Inrush current of lamp

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1 Introduction

Lamps are quantitatively important group of consumers. Therefore the question about optimizing their operations is still topical problem. In this context, operator efforts to reduce consumption and costs associated with maintenance and lighting system. In the past, thermal light source was dominated and for start it or operation of this lamp was not necessary driver or ballast. With discharge lamps using appear ballasts and later in an effort to reduce losses classic ballast pass to electronic ballast. Recently, LED light sources enter to using in interior and exterior lighting systems. When LED lamp is powered up from distribution network (for example 230 V AC) then lamp need driver for voltage and current stabilization.
Driver is electronic circuit shown schematically in the figure below. In term of transients the peaks of current are during startup. Switching affects depend on size of the capacitor in DC side of bridge rectifier. His rapid charging cause increased value of startup current.

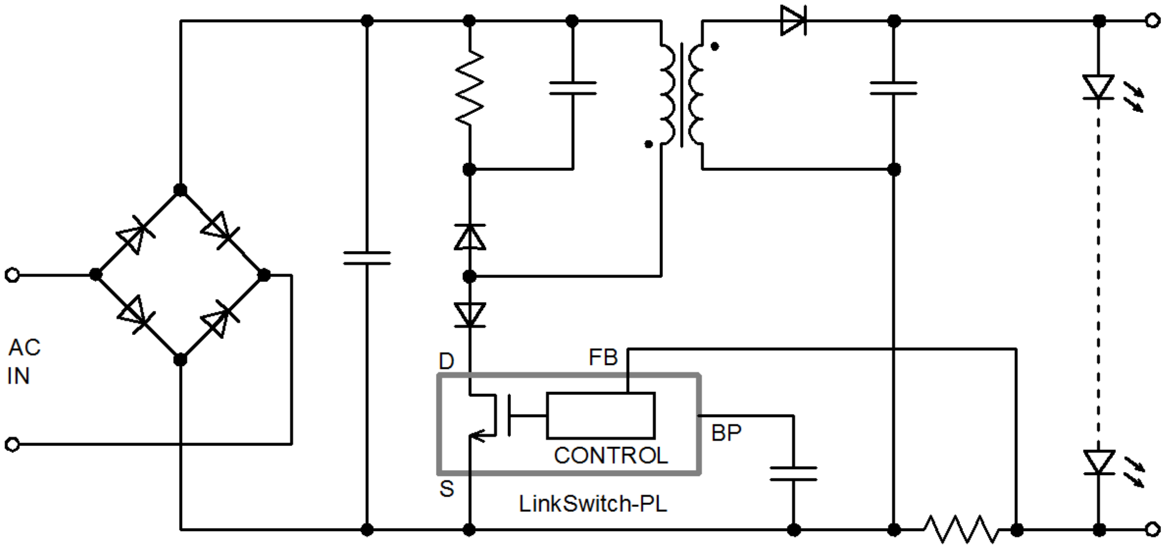

Fig.1. Scheme of components in driver for LED lamp

Next transient is during driver output LED load connection. This transient is much smaller and its size and delay depending on lamp type. Delay between first and second transient is less than one second usually. The second current increase is about half of first transient. Size and time when current peaks comes are depending on the driver construction, used LED modules, capacitor discharge (re-start) and phase of voltage when turning on the lamp. In the case driver with harmonic filter may be the size of starting current depends on inductance and capacitance of this filter also [4].

2 Inrush current LED lamp with driver

During the start of a lamp with LED driver occur two transients. Fig 2 shows behavior of two different lamps starts and shows what a difference may be when lamp start from normal status (cold start) and when lamp is restarted (hot start). The upper waveforms show start from cold status and bottom waveforms show start from warm-up lamp. During this measurements were phase and size of voltage identical. The aims of these measurements are show the differences of delay between first and second current peak.

