Power Factor in street furniture

A variety of myths have developed about power factor correction for street furniture which this article seeks to clarify. This article does not aim to explain power factor, that is a challenge left to many engineering lecturers[1], but poor power factor has two impacts:

- the current in the supply cable increases, and then;
- the increase in current causes an increased heating affect.

Taking each in turn, using a typical street lighting situation where a column is connected by a length of service cable to a distribution main in the street. The service cable of this type is sized to support the fault current rather than the rated load. For example, a 16mm^2 specified cable, could carry a load of 95 amps, although in most street lighting situations it actually carries a load current of less than one amp. The distribution main cable in the typical residential street will be sized from 95 to 300mm^2 based on the connected consumers, volt drop, interconnection requirements, etc. In respect of the distribution main cable in a residential street, the street lighting load will be very low compared with the other connected customer load.

Current

The familiar formula for power is:

Power (watts) = current (amps) x voltage (volts) x power factor

For a nominal 70 watt SON lamp with a magnetic ballast the Elexon Charge Code identify it as actually consuming 90 watts. The 20 watts not consumed in the lamp are ‘wasted’ as heat in the ballast.

A lamp with a working or a failed power factor correction capacitor will have different power factors, typically:

@power factor of 0.90, Current = 90/(240 x 0.9) = 0.416 amps

@power factor of 0.60, Current = 90/(240 x 0.6) = 0.625 amps (50% increase)

These currents will not approach the service cable rating or the protective fuse (say 25 amps) of a typical street light column. Hence single columns with failed power factor correction capacitors continue to work perfectly normally.

The exception - The cables connecting a series of street lights along a motorway or trunk road *are* sized for the connected lighting load (and volt drop). On these dedicated private street lighting distribution cables, if the power factor capacitors were to fail at every column along the cable length, the current can increase so that the protective fuses of the cable blow due to excessive current. The fuses protect the cable from overload, exactly as they are designed to do.

[1] http://en.wikipedia.org/wiki/Power_factor

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Heating Effect

The second effect of poor power factor is that the increased current increases the heating effect of the supply cable. The heating loss is derived from:

Energy (watts) = Current (amps)^2 x Resistance (ohms)

The energy loss increases by the *square* of the current, so a small increase in current has a large impact on heating effect.

So assuming our lamp has a 5 metre service cable, and assuming the service cable has a cross sectional area of 16mm^2, which therefore has a resistance[2] of 0.0045 ohm/m. The heating loss is:

@power factor of 0.85	Energy = 0.416^2 x 0.0045 x 5	= 0.004 watts
@power factor of 0.60	Energy = 0.625^2 x 0.0045 x 5	= 0.009 watts

A difference in heating effect of 5 milliwatts. A tiny percentage (0.006%) of our 90 watt lamp consumption. In practice this is too small to notice, and swamped by the various other operating characteristics of different ballasts and lamps.

The loss in the distribution main will be even smaller due to the cable's much larger cross section and therefore lower resistance.

Distribution network companies already allow for the losses associated with distribution cables, transformers, theft, unrecorded units (e.g. incorrect street lighting inventories or unregistered meters) etc. Across the country the distribution network companies add between 5 and 9% to the assessed (or metered) energy to compensate for these losses, which more than allows for the 0.006% which may be attributable to poor power factor.

YALE Document

The YALE document "Power Factor Correction for Unmetered Supplies – An Environmental Discussion Document" has been published in various forums, including the members area of the ILE website[3]. Since we were first aware of the document we have expressed our concerns about its accuracy to the Yorkshire Purchasing Organisation.

The concerns include:

- the flawed conclusion of the potential saving in energy across the whole energy unmetered market, and
- the recommendation to replace failed power factor capacitors.

Section 8 of the YALE document concludes with a saving of 500,000 tonnes of CO_2 – an impressive saving, however the calculation is considerably different to that stated above. The calculation steps are not clear making it difficult to follow, nevertheless working backwards, these 500,000 tonnes of CO_2 using the quoted figure of 430g of CO_2/kWh equate to 1,162,790,698kWh - a lot of energy. In fact, the annual unmetered energy (mostly street lighting) in GB was 3,824,353,000kWh[4]. The implication is that if every lighting authority followed the YALE advice to replace failed power factor correction capacitors then GB can save £382million, or 30% of all the electricity consumed by street lighting – this is clearly not right!

[2] IEE Wiring Regulations. 17th edition, table 4H2B
[3] Link removed as no longer available
[4] Recorded unmetered consumption going through settlement in 2007/08, source: Elexon

Other Considerations

The EU wide standard BS EN 61000-3-2:2006, requires lighting equipment connected to a mains supply to have a ‘good’ power factor, but only when the equipment is above 25 watts. Similar standards exist in the US and across the rest of the world.

The distribution network operator connection agreement requires the connected load to be maintained above 0.85 or 0.9 power factor. However, there are no charges associated with poor power factor on unmetered equipment and no obvious method of introducing it on an equitable basis. If the distribution company indicated a breach of contract they would have to demonstrate the damages, the quantity of these damages is not apparent from the above analysis.

In some areas of the country the distribution network operator is requiring lighting loads above 500 watts to be metered. The metering for this size of load is similar to a domestic or small business customer and this metering equipment does not include reactive power measurement (until it gets above 70kW). Further indicating an inconsistent approach.

And finally, it should not be forgotten that the government is promoting domestic customers to install compact fluorescent lamps, these meet the EN61000-3:2006 as they are sized below 25 watts, but often have a poor power factor.

Power Data Associates Recommendations

Most Lighting Authorities are already installing electronic ballasts on a new and replacement basis. This is welcomed, and has a genuine business case. An electronic ballast generally always keeps the power factor near to unity, and most importantly has lower losses in the ballast. For example a 70 watt SON lamp with electronic ballast, Elexon assess as consuming 79 watts, a saving over a magnetic ballast of 11 watts for every hour operating, or 12% of real energy reduction, a real CO_2 saving, and a real year-on-year financial saving. This equates to a financial saving for dusk-dawn operation at today’s typical energy prices of £3.85/lamp/year.

Many lighting authorities are developing various ‘invest to save’ schemes, including:

- Disconnect unnecessary lighting/signs
- Part night lighting
- Part night dimming of lighting
- Centrally Managed Systems to give variable lighting and switching.

Most of these initiatives rely on electronic ballasts, all have their advantages/disadvantages. Power Data Associates operate as a Meter Administrator and are happy to discuss how lighting authorities can maximise the energy cost savings from these for each of these schemes.

Tom Chevalier MIET, would like to thank the many reviewers for their many comments and suggestions.

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