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The influence of Lighting Equipment on the Power Quality of the Grid

- Lighting equipment, which complies with **primary metrics and the corresponding international requirements** does not have any negative effects on the power quality of the grid
- ELC recommends the **use of primary metrics** instead of the composite metric, as this helps regulators to monitor and regulate the real causes of PQ issues.
- **Power Quality requirements** for lighting equipment are more stringent than any requirements for any other electronic equipment
- **Local grid capacities and dynamics** must be taken into account in order to avoid overly rigid PQ requirements which would negatively impact the successful introduction of energy efficient lamps into the market.

Discussion on Power Factor

The question as to whether the power factor of lighting equipment has had a significant impact on the grid has been an on-going discussion ever since the first compact fluorescent lamps (CFLs) entered the market.

This discussion is timelier than ever, particularly due to the fact that the recent wave of incandescent phase-outs is spreading worldwide. Alternative lighting technologies requiring integrated or external electronics to operate lamps such as low and high intensity discharge and LEDs- are therefore likely to dominate the consumer market in the near future.

The move to energy efficient technologies with decreased peak-load demands will result in reducing the strain on many overloaded grids. The technical challenge of being able to replace incandescent technologies effectively is a significant one. The main barriers to achieving their savings potential include their initial high price, size and reliability. The political decision on whether or not to make the use of high power factor (HPF) lamps compulsory will on many occasions have an impact on these barriers.

The decision to bring in HPF or low power factor (LPF) lamps into the market remains in the hands of policy makers. Given the information currently available is complex and does not always address all the relevant policy considerations, this may lead to decisions being taken which do not maximize the potential benefits of using energy efficient lighting solutions.

Power Quality

The influence of the new lighting solutions on the Power Quality (PQ) of the grid is a key factor with regards to the introduction of energy saving lamps into the market.

The ELC position paper "Mains power-quality effects by electronic lighting equipment" of May 2009 [1] showed that the requirements of the internationally accepted regulations [2][3] and standards [4] - managed by the relevant stakeholders (grid operators, test laboratories, manufacturers) - sufficiently safeguard the PQ of the grid. This has been reconfirmed by recent independent studies [5][6][7] . No negative effects on the grid are therefore to be expected from energy-saving lamps which will comply with these regulations and standards in the near future.

Due to future developments such as e.g. the charging of electrical cars, decentralized energy generation of wind and solar systems, it is not yet possible to predict how the grid will function in 20 years time. We therefore believe that no long-term conclusions should be drawn. The issues should be addressed as and when relevant standards are due for revision.

Finally it should be emphasized that the metric Power Factor (*PF*), which is used to quantify the effect of lighting equipment on the PQ of the grid, is not the most effective metric. The reason is that the *PF* metric is a composite metric consisting of the primary metrics displacement factor ($\kappa_{displacement}$) and distortion factor ($\kappa_{distortion}$).

The relation between the composite metric $PF\ (\lambda)$ and its primary $\kappa_{displacement}$ and $\kappa_{distortion}$ metrics is demonstrated in the following equations:

$$PF\ (\lambda) = \kappa_{displacement} \cdot \kappa_{distortion}$$

with

$$\kappa_{displacement} = \cos\varphi_1$$

and

$$\kappa_{\text{distortion}} = \frac{1}{\sqrt{1+THD_i^{\,2}}}$$

resulting in

$$PF(\lambda) = \frac{\cos\varphi_1}{\sqrt{1+THD_i^{\,2}}}$$

Note: Linear loads have no distortion ($THD_i = 0$). In that case $PF\ (\lambda) = \cos\varphi_1$

Angle φ_1 is the phase angle between the fundamental of the supply voltage and the fundamental of the mains current. The Total Harmonic Distortion (THD_i) is quantified by the harmonics of the mains current, which are already regulated according to the international standard IEC 61000-3-2. The relation between the individual harmonics of the mains current and the THD_i is explained in the equation:

$$THD_i = \sqrt{\sum_{n=2}^{\infty}\left(\frac{i_n}{i_1}\right)^2}$$

where i_n is the amplitude of the n^{th} harmonic of the mains current.