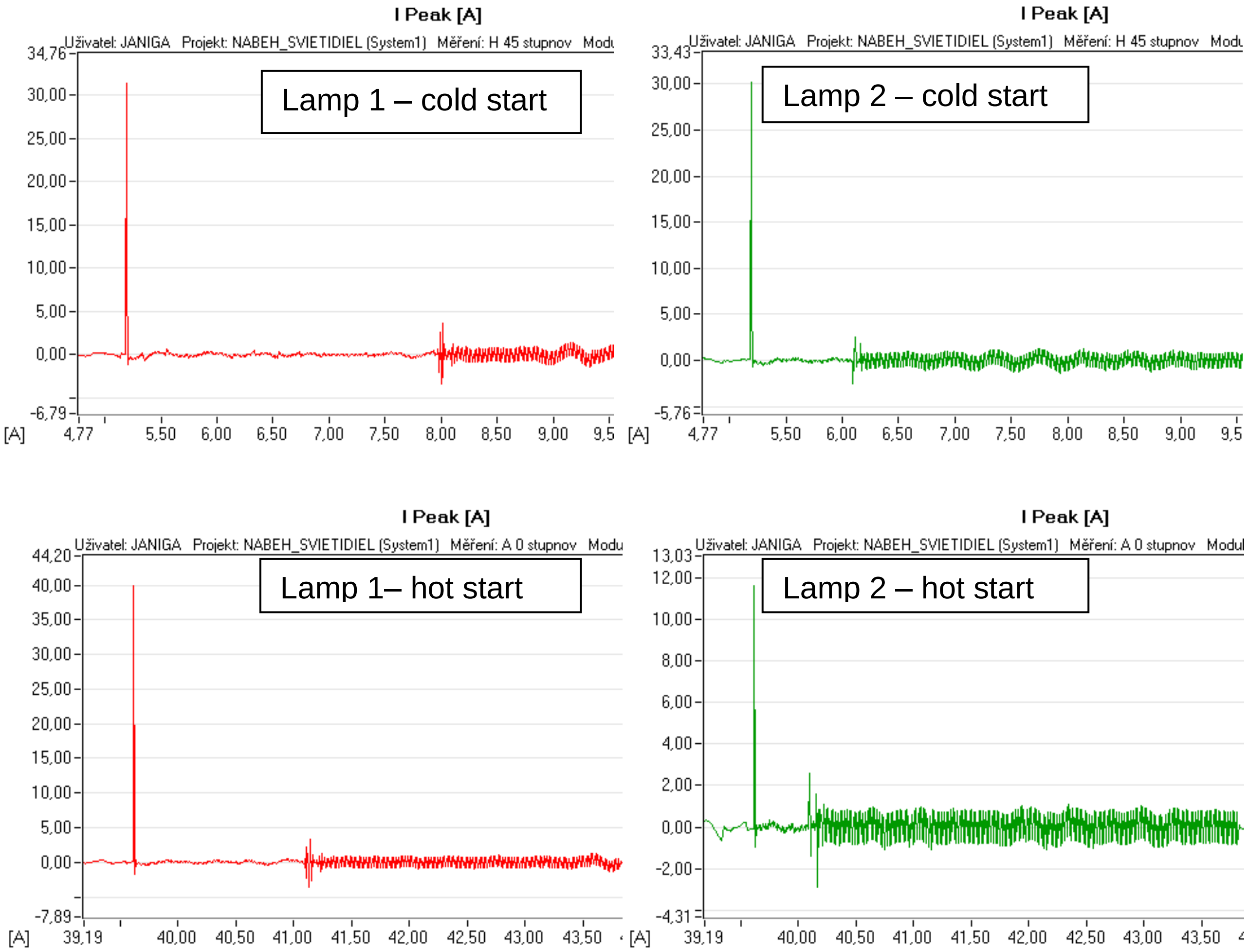

Fig.2. Current during start. Cold start on upper figures and hot start on bottom figures

Repeated starts may cause overloading and design of installations has switched off protection. These transients may bring about problems with power quality and other device function disturb. [1]. In case of repeated starts shortly consecutive, the current peaks increase stress on internal circuit of driver and lamp. This overloading is caused by repeating current peaks. The Fig. 2 shows decreased first current peak during hot start in the case of lamps 2th.

