

Optimizing efficiency of Low-Pressure Lamp UV Systems

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ABSTRACT

Increasing worldwide interest for Ultra Violet disinfection systems and the continuous drive to use energy efficient solutions, have positioned the low pressure UV lamps back in the spotlight. Optimizing the design of wiring harness and cables used, can prevent unwanted additional losses and therefore lower UV output.

INTRODUCTION

The low-pressure lamp technology has proven to be 2.5 to 3 times more energy efficient in their capabilities to convert electrical energy to the needed UV light, compared to medium pressure lamps. Despite the drawback of this lower efficiency, the medium pressure lamps however, have unsurpassed power capabilities at small dimensions

for the needed equipment. We have seen medium-pressure UV lamps at 35kW used in very compact water disinfection systems.

The “green quest” for more energy efficient systems has led to new low-pressure lamps with power handling of 800 to 1000 watt per (amalgam) lamp. Also new, high-efficient and intelligent lamp drivers to preheat, ignite and power the lamps at various power levels are available now.

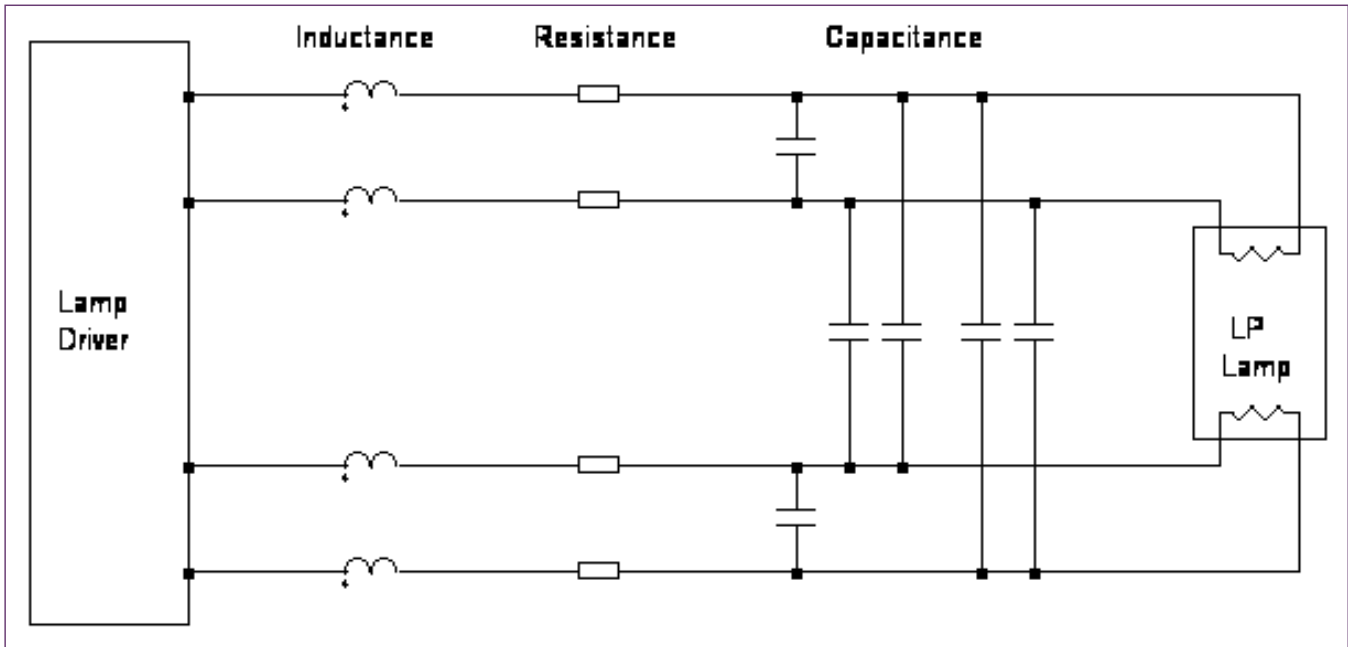


Figure 1

Following aspects will become more important for new designs of UV disinfection systems:

- Allow long distances between lamp driver and lamps
- Optimal preheat and starting sequence
- Dimming capabilities, without lowering specified lamp lifetime expectations
- Protect lamp driver for leakage currents, shorts to ground and End of Life (EOL) effects of lamps
- Full control and monitoring of UV lamps

Operation of discharge lamps on High-Frequency Lamp Drivers (Ballasts) offers several advantages over operation on electromagnetic (EM) ballasts operating at 50 or 60 Hertz, especially for LP lamps, as these lamps are 10-15% more efficient at high frequency operation.

