Power Quality Effects of CFLs – A Field Study

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ABSTRACT

The energy advantages and disadvantages of compact fluorescent lamps (CFL) have been debated during the last few years. The main advantages are low energy consumption and long life. The main disadvantages are low power factor and high harmonic distortion. Since the power utilities and their customers are showing an increased concern about the power quality aspects, there are some mixed feelings towards CFLs.

In order to estimate the power quality effects of CFLs, NUTEK has designed and conducted a field test in a residential district in a Stockholm suburb.

The purpose of the test was to determine the effects of an increased use of CFLs on the harmonic distortion of the electrical feeding system. The test results shall constitute a basis for forming NUTEK's future policy regarding promotion of CFLs in Sweden.

The test was divided in two phases:

Phase 1: Measurements in a one-family house.

The measurements were taken first without CFLs and then after installing five CFLs. The purpose of Phase 1 of the test was to determine the characteristics and harmonic spectra from several CFLs as well as to estimate the risk of overloading conductors and other network components in a villa or apartment with CFLs.

Phase 2: Measurements in a residential district.

The measurements were taken in a residential district consisting of 17 houses at existing load and then after installing of three and six CFLs respectively in each house. The purpose of Phase 2 of the project was to determine the changes in harmonic distortion caused by installing a larger number of CFLs in the system and to evaluate the summation and cancellation effects.

CURRENT CURVE AND HARMONIC SPECTRUM FROM CFLS

CFLs are fed by power supply units which conduct the current only during a very small part of the 50 or 60 Hz period so that the current taken from the AC net has the shape of a short impulse. The remaining part of the sine wave is returned to the AC network producing distortion of the current wave of the supply system. The distorted current wave can be analysed using the Fourier Theorem and thus be represented by the fundamental sinusoidal component and a series of higher order harmonic components at frequencies that are integer multiples of the fundamental frequency, normally called ”harmonics”.

Fig. 1 shows the current wave and harmonic spectrum from four CFLs from OSRAM (2x11W+2x7W).

Harmonic spectra for the different lamp types used in the study are presented in figure 2, where:

Type 1 = OSRAM 2x11W+2x7W
Type 2 = Philips 11W+2x9W+5W
Type 3 = GE 15W+2x11W+2x7W.

The graph shows the Individual Harmonic Distortion expressed in percent of the fundamental current and the Total Harmonic Distortion (THD) defined by the formula:

$$THD = \frac{\sqrt{\sum_{n=2}^{40} I_n^2}}{I_1} \times 100\%$$

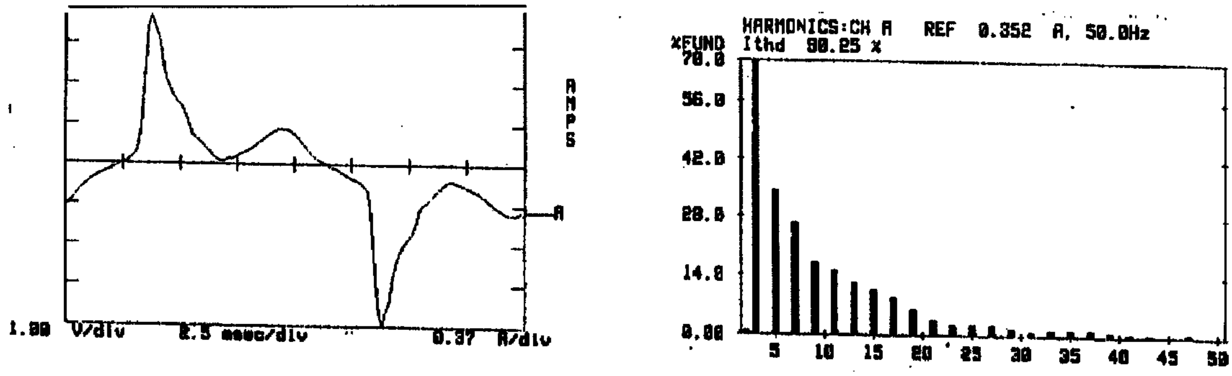

Fig. 1. Current wave and harmonic spectra for 2x11 W + 2x7 W CFLs.