3 Current peak during lamp start

During the analysis were investigated three different LED lamps and they were analyzed during the switching on transient. Voltages and currents are plot in figures below. Curves of voltages and current are colored, where lamp1 is red, the lamp 2 is green and the lamp 3 is blue. The figures show the impact of voltage phase at start to current behavior. If voltage phase is near 90 degree the current peak is maximal. Duration of current peak is depend on capacitor but for reliable operation is no possible to decrease capacity of this capacitor.

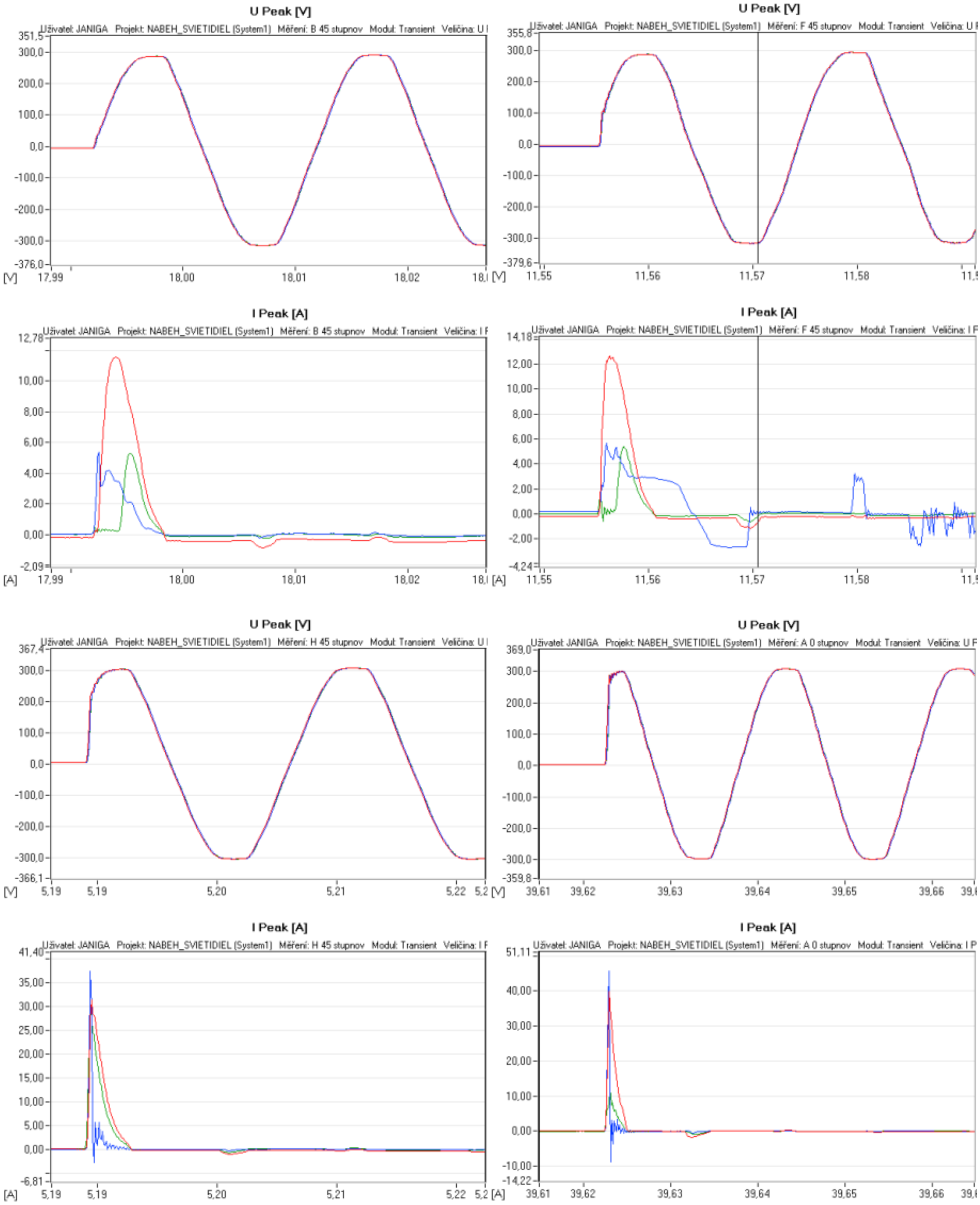

Fig.3. Change current peak in dependence on phase of voltage

The voltage phase depends on turn on lamp moment. Greater instantaneous voltage during start moment cause greater current peak. Results of measuring shows behavior of lamps with drivers but from measurement is not possible provide general information about startup current. Different drivers generate different behavior of current. If we try to found formula for behavior description during startup, then it is possible to describe like as transient during capacitive load switching on.

