Effect of Temperature on Low Frequency Noise Emission from Modern Lamps

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Abstract: The increased usage of modern lighting lamps produces increased electromagnetic emissions. From the frequency point of view the conducted electromagnetic emissions are divided into two groups: low frequency emissions and high frequency emissions. The electronic devices, which contain single phase rectifiers, have significant harmonics emissions. Modern lamps are driving by electronic ballast, which contains single phase rectifiers. The modern lamps are nonlinear loads and introduce harmonic distortions in power supply lines comparison to incandescent lamp which has no harmonics emission. Lighting is highly sensitive to rms voltage changes; even a slight deviation (of the order of 0.25%) is perceptible to the human eye in some types of lamps. Superimposed interharmonic voltages in the supply voltage are a significant cause of light flicker in both incandescent and fluorescent lamps [1]. Power Factor PF and Total Harmonic Distortion THD provide a quantitative measure of the power quality in an electrical system. The THD emission of a lamp could be influenced by temperature. The amount of useful power being consumed by an electrical system is predominantly decided by the PF of the system [2].

Keywords: keyword1; keyword2; keyword3; etc. 9 pt Justify Power Factor; Total Harmonic Distortion; electronic ballast; modern lighting

1 Introduction

Replacing of the incandescent bulbs are doing continuously. The main reason of replacing is the low efficiency of the incandescent bulbs. Using of modern lamps conduct to a decrease of energy consumption in lighting field. The energy saving is an important thing, which the modern lighting try to fulfil, but the apparition of modern lamps determines new questions. One of them is electromagnetic compatibility – EMC [3]. All the modern lamps: compact fluorescent lamps, induction lamps, LED, are driven by electronic ballasts. It is well known that the functionality of the electronic ballast is accompanied by noise emissions. This noise emission has low and high frequencies. The spreading path of electromagnetic noise are next: conducted through power and signal cable and radiated. The conducted emission is divided in two groups: low frequency conducted emission as harmonic and flicker emission. The low frequency conducted emissions are noise emissions up to 9 kHz. The high frequency conducted emissions are noise emissions between 9 kHz-30 MHz In case of modern lighting the low frequency, noise is mean typically the harmonic emission. The flicker emission does not represent a problem in case of lighting lamps.

2 Harmonic and total harmonic distortion

If a non-linear load is connected to the power system, it draws a current that is not sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. The current waveform is described with the help of Fourier series analysis [3]. It is divided into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency.

The voltage from power source is distorted by current harmonics due to source impedance. If the voltage source has small source impedance, the current harmonics will cause only small voltage harmonics. This is the case when voltage harmonics are small compared to current harmonics. It is typically for lighting electronic ballast.

Total Harmonic Distortion (THD) is a measurement of the level of harmonic distortion present in power systems. Total harmonic distortion can be related to either current harmonics or voltage harmonics, and it is defined as the ratio of total harmonics to the value at fundamental frequency times 100% [4].

$$THD_V = \frac{\sqrt{V_2^2 + V_3^2 + \Lambda + V_n^2}}{V_1} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{n} V_k^2}}{V_1} \cdot 100\% , \quad (1)$$

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + \Lambda + I_n^2}}{I_1} \cdot 100\% = \frac{\sqrt{\sum_{k=2}^{n} I_k^2}}{I_1} \cdot 100\% , \quad (2)$$

where V_n is the RMS voltage of k-th voltage harmonic; I_n is the RMS current of the k-th current harmonic; k=1 fundamental frequency.

3 Effects of harmonics

Motors and generators

The voltage and current harmonics in motors and generators increase heating due to iron and cooper losses at the harmonic frequencies, and affects the efficiency and developed torque as well. The harmonic currents in a motor can raise the audible noise emission, and produce a resultant flux distribution in the air gap. The fifth and seventh harmonics can create mechanical oscillation in a turbine-generator combination or in a motor load system.

Transformers

Current harmonics cause an increase in cooper losses and stray flux losses. Voltage harmonics cause an increase in iron losses. The result is transformer heating increases. The losses increase with frequency. The higher frequency harmonic components are more important than the lower frequency component. Another effect of harmonics is increasing audible noises.