LAMP WIRING

The advantages of electronic lamp drivers include higher efficiency, better controllability of lamp power or current, stepless dimming, very low warm up mains current and longer lamp life. To maintain these advantages even at large distances between lamp and driver, the design and specification of the wiring or cable between driver and lamp need extra attention.

The following simplified circuit can be used to discuss lamp wiring effects:

Wiring properties that can degrade performance at high frequencies are:

1. **Cable capacitance.** When lamp drivers use a resonant tank circuit at its output to allow power control and enable ignition, additional capacitance from the cable will cause a shift in operating frequency and could be detrimental for ignition. The capacitance depends on the geometry (conductor diameter and distances) and insulation properties. Nedap electronic lamp drivers can compensate for

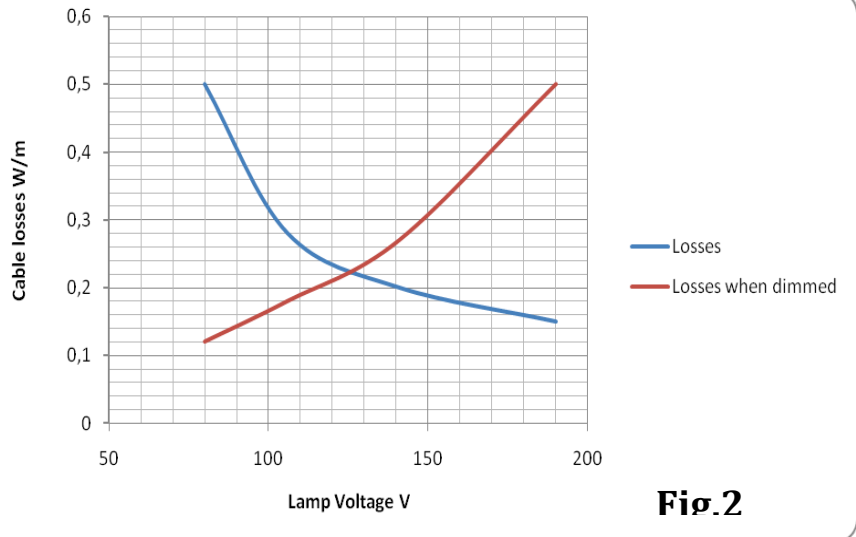


Figure 2 shows typical influence on electrical losses per meter cable length, at different lamp voltages, at maximum power and at 50% dimming level. Cable: PVC insulated 4x1mm² (18AWG); lamp power is 220W.