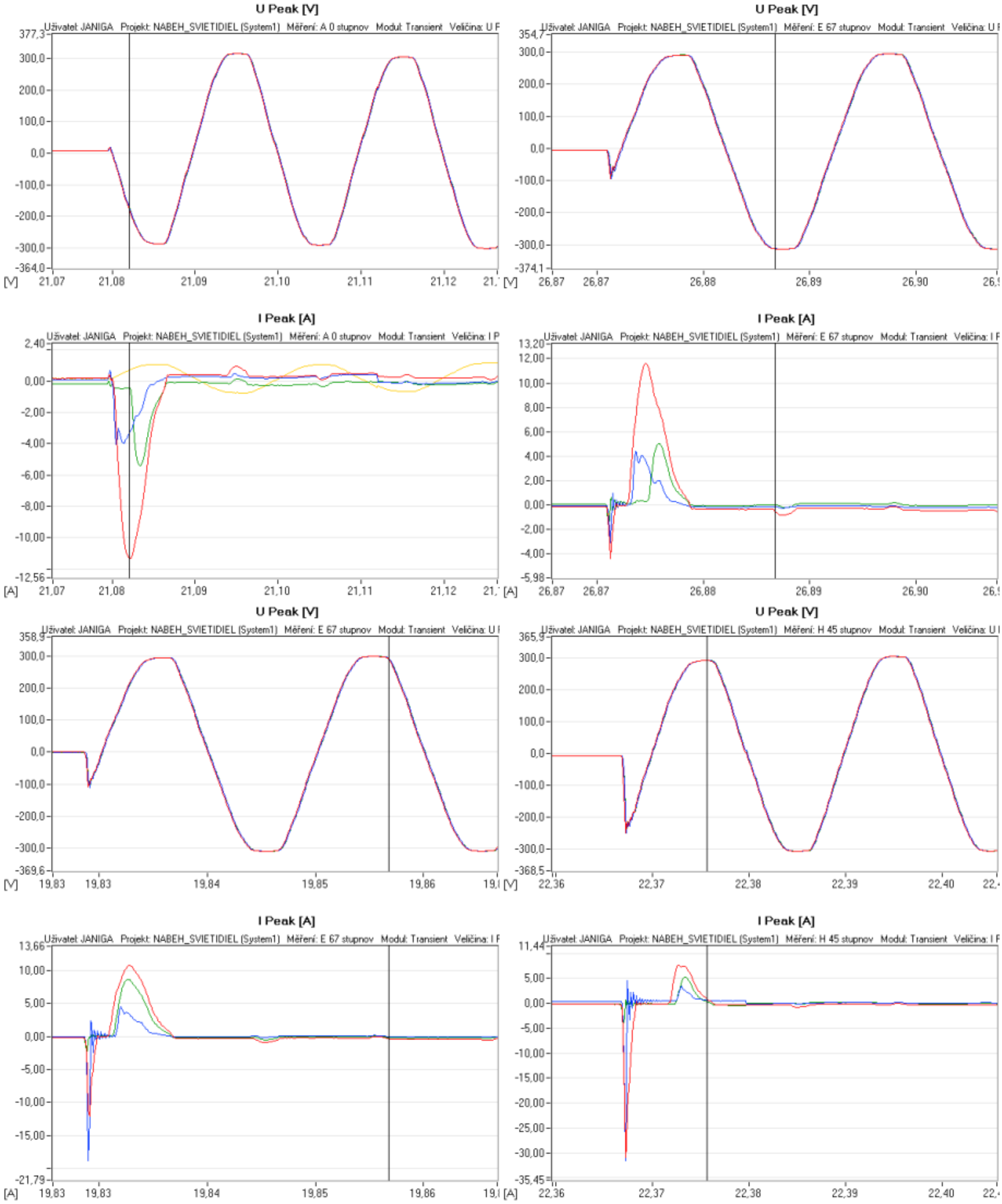

Fig.4. Change current peak in dependence on phase of voltage (angle from 270 to 360 degree)

Results of investigation of startup current with phase voltage from 180 to 360 degree are showed on Fig. 4. There is interested the behavior around the 180 degree, where voltage cross the axis. In this case is current peak divide to two small peaks. It can decrease current peak during startup of lamp driver.

4 Switching flash

Switching of lamp is solved by switching elements with mechanical switching contacts most often. In consequence the mechanical property of switching contacts is switching flash very often. It is small oscillations of contacts and it cause oscillations of voltage. On Fig. 5 is possible to view this oscillations and also oscillation of current.