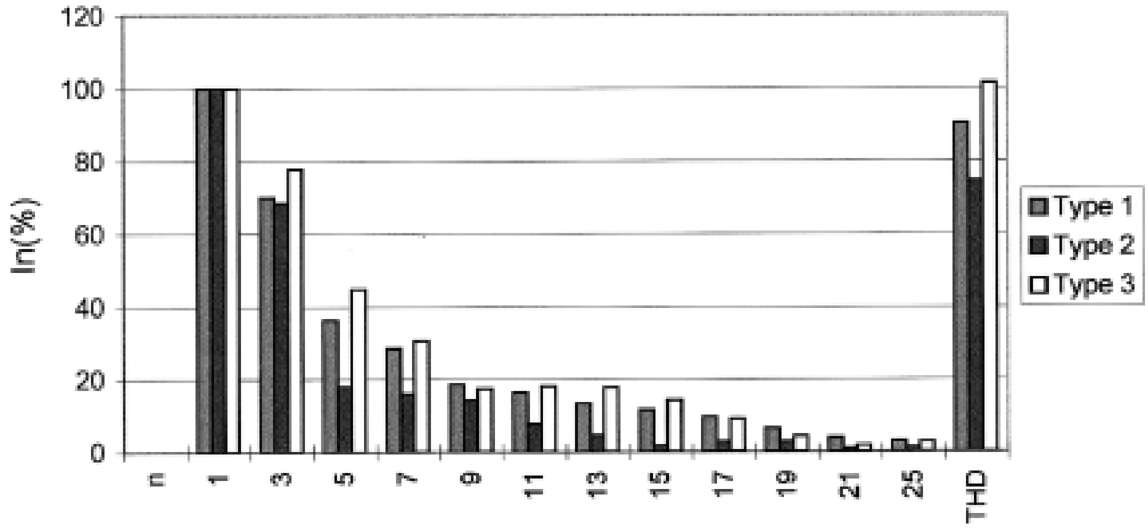

Fig. 2 Harmonic spectra for different lamp combinations

The spectrum of the current is characterised by a very high third harmonic component. Magnitudes of the higher harmonics are decreasing with the harmonic order. The Total Harmonic Distortion of the current (ITHD) is between 85% and 103%.

MEASUREMENTS IN A ONE-FAMILY HOUSE

The biggest problem when installing non linear loads in apartments is the risk of overloading the neutral conductor. Normally, the current through the neutral is very low and consequently, the neutral conductors are not protected by fuses. Recent studies have shown however, that nonlinear loads can generate significant amounts of the third harmonic which lead to overloading of the neutral conductors. The fundamental- and harmonic currents in the neutral during different operation conditions have been therefore recorded. Fig. 3 shows the maximum values of the neutral current prior to the installation of CFLs (Measurement 1) and with CFLs in the following combinations:

Measurement 2: OSRAM (15W+2x11W+2x7W)

Measurement 3: OSRAM (15W+11W+7W) + Philips (15W+9W)

Measurement 4: Philips (15W+11W+2x9W+5W)

The duration of each measurement was 48 hours. The lamps were switched on during the whole test period while all other apparatus were operated according to normal household routines.

The last bar in the diagram (Figure 3) shows the RMS value of the harmonic currents.

The load in a typical Swedish household mainly consists of single-phase apparatus such as a dish-washer, a washing-machine, a TV, a VCR, a PC, a coffee machine, etc. The measurements show, that at some operation modes, the load in the three phases is asymmetrical resulting in high neutral current. The fundamental component of the neutral current has reached the value of 9 A while the maximum RMS value of the harmonic currents was 1,9 A and was basically unaffected by the CFLs. It can therefore be concluded that the effect of harmonic currents from the CFLs is negligible compared to the total load of the neutral conductor.

Since the results of Phase 1 of the study proved that installation of a few CFLs will not create any overload problems in the houses, we could proceed with the next phase and investigated the effects of installing a large number of CFLs on the power quality of the network.