Power cables

If cables take part in a resonance system, the cables could be affected by voltage stress and corona, which can produce dielectric failure.

Capacitors

The reactance of a capacitor bank decreases with frequency, and the bank acts as a sink for higher harmonic currents. This effect increases the heating and dielectric stresses.

Electronic equipment

Electronic devices, which are sensitive to the zero-crossing point of the voltage waveform, can be affected by harmonic distortion. Harmonics can shift the voltage zero crossing or the point at which one phase-to-phase voltage becomes greater than another phase-to-phase voltage.

Other types of electronic devices can be affected by transmission of ac supply harmonics through the equipment power supply or by magnetic coupling of harmonics, which can produce malfunctions of device. The harmonic voltage distortion factor has to be no more than 5% and the largest single harmonic no more than 3% [5].

4 Measurement system

IEC 61000-3-2 is the standard, which describes the harmonic measurements method for lighting equipment. The measurement system is presented in *Fig 1*.

The power supply of the measurement system has to be a 'clean supply' with a stable voltage, frequency and poor harmonic emission.

The voltage of power supply has to be the same as the rated voltage of the device under test. In the case of 220V – 240V voltage range, the test voltage has to be 230 V. The variation of test voltage has to be within ±2.0% and the frequency within ±0.5% of the nominal value.

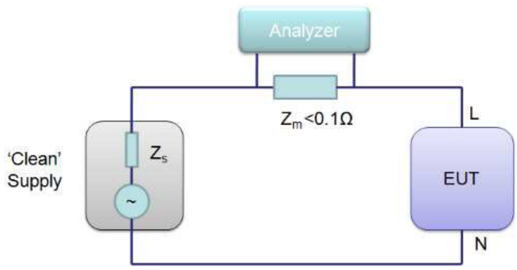

Fig. 1. Harmonic emission measurement system

The harmonic emissions must not exceeded the next values:

- 0.9 % for harmonic of order 3;
- 0.4 % for harmonic of order 5;
- 0.3 % for harmonic of order 7;
- 0.2 % for harmonic of order 9;
- 0.2 % for even harmonics of order from 2 to 10;
- 0.1 % for harmonics of order from 11 to 40.

The peak value of the test voltage shall be within 1.40 and 1.42 times its RMS value and shall be reached within 87° to 93° after the zero crossing [6]. The EUT (equipment under test) in this case is a lighting lamp.

5 Low frequency noise emission

The standards, which refer to harmonic emission, require measurements of only one device, but what is happening when the devices are working in a network. One idea is that the increase of the number of the lamps results in noise emission increase. In Fig. 2 the typical circuit diagram of electronic ballast is presented. The AC line input voltage, typically 220-240 VAC 50/60 Hz, an EMI filter to block the noise emission, a rectifier with smoothing capacitor, a half-bridge inverter for DC to AC conversion, and the resonant circuit to ignite and run the lamp. The main source of low frequency harmonics is the rectifier stage [7].

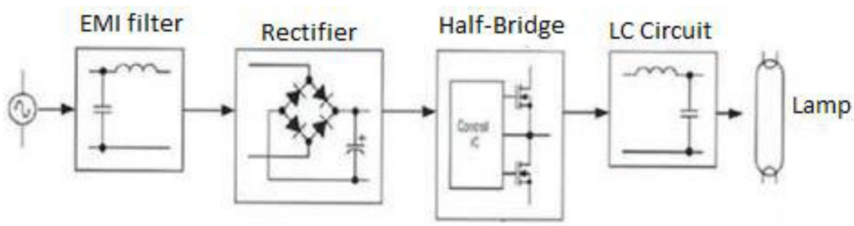

Fig. 2. Circuit diagram of electronic ballast

In Fig. 3 the voltage and current wave form of a 11 W compact fluorescent lamp is presented. The measurement result of a 23 W induction lamps is presented in Fig. 4. In both cases the current consumption is not sinusoidal, which means that the harmonic current emission is high. The amount of harmonic emission is higher if the current waveform starts to increase later than voltage wave form. Important is that current has to start flowing before 60° [6]. From measurement results it can be seen (Fig. 3 and Fig. 4) that the harmonic emission of induction compact fluorescent lamp is higher than the emission of compact fluorescent lamp.

