TECHNICAL BULLETIN

THE EFFECT OF LOW VOLTAGE POWER FACTOR CORRECTION ON LOSSES AND CO_2 EMISSIONS IN THE UK TRANSMISSION AND DISTRIBUTION SYSTEMS

NOVEMBER 2011

As a result of various market activities, driving forces and technical considerations in Industry over a number of years, there is a quantity of existing Power Factor Correction (PFC) equipment installed and operational across the UK.

This existing PFC equipment is providing significant benefit to the UK Transmission and Distribution network, as:

- the power factor is being improved from its natural, uncorrected level of **0.887** to a higher level of **0.941**
- the Transmission and Distribution systems are being 'off-loaded' by approx. **6%**
- losses in the Transmission and Distribution networks are being reduced by some **2,269GWh** per annum
- CO_2emissions are being reduced by some **1.24 million tonnes** per annum
- A reduction in CO_2 emissions for the whole of the Electrical System in the UK of **0.6%** of all power generated is being achieved

With the appropriate incentives in place to further promote the uptake of PFC equipment by raising the nominal target power factor from 0.95 to 0.97, additional benefits would be achieved, as:

- the power factor would be **further** improved from its present level of **0.941** to **0.982**
- the Transmission and Distribution systems would be 'off-loaded' by approx. **10%**
- a **further** reduction in system losses of **1,479GWh** would be achieved
- a **further** reduction in CO_2 emissions of **0.81 million tonnes** would be achieved
- a **total** reduction in system losses of **3,748GWh** would be achieved
- a **total** reduction in CO_2 emissions of **2.04 million tonnes** would be achieved
- the reduction in CO_2 emissions for the whole of the Electrical System in the UK attributable to PFC equipment would be **1.0%** of all power generated

The effect of each kVAr of PFC equipment presently installed on the UK Electrical System is

- a reduction in network losses of **267kWh** per annum
- a reduction in CO_2 emissions of **146kg**[(1)] per annum

Without the appropriate incentives, the installation of PFC equipment will continue to decline, resulting in an increase in system losses and CO_2 emissions of over **1.8million tonnes** per annum. In light of the projected increase in demand for Electricity in the coming years, these benefits should be viewed as conservative estimates of the total benefits available in the future.

To implement this positive change would be very straightforward, as

- the mechanisms are already in place (half-hourly tariffs)
- the existing PFC industry in the UK has the capacity to support the increase in demand

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Notes

(1) This figure supersedes previous, less well documented, figures published by the BCMA.

Calculation

The procedure by which these results are obtained (with data as published for 2009) is:

1a – 'by sector' values of natural or un-corrected power factors agreed by the BCMA, based on over a collective century of practical industry experience and testing.

1b – figures taken from the DUKES report for 2009, 311-DUKES-2010-Ch5, indicating the 'by sector' consumption of electricity.

Results: the 'uncorrected' power factor for the whole system is 0.887
the 'existing' power factor for the whole system is 0.942
the 'improved' power factor for the whole system (with the target raised from 0.95 to 0.97) would be 0.982.

see table 1 below

table 1

DUKES 2009 energy consumption by sector and BCMA estimates of natural and 'existing corrected' power factors

from DUKES report			BCMA estimate and subsequent calculation										
Sector	%age	GWh	Natural Power Factor	Corrected Power Factor	Target Power Factor	natural GVAh	natural GVArh	corrected GVAh	corrected GVArh	existing GVArh(C)	target GVAh	target GVArh	additional target GVARh(C)
Industry	26.00%	98079	0.800	0.910	0.970	122599	73559	107779	44686	28873	101112	24581	20105
Domestic	32.00%	122543	1.000	1.000	1.000	122543	0	122543	0	0	122543	0	0
Transport	2.00%	8764	0.950	0.950	0.970	9225	2881	9225	2881	0	9035	2196	684
Public Admin.	5.00%	19073	0.900	0.970	0.970	21192	9237	19663	4780	4457	19663	4780	0
Commercial	19.00%	70191	0.870	0.900	0.970	80679	39779	77990	33995	5784	72362	17592	16404
Agriculture	1.00%	3766	0.850	0.850	0.970	4431	2334	4431	2334	0	3882	944	1390
Energy Ind.	8.00%	29386	0.750	0.870	0.970	39181	25916	33777	16654	9262	30295	7365	9289
										0			0
losses	7.00%	26912	1.000	1.000	1.000	26912	0	26912	0	0	26912	0	0
										0			0
Total	100.00%	**378714**	**0.887**	**0.941**	**0.982**	426762	153706	402320	105330	**48377**	385804	57458	**47872**

2 – Figures taken from the National Grid Seven Year Statement 2009

Results: the average of winter and summer power factors for the whole system is 0.942 (agreeing closely with **(1)** above)

3 – Calculation of the 'existing' reactive power consumption and apparent power consumption, enabling the reactive power being supplied by 'existing' PFC equipment to be calculated. Similarly, calculation of the apparent and reactive power consumption for the 'improved' power factor condition proposed, enabling the additional reactive power required to be calculated.