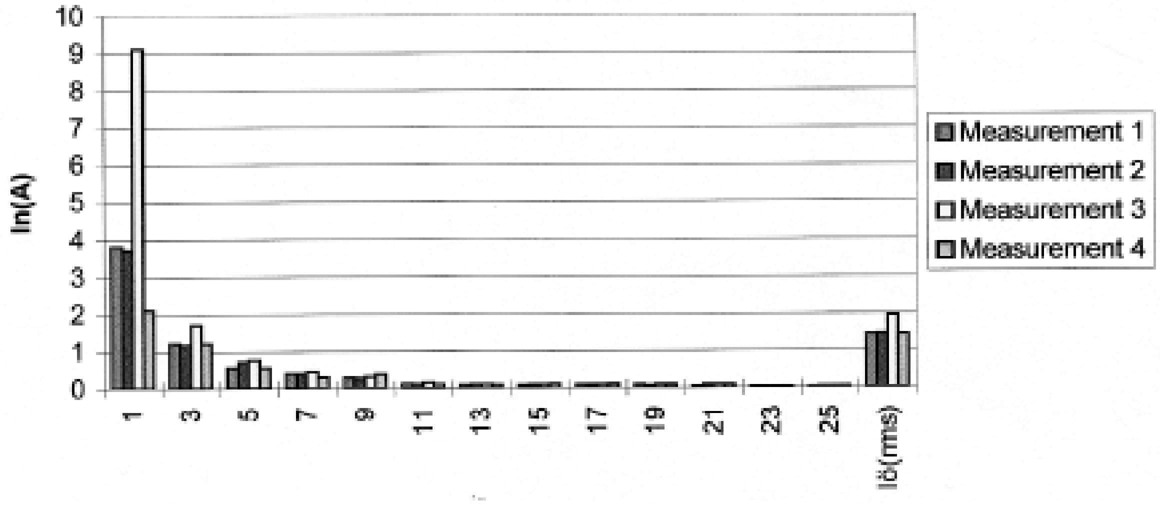

Figure 3. Maximum neutral currents.

Table 1. List of lamps installed in Steps 2 and 3.

Step 2:				
GE Lighting	4x7W	9x11W	2x15W	
Osram		6x11W	8x15W	
Philips	5x9W	4x11W	7x15W	
Sylvania	5x7W	7x11W	1x15W	
Step 3:				
GE Lighting	2x7W	3x11W		
Osram	8x7W	4x11W	3x12W	4x15W
Philips	3x7W		16x15W	
Sylvania	1x7W	4x11W		

MEASUREMENTS IN A RESIDENTIAL DISTRICT

The Phase 2 of the project was conducted in co-operation with the local power company, house owners, and CFL manufacturers (GE Lighting, OSRAM, Philips and Sylvania).

As a test location we have selected a part of a residential district consisting of 17 one-family houses in a suburb of Stockholm (Huddinge). The houses are almost identical. Only one apartment has electrical heating, the others are connected to a central heating system.

The supplying network was arranged in such a way that the test object was fed by a specially designated cable. As step 1, the currents and voltages of the existing load were recorded over the course of one week in 10-minute intervals. After that, the CFLs were installed in two steps. The aim of the first step was to install three lamps in each house (Step 2) and the aim of the second step was to increase the number of lamps in each house to six (Step 3). In practice the lighting arrangements in the apartments meant that in the first round, 58 CFLs were installed with the total power of 664 W and in the second round, 48 CFLs were installed with the total power of 555 W. A complete list of the types and sizes of lamps installed in Steps 2 and 3 is presented in Table 1.

After each installation round, one week's measurements as described for Step 1 were performed.

The results of the measurements are presented in Figures 4-6. Since the test object constitutes only a small part of the total load of the transformer, it is difficult to make an unequivocal interpretation of the test results.

First of all, the effects on the current- and voltage distortion will be different as the current measurements reflect changes of the harmonics in the test object while the voltage measurements reflect changes of harmonics in the total transformer load.

Fig. 4 shows the bar diagram of the maximum values of the harmonic currents.

It can be concluded that the third harmonic is the highest component of the harmonic spectrum both with CFLs and without CFLs. After the installation of 58 CFLs (3,35 CFLs per house), the third harmonic current has increased by 0,93 A and after installation of 106 CFLs (6,23 CFLs per house) the third harmonic current has increased by 1,34 A. Also the fifth harmonic current has increased by 0,54 and 0,67 A respectively. Meanwhile, it can be assumed that the reduction of the fundamental current due to the replacement of incandescent lamps by CFLs is about 20 A. Totally then, we can count on reduction of current in the phase conductors.