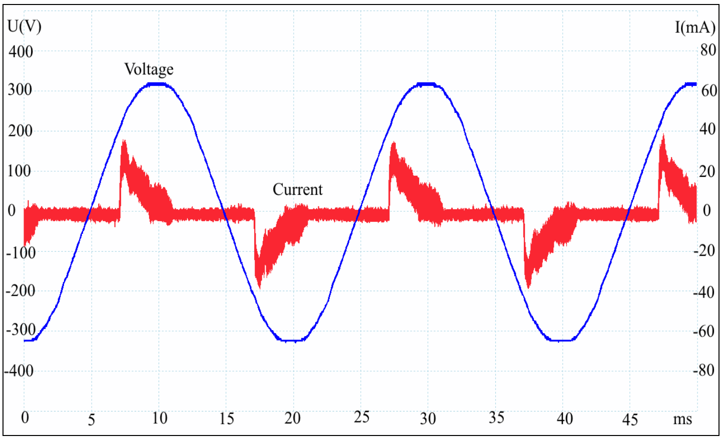

Fig 3. Voltage and current wave form of a compact fluorescent lamp

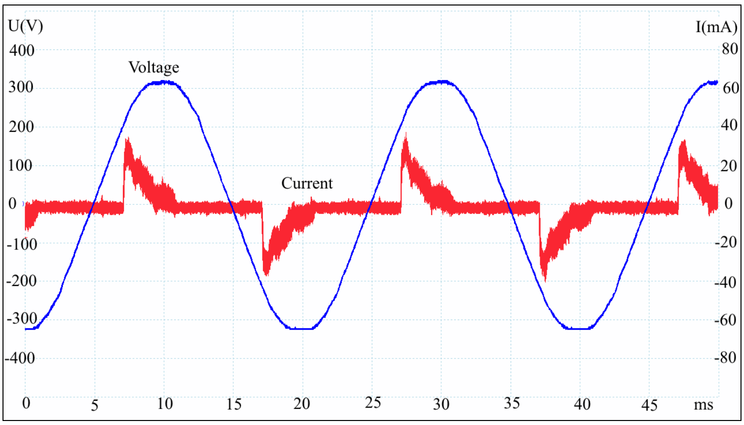

Fig 4. Voltage and current wave form of an induction lamp

Power Factor PF and Total Harmonic Distortion THD provide a quantitative measure of the power quality in an electrical system. The amount of useful power being consumed by an electrical system is predominantly decided by the PF of the system [2].

In case of cheap LEDs and compact fluorescent lamps the power factor correction is done with inductors which are used on DC side or AC side, Fig. 5 and Fig. 6.

C_i - capacitor could improve the power factor.

Typically, in case of LED lamps the harmonic emission in lower than in case of CFL lamps [8][9]. The reason is that the electronic ballast of LED contains active power factor correction circuits. In Fig. 7 is presented the wave forms of current and voltage of a 9W LED and a 7W LED lamp. It could be seen that the current wave form of 7W LED is close to sinusoidal shape what is mean the harmonics emissions are on a low level. The current wave form of 9W LED lamp has spike form, what is mean this lamp has a high harmonic emission. Unfortunately, not all LEDs have a good power factor correction.

For higher quality LED lamps a better power factor is achieved with active power factor correction circuits[8]. In Fig. 8 is presented the measurement results for a 15W LED with good power factor correction and a 15W LED with poor factor correction. The voltage wave forms are the same. In case of modern lightings, the voltage total harmonic distortion is very low. The current wave forms are different. The LED with low power factor correction has a spike current wave form which is similar with current wave form of compact fluorescent lamps. In Fig. 9 is presented the measurement results of a 23W and a 22W compact fluorescent lamps. The current wave form are similar, but the in case of 23W lamp the current start to increase earlier than the 22W lamp, that is mean the harmonic emission of first lamp is lower. The second observation is that the current of second lamp is much lower, that is mean the wattage of the lamp is lower than the wattage specified on the lamp. In table 1 is presented the total current harmonic distortion and power factors of different compact fluorescent LED and induction lamps. The total harmonic distortion emission of LED lamp with a good power factor correction is more than 3 times lower than in case of LED with poor power factor correction.

