability to a small enough element to be ignored. (The UK trials of smart meters were conducted in 40,000 households with a further 10,000 in a control group.) Moreover, any shortfall in service delivery relative to requirements cannot be measured in the field. As a voltage optimiser/reducer does not change the *demand* for services by house occupants, a reduction of service may be tolerated in the short term but not the long term: over a long period service levels will tend to revert to what they were before.

6) Variation of efficacy with voltage: categorisation

Dropping the voltage over a modest range, say from 230 down to 210, will have an effect on service delivered and power consumed that can be categorised as follows:

(a) the service delivered falls proportionately with drop in power. Efficacy is unchanged. This occurs, for example, in heating appliances that are simple resistive loads. If the lower voltage causes the electrical power to fall by 5% then the heat output (which is the useful service from a heating appliance) also falls by 5%. If the appliance is controlled by a thermostat then a longer time will be taken to produce sufficient heat to activate the thermostat.

(b) the service delivered falls at a disproportionately greater rate than the drop in power. Efficacy is reduced. This applies, for example, to traditional filament lamps, where the luminous efficacy (measured in lumens per watt) becomes lower as the voltage falls. This is a disadvantage, as to produce the same amount of lighting (in lumens) as before will require more lamps, or more powerful lamps, and a greater amount of energy will be consumed.

(c) the service delivered falls at a disproportionately smaller rate than the drop in power. Here dropping the voltage gives an advantage, as the efficacy (measured in useful output per watt) is raised. If the same level of service were to be provided at a lower voltage it would consume less power.

(d) the service delivered and power consumed remain the same, even though the voltage has been reduced. Examples are modern products and appliances that have their own internal power conversion and regulation circuits; typically audio-visual equipment, home computers, and other products with electronics operating at low voltages. Modern internal power supplies are themselves electronic, and capable of maintaining the same level of service and same power consumption irrespective of the voltage.

7) Power regulation in individual equipment

Much of the modern electrical equipment for use in homes now contains internal electronics for power conversion and regulation, and is expected to fall into category (d) of section (6) above. This extends even to CFLs, widely used as replacements for filament lamps. Household appliances have been the focus of regulatory attention for energy labelling for some years, and are now much more likely to include effective power regulation to improve their efficacy and hence the index of energy performance used on the label.

The effect of on-board regulation is that there should be little or no change in either the power consumed or the functional output of the device over a range of voltages. This expectation would have to be proved or disproved by testing.

8) Equipment without internal power regulation

The main examples are high-power heating apparatus, such as radiators, convectors, fan heaters, showers, immersion heaters, ovens, hobs, kettles, and toasters. These fall into category (a) of section (6) above, and as their functional output is heat there is no change in efficacy and no prospective energy saving from an optimiser/reducer. For equipment whose function is not to produce heat there may be disproportionate differences in the useful output and the power consumed as the voltage is varied, and – in some cases – there will be an advantage in altering the voltage.

It is possible, therefore, that some products have a higher efficacy at 230V than 240V. It is unlikely that efficacy will be greater at either lower or higher voltages than the design standard (230V), though that can be shown by experiment on individual products.

9) Testing for efficacy

Efficacy can be evaluated in a laboratory properly equipped to measure functional and electrical performance. As products have different functions it is essential to identify what they are and design the experiment so that they can be accurately measured and quantified. The laboratory experiment must be designed to measure how the *useful output* and the *power consumed* vary as the *voltage* is changed.

10) Longer term tests for a delivered service

Although a voltage optimiser or reducer may produce an immediate reduction in the instantaneous electrical power consumed, it is necessary to consider how consumption over a longer period is affected. This applies in particular to those that operate cyclically, as cycle times may be affected by voltage change.

11) Power losses incurred in running a voltage optimiser or reducer

Energy losses occur in voltage conversion equipment and it is necessary to measure them over the full power range in which a optimiser/reducer operates. From the results the annual energy losses must be estimated, using a realistic profile of variation in the domestic electrical load. If the optimiser/reducer is installed in heated living space the energy loss can be counted as an adventitious heat gain during the heating season.