The relation between potential PQ issues and the fundamental metrics is described in table 1.

Potential PQ issue:	Cause:	
	Displacement	Distortion:
Additional losses in the grid	Yes	Minor effect
Overload of the PEN conductor	n.a.	Yes
Distortion of the mains-voltage	n.a.	Yes

Table 1: Potential PQ issues and their causes

ELC position on Power Quality

ELC would like to emphasize that no negative effects on the grid are to be expected from lighting equipment which complies with the following primary metrics and the corresponding international requirements:

Table 2: Lighting Equipment (except mains-voltage self-ballasted lamps):

Metric	Limit *)		
	P ≤ 5W	5W < P ≤ 25W	P > 25W
$\kappa_{displacement}$ $(\cos\varphi_1)$	No Limit	≥ 0.7	≥ 0.9
$\kappa_{distortion}$ Regulated by IEC 61000-3-2	No Limit	Clause 7.3b	Clause 7.3a

Table 3: Mains-voltage self-ballasted lamps

Metric	Limit *)			
	P ≤ 2W	2W ≤ P ≤ 5W	5W < P ≤ 25W	P > 25W
$\kappa_{displacement}$ $(\cos\varphi_1)$	No Limit	≥ 0.4	≥ 0.7	≥ 0.9
$\kappa_{distortion}$ Regulated by IEC 61000-3-2	No Limit	No Limit	Clause 7.3b	Clause 7.3a

** These limits are set and continuously monitored by the regional regulators and the International Electronic Committee (IEC).*

In addition, these PQ requirements for lighting equipment are more stringent than requirements for any other electronic equipment.

Local grid capacities and dynamics must be taken into account in order to avoid overly rigid PQ requirements which would negatively impact the successful introduction of energy efficient lamps into the market.

ELC strongly recommends the use of primary metrics instead of the composite metric, as this helps regulators to monitor and regulate the real causes of PQ issues. It also provides guidance to installers and end-users on how to correctly select and implement lighting equipment.

About the European Lamp Companies Federation (ELC)

As a federation committed to addressing sustainability issues, ELC supports and promotes initiatives to switch to new lighting solutions which will improve the comfort of artificial light whilst reducing the ecological footprint of our products. Our aim is to:

- *Provide excellent light quality – to increase visibility and visual comfort*
- *Supply energy-efficient lighting solutions – to reduce energy consumption and costs*
- *Care for the environment – by helping to reduce carbon emissions and minimizing the use of hazardous substances.*

We believe that the interests of end-users, consumers and customers are best served by the creation of an appropriately regulated and effectively monitored market that offers competing manufacturers a genuinely level playing field.

References

[1] European Lamp Companies Federation position paper, Mains power-quality effects by electronic lighting equipment, 18 May 2009 (see http://www.elcfed.org/).

[2] Ecodesign Directive: European Directive for the setting of Ecodesign requirements for Energy related Products 2009/125/EC: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:285:0010:0035:en:PDF

[3] Ecodesign Implementing Measure Domestic Lighting phase 1: Commission Regulation (EC) No 244/2009 of 18 March 2009 and amendment 859/2009 of 18 September 2009. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0003:0016:EN:PDF http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:247:0003:0005:EN:PDF

[4] International Electrotechnical Commission Standard IEC 61000-3-2, Limits for harmonic current emissions.

[5] S.K. Rönnberg, M.H.J. Bollen, M. Wahlberg, Harmonic emission before and after changing to LED and CFL - Part I: laboratory measurements for a domestic customer, ICHQP 2010, Bergamo, September 2010.

[6] S.K. Rönnberg, M. Wahlberg, M.H.J. Bollen, Harmonic emission from a hotel before and after changing to CFL and diode lamps, ICHQP 2010, Bergamo, September 2010.

[7] E. Page, M. Ton, Power Factor: Policy Implications for the scale-up of CFL programs, USAID | ASIA, December 2010.