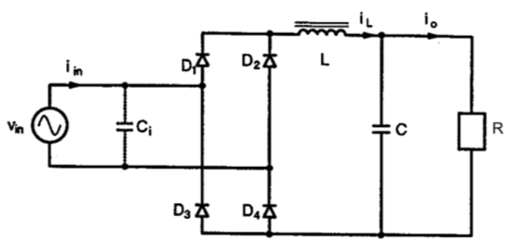

Figure 5. Full-wave rectifier with LC filter dc-side inductor

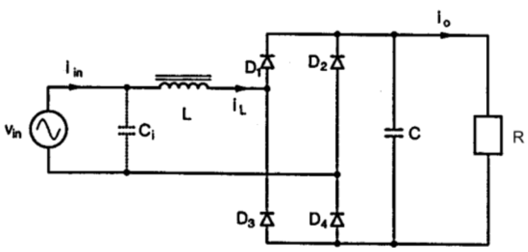

Figure 6. Full-wave rectifier with LC filter ac-side inductor

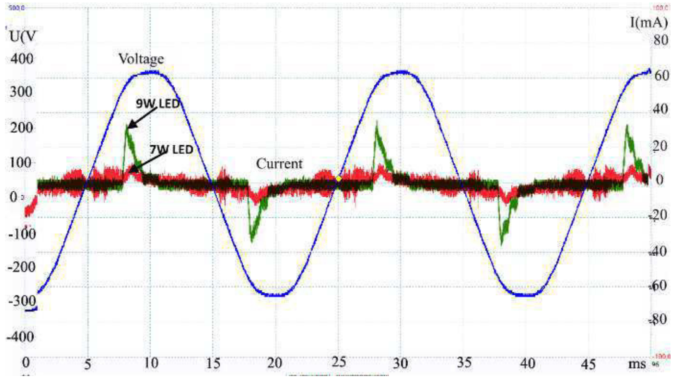

Figure 7. Current and voltage wave form of a 9W LED and a 7W LED

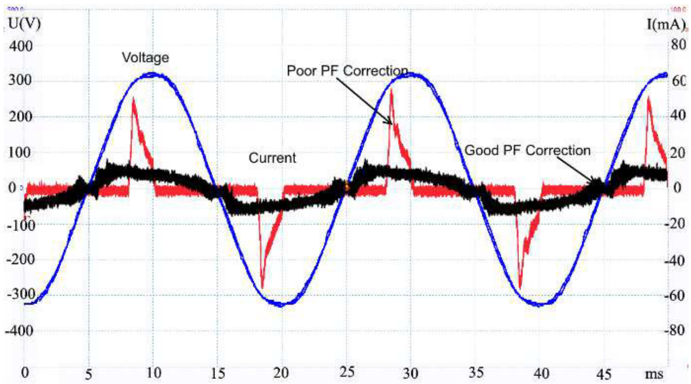

Figure 8. Current and voltage wave form of a 15W LED with good PF correction and a 15W LED with poor PF correction

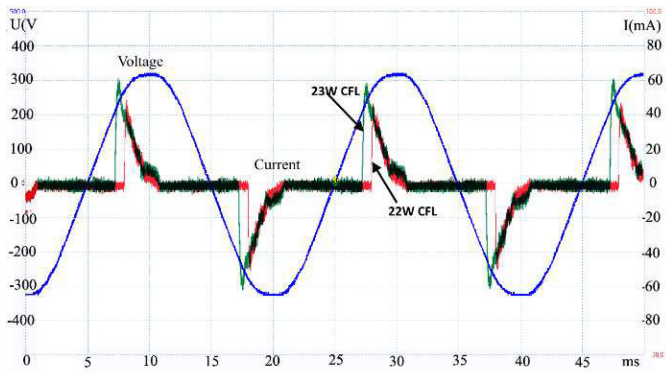

Figure 9. Current and voltage wave form of a 23W and 22W compact fluorescent lamps

6 Measurement results of lighting networks

As mentioned before, the standard measurement are required only one lamp to be measured, but in a office there are more than one lamp. In figure 10 can be seen the variation of noise emission function of CFL lamps number variation.