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Results: 'existing' PFC equipment is providing 48,377GVArh per annum

An additional 47,872GVArh is required to achieve the proposed 'improved' power factor

4 – From 311-DUKES-2010-CH5 5.8 and 5.13, the total losses in the system for 2009 were 26,912GWh, of which 22% occurred in the Transmission network, 74% occurred in the Distribution network, and 4% were attributed to unmetered supplies, theft and fraud.

From the Ofgem Distribution Losses Consultation 2003, approx. 70% of system losses are current dependant and 30% are fixed.

Consequently, (70% x 74%) + (70% x 22%) = 67.2% of the total losses are current dependant.

Of the whole 26,912GWh of losses, those which are dependant on the current in the network which may be addressed by PFC equipment are 67.2% of the whole, or some 18,085GWh.

5 – Consideration of the Reduction in losses and emissions due to existing PFC equipment. System losses which are current dependant vary as the square of the current. The current in the system varies as the inverse of the power factor.

On a change in the power factor from PF1 to PF2, for an otherwise constant load, the current will increase by the ratio PF1/PF2. If the change is the result of an increase in power factor, this will result in a decrease in current.

The losses in the system will change by the ratio $(PF1/PF2)^2$

With current dependant losses of 18,085GWh, PF1=0.887 and PF2=0.941, then

'uncorrected' losses x $(0.887/0.941)^2$ = 18,085GWh

i.e. 'uncorrected' losses = $(0.941/0.887)^2$ x 18,085 = 20,354GWh

i.e. the existing PFC equipment is achieving a reduction in system losses of 20,354 - 18,085 = 2,269GWh

At the equivalence of 0.54522kg CO_2 per kWh, this corresponds to an 'existing' reduction of 1.24 million tonnes or 11.1%.

6 – Further reduction in losses due to a further improved power factor

As in **(5)**, with 'existing' current dependant losses of 18,085GWh, PF1=0.941 and PF2=0.982, the losses with improved power factor would be:

'improved' losses = 18,085 x $(0.941/0.982)^2$ = 16,606GWh

A further reduction of 18,085 – 16,606 = 1,479GWh or 0.81 million tonnes of CO_2.

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The combined reduction of both the 'existing' and 'proposed' PFC equipment would be reductions of 3,748GWh and 2.04 million tonnes of CO_2.

7 – if the PFC equipment is operational for an average of 5,694 hours a year (a load factor of 65%, typically associated with a '2 shift plus overtime' working pattern), then a total of 48,377GVArh/5694 = 8.5GVAr of PFC equipment is already operational.

A further 47,872GVArh/5694 = 8.4GVAr of PFC equipment would be required to achieve the improved power factor.

Associating the existing reduction in losses of 2,269GWh with the existing 8.5GVAr suggests a reduction in losses of 267kWh per kVAr per annum, a reduction in CO_2 emissions of 146kg/kVAr.

Associating the 'improved power factor' additional reduction in losses of 1,479GWh with the 8.4GVAr required suggests a reduction in losses of 176kWh per kVAr per annum, a reduction in CO_2 emissions of 96kg/kVAr.

Associating the total reduction in losses of 3,748GWh with the total 16.9GVAr suggests a reduction in losses of 222kWh per kVAr per annum, a reduction in CO_2 emissions of 121kg/kVAr.

Refinements

The accuracy of this calculation could be improved by including consideration of:

- the losses occurring within the PFC equipment
- the reduction in losses achievable within a consumers' network which are identified by the metering system as consumption rather than losses

Previous studies by B. Oliver show that the reduction in losses within a local network is approx. 50% greater than the losses within the PFC equipment itself, suggesting that the figures proposed in this document for loss reduction and CO_2 abatement are conservative estimates.

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Based on previous work by B. Oliver F.I.E.T