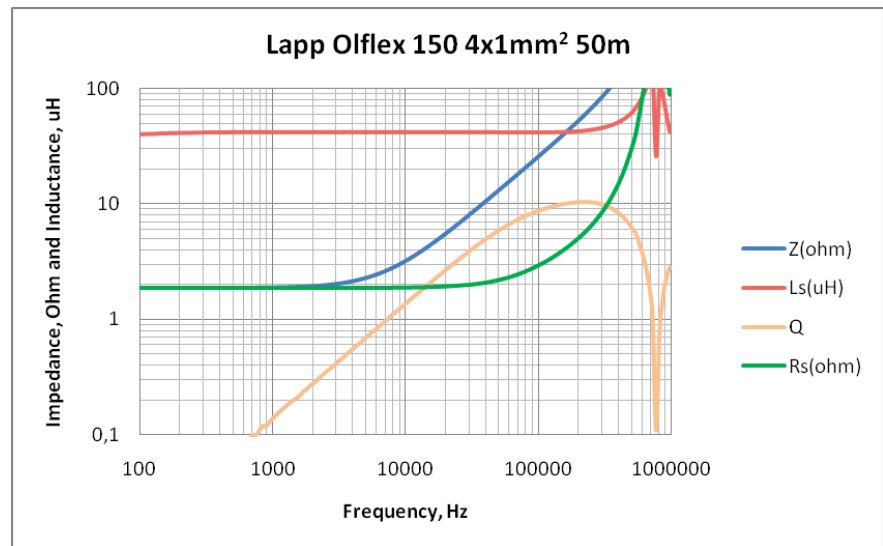


Figure 3 Impedance, resistance and inductance of a 50m length of Lapp Olflex 150 4x1mm² (18AWG)

wiring capacitance over a relative large range of capacitance. Beyond that range the peak ignition voltage will reduce somewhat, as will the efficiency during dimming, due to the additional capacitive output current.

2. **Cable inductance.** The impedance of an inductance is proportional to frequency, so at high frequencies (HF) the voltage drop across this inductance will increase. This voltage drop has a 90° angle to the lamp voltage. The longer the cable and the higher the frequency, the higher the voltage the lamp driver has to supply to maintain the same lamp voltage. Since most lamp drivers will

control lamp power by changing the operating frequency, the increase in lamp driver output voltage will cause a change in operating frequency. Since all lamp drivers have a limited output voltage range in which they can supply maximum power, a too high voltage drop across the wiring will reduce the maximum power that can be delivered to the lamp. A second effect is that the cable inductance, together with the wiring capacitance, will cause additional resonances.

3. **Cable series resistance.** Skin effects (the magnetic field of the HF current causes the current to flow at the outside of the conductor) and proximity effects (the magnetic field of the HF current causes eddy current losses in adjacent conductors) are the cause of an increase in the effective series resistance at higher frequencies. The effect is that for the same current the conductor losses, and therefore cable temperature rise, will be higher for the HF current. This effect depends on the strand diameter and isolation and the number of strands. So for the same wire, the wiring losses at high-frequency operation are higher than at low-frequency operation and a derating factor has to be taken into account.
4. **Cable dielectric losses.** These occur in the insulation material and are (at constant voltage and dissipation factor) proportional to frequency. They add to the total cable losses and temperature rise. PVC types of insulation tend to have higher dielectric losses than e.g. silicone insulation.

RESULTS

The increasing losses at high lamp voltages during dimming are mainly caused by the dielectric losses due to the higher frequency during dimming.

Figure 3 shows the impedance parameters of 50m Lapp cable Olflex 150 4x1mm². The cable was on a reel. This is somewhat comparable to multiple cables placed close together in a conduit.

It can be clearly seen that above 40-50kHz the effective resistance starts to increase and that the inductance has a small decrease. Both effects are due to the skin effect.

The resistance increases from 1.87 Ohm at DC to 1.96 Ohm at 45kHz and 3.68 Ohm at 140kHz. So the current derating factor due to the skin effect at 45kHz is $\text{SQRT}(1.87/1.96)=0.977$ and at 140kHz is $\text{SQRT}(1.87/3.68)=0.713$.

The frequency, at which the effective resistance starts to increase, can be shifted upward by choosing wires with more, but thinner strands. Or even better by isolating the individual strands (Litz wire).

In a system using multiple 160W Low Pressure Lamps running nominal at 180V, using 30 meter PVC insulated cable for the lamps, we found following results at a dimming rate of 50% (in power), so at 80W. The measured power at the lamp was only 65W and the cable losses went up to 15W. This means that 19% less power was delivered to the lamp and therefore substantial less UV output was generated. Choosing a lower lamp voltage and the right cable type, the losses could be brought back well below 5%.

CONCLUSION

New intelligent lamp drivers are specially designed for higher power levels, optimal ignition, maximal dimming capabilities and allowing longer lamp cables without compromising lamp performance and life expectancy. But shifting to higher operating frequencies to drive the UV lamps will need a new approach for the design of connecting cables between lamps and lamp drivers. Optimizing the lamp cables can prevent overheating of cables due to additional losses and can improve overall performance, efficiency and reliability of UV systems.

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