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Starting characteristics of fluorescent tubes and compact fluorescent lamps operating with electronic ballasts

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ABSTRACT

The paper presents the results from an experimental investigation of the starting parameters of fluorescent lamps operating with electronic ballasts. Two types of lamps are investigated, T5 tubes and compact fluorescent lamps, operating with three types of ballasts: instant start, rapid start and programmed start type. Five different operating cycles are employed. Starting and operating voltage and current waveforms are recorded at regular time intervals of the lamp life at different starting scenarios. The preheat ratio is also calculated at the end of the preheat time for the systems working with preheating ballasts. This ratio indicates the temperature at the moment of starting, which is critical for the lamp life. Its value in real time is also calculated for each lamp system during the starting period. The signatures of the lamp starting scenarios are discussed and a comparison is given between the different ballast operations. Their potential consequences on lamp life are examined.

1. Introduction

In recent years the need for energy saving as well as the reduction of purchase cost and maintenance of all electric systems has become imperative. The business sector of the economy, citizens and companies producing lighting systems of all kinds are involved in this effort.

With regard to electric lamps, the effort is focused mainly on the following points:

- The increase of the system efficiency for every consumed Watt.
- Longer lamp life and system life in general.
- Better light quality and less disturbances in the electrical distribution system.

This paper describes an experiment which aims to determine the values of certain parameters which affect the life of fluorescent lamps driven by electronic ballast. The fluorescent lighting systems are working in various operating cycles. The long-term purpose is to find a correlation between lamp life and the duration of the corresponding cycle. Very few reports have been published on the subject because experiments of this type are time-consuming, expensive and require a lot of attention and work [1–5].

Results from the first measurements are presented. Particular emphasis is given to the starting conditions for systems with ballast providing electrode preheating. For these systems the interest is focused on the electrode temperature at the end of the preheating period. The method for this calculation is described and real time pictures are taken with the oscilloscope. For the systems with instant start ballast the values of specific parameters are presented.

2. Fundamentals

One of the targets of the experiment is the measuring of life of all the lamps, therefore, it is worth examining the

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way they fail. When one of the lamp electrodes is cut, the lamp either fails or works in a wrong way and shortly it is driven to failure. The commonest reason for the electrode to be cut is when its emissive coating is completely exhausted. The failure also happens when only a part of the filament is stripped of its emissive coating, usually at the edge of the filament [6–9]. The tungsten filament is covered with a mixture of Ba, Ca and Sr oxides in order to reduce the work function. This results in lower starting voltage when the lamp starts or when its polarity changes [6]. It is known that the electrode temperature must be below 1000 °C and above 700 °C, for a longer lamp life. When all the emissive material is lost from the filament or from a part of it, the voltage at the starting point (hot spot) will damage the electrode and finally will melt it at that point.

It is known that the loss of the electrode coating occurs due to evaporation and sputtering [10]. In particular, when the electrode temperature is too high, emissive coating is lost by evaporation. Ordinarily this happens during steady state operation, while the electrode temperature is high. On the contrary, when the lamp works at low temperatures the cathode fall voltage is too high. This causes sputtering because of destructive impacts of the positive ions on the cathode [11,12]. Low temperatures occur mainly during the start of the lamp. Therefore, electrode temperature highly affects the erosion of electrodes and decreases lamp life. For a longer lamp life these two procedures must be minimized so that the starting and operating electrode temperature would be between 700 °C and 1000 °C [10].

Statistically, the starting of the lamp plays the most important role for the lamp life. If starting occurs at a low temperature the rate of electrode erosion is high due to sputtering [13]. For this reason cold starting scenarios are used when the system works for many hours without interruption. In this case the lamp is driven by an Instant Start Ballast (ISB), without a significant decrease of the lamp life. When the fluorescent lighting system is expected to start more than 2–3 times a day, electrode heating should be provided before starting. Thus when the starting happens, the temperature will be high and the sputtering is insignificant.

3. Experimental design

The lighting systems used in the current experiment, operate on five different operating cycles. All these cycles have the same off-time period, which is 15 min. This time is enough for the electrodes to acquire the ambient temperature. This off-time period was chosen after the results of other experiments [1,5] which showed that the filament temperature relating directly to electrode resistance requires at least 10 min to stabilize. To increase the reliability of our experiment before our measurements, the cooling time is at least 1 h, which is generally acceptable, though it is known that the time required to attain the ambient temperature is several hours. The on-time period differs from cycle to cycle. Three lamp groups operate on short operating periods, i.e. 20 s, 1 min and 5 min and the other two groups on 45 min and 165 min (2 h–45 min). The last cycle is the European standard operating cycle. The short on-time periods were selected in accordance with the experiments of other researchers who tried to minimize the time required for lamp life determination [2,3,5].

3.1. Systems' arrangement

For the current project two different kinds of lamps are used: linear type T5 and compact type. Linear lamps are 14 W from manufacturers A and B while compact lamps are 18 W and they come from manufacturer B. All the systems operate with electronic ballast. Some ballasts provide preheating to the electrodes and others are ISB type. The preheating ballasts are either rapid start type or programmed start type and here they are called Preheat Start Ballasts (PSB). The ballasts come from three different manufacturers. The systems were grouped in five groups, and each one contains 24 lighting systems. These 24 systems are placed on a wooden framework and all of them operate on the same operating cycle. The position of the lamps is horizontal.

The operating cycles have been selected specifically for the achievement of the objectives of the experiment. Each operating cycle includes different kinds of lamps. Each lamp type is driven by two different ballasts, and there are six different lamp–ballast systems. Every lamp–ballast system is recommended as fit to work, from both lamp and ballast manufacturer. Table 1 presents the characteristics of the six systems.

Each ballast in the systems 1 and 2 drives two lamps (designated as #1 and #2) while in systems 3, 4, 5 and 6, every ballast drives one lamp. Consequently, systems 1 and 2 comprise 8 lamps each for every operating cycle, while systems from 3 to 6 include 4 lamps each. The two lamps in the 2-lamp systems were given the names T5#1-A and T5#2-A respectively. The designation A and B indicates the manufacturer. The framework of the systems operating in the same cycle is supplied from the mains with electric current separately, through the programmable controller Crouzet Millenium II+ SA20 S 24VDC timer. Each T5 system is placed on a sheet-iron of dimensions 65×10 cm (single lamp system) or 65×15 cm (two lamp system). Starting aid distance is 1.1 cm. Compact lamp systems are placed two by two on a wooden frame. A picture of the arrangement of the systems is shown in Fig. 1 and a sketch of the framework in Fig. 2.

Table 1
Lamp and ballast characteristics

System number	Ballast type	Lamp type	Lamp ID
1	Electronic, rapid start, 2 lamp	Linear T5-14W	T5#1-A
		Linear T5-14 W	T5#2-A
2	Electronic, programmed start, 2 lamp	Linear T5-14 W	T5#1-A
		Linear T5-14 W	T5#2-A
3	Electronic, programmed start	Linear T5-14 W	T5-B
4	Electronic, instant start	Linear T5-14 W	T5-B
5	Electronic, programmed start	Compact – 18 W	CFL-B
6	Electronic, instant start	Compact – 18 W	CFL-B