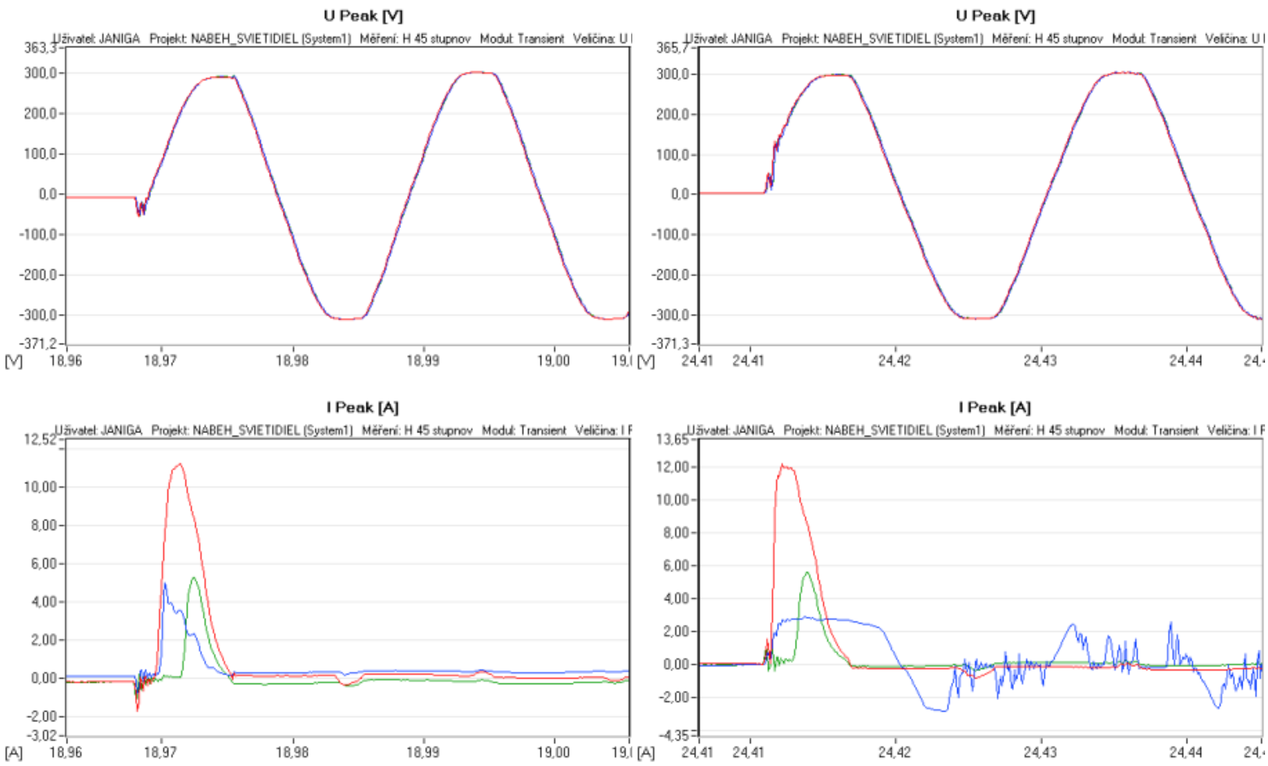

Fig.5. Change current peak in dependence on relay contact

Semiconductor switching elements can eliminate the problem about switching flash but now is used rarely.[2]

5 Mathematical description of startup current

Calculation of the startup current of LED lamp can be solved in two ways. Comprehensive method is by modelling whole electrical circuit of driver and LED modules. Simply method for startup current calculation is by modelling lamp like capacitive load (capacitor) or inductive load (transformer). This simplification reduces calculation to solving problem switching inductive or capacitive load. Current waveforms during inductive or capacitive load switching are calculated using differential equations. [3]

Inductive load switching

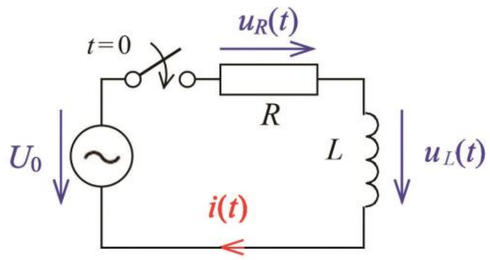

Fig.6. Simple circuit with switching RL load

Resultant current formula i(t) is calculated:

$$i(t) = \frac{U_{0m}}{Z}\left[\sin(\omega t + \alpha - \delta) - \sin(\alpha - \delta)\, e^{-\frac{R}{L}t}\right]$$

(1)

where U_{0_m} – maximum voltage of power supply,

Z – circuit impedance,

ω – angular speed 2πf,

δ – phase difference.

Capacitive load switching

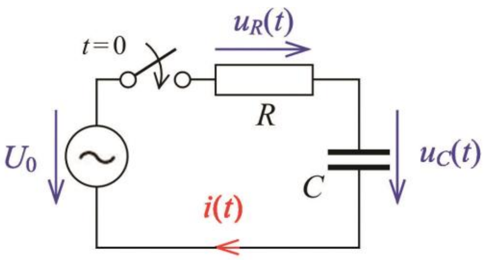

Fig.7. Simple circuit with switching RC load

$$i(t) = \frac{U_{0m}}{Z}\sin(\omega t + \alpha - \delta) - \frac{\cos(\alpha+\delta)}{\omega RC} e^{-\frac{t}{RC}} \quad (2)$$

Although capacitor and transformer are located in the DC part of the circuit, description of transient is preferable with formulas for AC circuits. It is due, the voltage in DC circuit copy the voltage on AC during startup (half of period). At the rise time the voltage is in half of period, it is still unidirectional and it has sinusoidal shape.

6 Conclusion

LED lamps using is increasing in field of interior and exterior lighting. It is reason why is LED lighting topic more often discussed. Exercitation of LED lamp shows problems of this technology. Some problems have electrical character. One of them is startup current. It is difficulty identifiable by electrical engineering without special measuring equipment because startup current is very fast with high current peak. This paper show results of measuring of startup current and it give information about this problem.
Aim of this paper is also describe methodology of calculation startup current. Exactly calculation of current peak is difficult and for calculation is necessary information about all components of lamp. Paper describes simplified calculation which gives information about current behavior during startup.

Acknowledge

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