Fig. 5 shows the bar diagram of the maximum values of the harmonic currents in the neutral.

Also in this case the third harmonic is the biggest component of the current spectrum.

After the installation of 58 CFLs (3,35 CFLs per apartment), the third harmonic current has increased by 0,55 A and after installation of 106 CFLs (6,23 CFLs per apartment) the third harmonic current has increased by 0,63. The other harmonics have changed very slightly.

It can be concluded that the harmonics from the CFLs constitute a very small part of the total harmonic current in the neutral which means that the major part of harmonics is generated by other loads i.e. radios, TVs, VCRs, PCs and other electronic equipment. It can also be seen that the fundamental component represents the largest

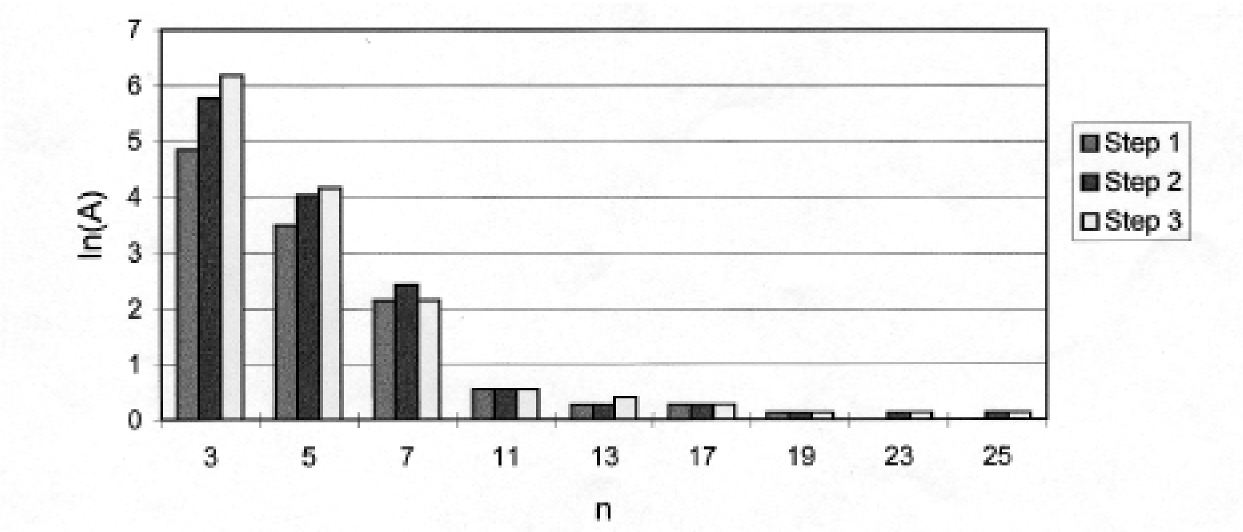

Fig. 4. Maximum phase currents.

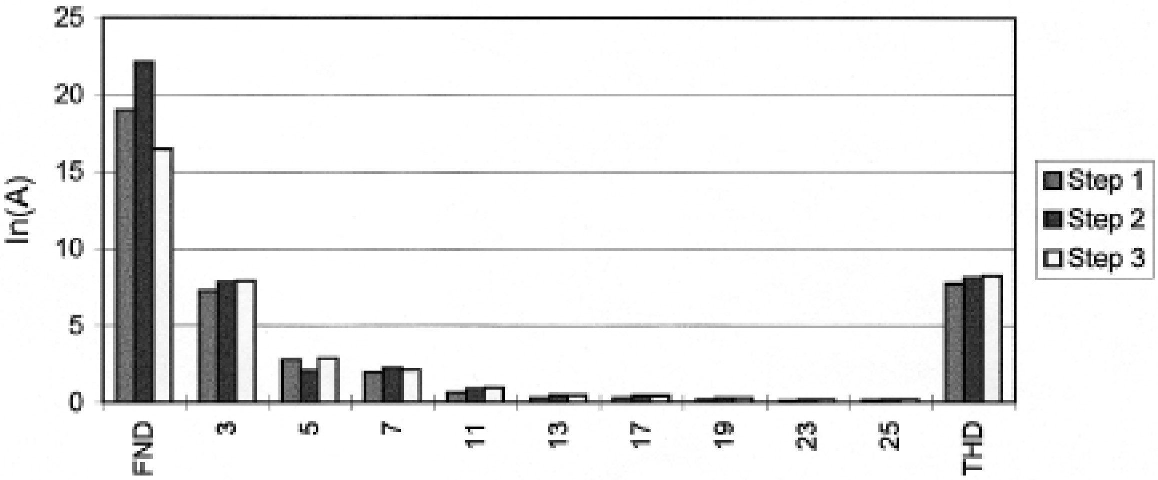

Fig. 5 Maximum currents in the neutral.