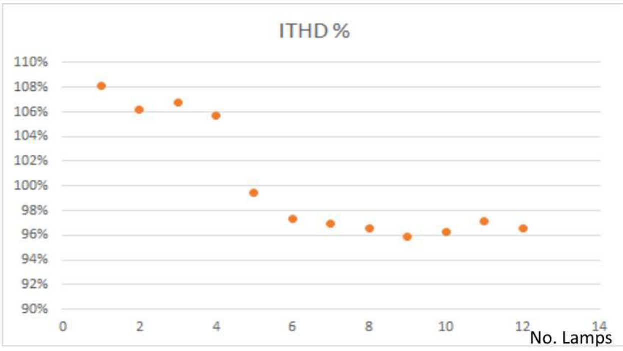

Figure 10. THD emission for different number of compact fluorescent lamps

The measurement results show that, increasing of number of CFL lamps, determine the noise emission decreasing from 108% to 96%. As the diagram show, if the number of lamps is higher than 8 the level of noise remain around of 96%. As a conclusion the emission of a CFL lamps network is lower than emission of one CFL lamp.

In figure 11. the noise emission was measured at different ambient temperature. The measurements were done with cold lamp, that is mean the lamps were switchen on and after 30 seconds the measurement was done. Variation of temperature determine a variation of noise emission too. During the measurements the lamps network contained 6 LED lamps.

In figure 12 is presented the noise emission variation function of working temeperature variation. The noise emission of lamps depend by working temperature of lamps. After switching on the lamps the the noise emission should be higher than usual noise emission level.

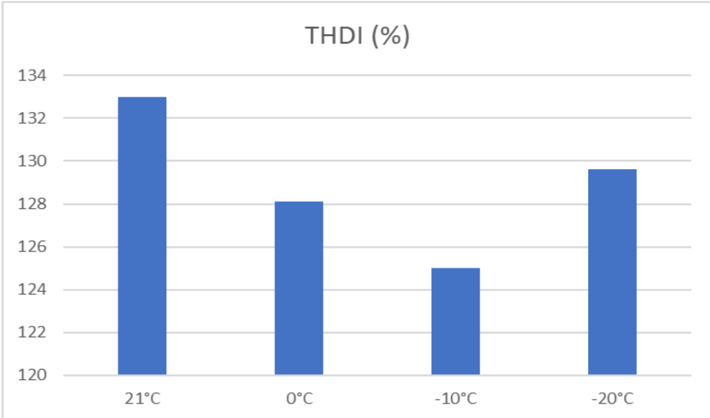

Figure 11. Variation of noise emission with variation of temperature

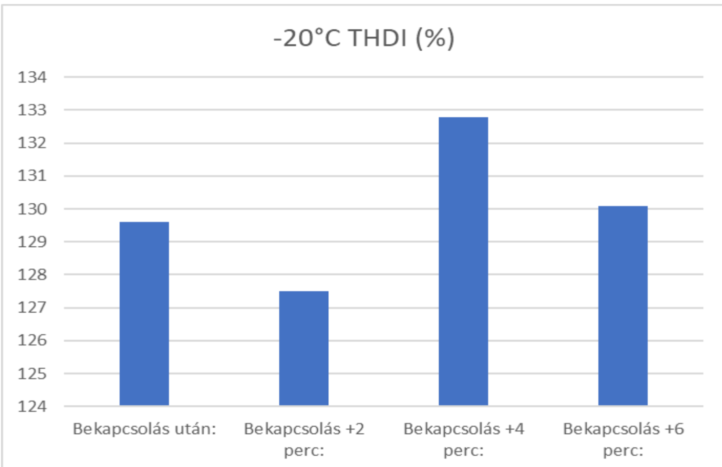

Figure 12. Variation of noise emission with variation of lamps working temperature

Conclusions

Some of modern lamps type have an important harmonic emission. Harmonic emission of some cheaper LED lamps could be higher than emission of compact fluorescent lamps. The differences between noise emissions in case of different compact fluorescent lamps are significantly, but the differences are not so high than in case of LED lamps. If the lamps are measured in a network, the noise emission is lower than in case of a single lamp. In case of CFL lamps this phenomena is more stronger than in case of LED lamps.

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