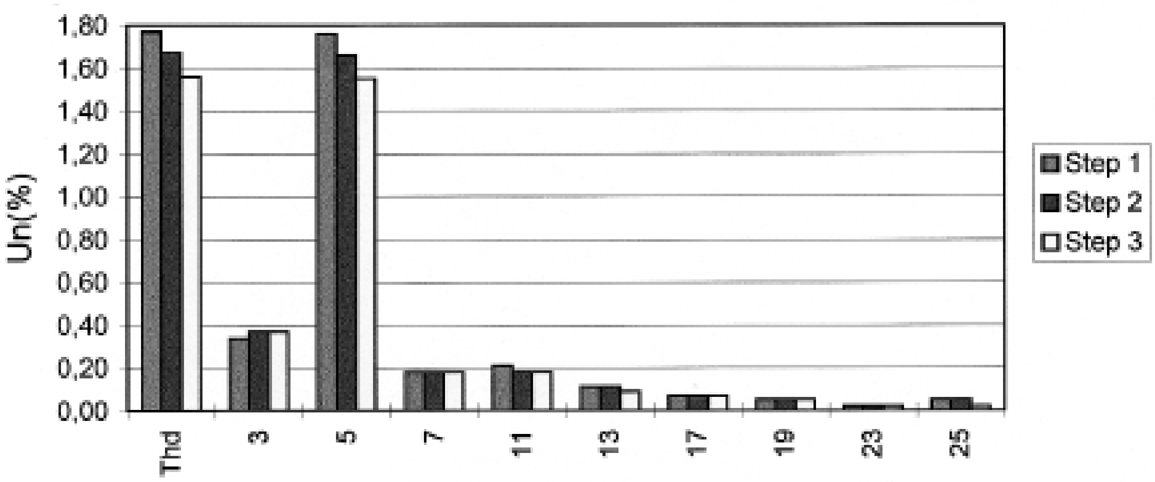

Fig. 6 Voltage distortion.

part of the current in the neutral. Compared with the total neutral current the contribution from the CFLs is negligible.

The results of voltage measurements are presented in Figure 6.

It can be concluded that the distortion on the 400 V busbar is rather low. The voltage distortion is basically due to the fifth harmonic. It is interesting to note that installing CFLs resulted in a reduction in voltage distortion instead of the expected increase. That may depend on a cancellation effect of harmonics from CFLs and from other harmonic sources. Because of the limited extent of the study we can not make any final conclusions on this aspect. The phenomena will be however investigated further.

SUMMARY

The study shows that replacement of incandescent lamps with CFLs is beneficial both for users and for utilities. The main advantages of CFLs are:

- reduced energy consumption
- long lifetime
- released capacity of the distribution system

High harmonic distortion is the main reason that utilities hesitate to advocate increased use of CFLs. They focus mainly on the high relative current distortion. It is true that for CFLs, the relative current distortion expressed in percent of the fundamental may exceed 100%. However, since fundamental current is very low (ca 110 mA for a 11W lamp), the values of harmonic currents are very low too. It is important to note that using CFLs reduces the total current in the distribution system; for example, the current drawn by 240W incandescent lamps is ca 1 A while the current drawn by CFLs with the same light intensity is only 0,5 A rms. Also the effects on voltage distortion and on the current in the neutral conductor has shown to be much more favourable than expected:

• The voltage distortion on the 400 V busbar has decreased by 0,2%.

• Harmonic current in the neutral conductor has increased by 0,63 A which is negligible compared to the total neutral current.

The results indicate, that the harmonic generated by the CFLs in residential districts have only a minor effect on power quality of the supply network. ●