Laboratory no. 2

The operating characteristics of the electric light sources

1. Generalities

The electric light sources are devices which transform the electrical energy in luminous energy using the incandescent phenomenon and/or luminescence. The technical-economical performances of this converters are highlighted by *the operating parameter of the light sources*. These indicators are constituted from the assembly of the electrical quantities, photometrically and energetically, through which is obtained a full characterization of the considered electrical source.

There are considered as necessary and sufficient the following physical measures:

✓ *Electrical parameters: I*- the current from the circuit, [A]; P — the power developed by the lamp, [W]; P_b — power losses, if it is the case, on the limitation stabilization element of the discharge, [W]; P_m — the power absorbed by the fitting from main grid, [W]; f — the form factor of the current wave.

✓ *Photometrical parameters*: Ø - the luminous flux of the lamp, [lm]; L — the luminance. [nt]; 3 = ($Ø_M$- $Ø_m$)/($Ø_M$+ $Ø_m$), the pulsation factor of the luminous flux, with $Ø_M$, $Ø_m$ maxim value, respective the minimal value of the luminous flux emitted by the source on an alternance of the supply voltage.

✓ *Electrical parameters:* $k=P_m / S_m$- the fitting power factor with $S_m=UI$ the apparent power required by the fitting from the main grid; $\eta = Ø/ P$ - the luminous efficacy of the light source, [lm/W]; $\eta_m = Ø/ P_m$ luminous efficacy of the fitting, [lm/W]; t_c - the lamp starting time, which represent the duration of the transitory process, after that the lamp flux reaches 80% from its regime value, [s]; D – the lamp life time, defined as the time until the luminous flux reaches 80% from the initial value, [hours].

The operating parameters differ from a source type to another, and for a similar lamp depend on the environment condition (temperature, humidity, wind), on the operation mode (connecting-disconnecting numbers, uninterrupted operating time, fitting version), on the power source characteristics (voltage, frequency) and on the time constant of their parameters.

Considering the normal operate conditions ($Ø_a=+20^oC$, p=760 mm-Hg, maximum humidity 75%) if it is considered as a variable the supply voltage U at its frequency f, then we can draw the operating characteristics of the electrical source of light

$$X=F(U) \quad or \quad X=F(f)$$

with X = the analyzed operating parameter.

Those dependences, presented under a graphical or analytical shape, are increasing the generalization rank if it is operated with relative values x* or in percent x [%], which leads to:

$$X^*=F(u^*),\ x^*=F(f^*) \quad sau \quad x\%=F(u\%),\ x\%=F(f\%)$$

where:

$u^*=U/U_n$, $f^*=f/f_n$- relative values whose reference/datum level is the voltage or rated frequency of the supply source.

$u\%=100U^*$, $f\%=100f^*$- percentage values of the independent variables.

$x=X/X_n$, $x\%=100x^*$- relative/percentage values of the operating parameter, with Xn absolute value corresponding to U_n/f_n.

The operating characteristics $x^*=F(u^*)$ can be expressed analytical through the following convergent series:

$$\lg x^* \sum_{j=1}^{n} a_j \lg^j u^*$$

where the a_j coefficients are experimentally determined.

In the case where the supply voltage variation fits in ±10% limits, the previous relation becomes:

$\lg x^*=a_1 \lg u^* \Leftrightarrow x^*=(u_*)a_1$

$\lg x^*=a_1 \lg u^*+a_2 \lg^2 u^*$- fluorescent lamps with mercury vapors at low pressure

2. The operating characteristics of the incandescent lamps

The standard operating parameters of the incandescent lamps are given as medium values for the rated supply voltage (lamp rating), because only through its variation can be obtained the lamps operating characteristics.

The tungsten filament is behaving like a selective radiator, and so the lamp luminous efficacy (fig. 2.1-a) will be directly proportional with the absolute temperature of this non-inertial, non-linear resistor.

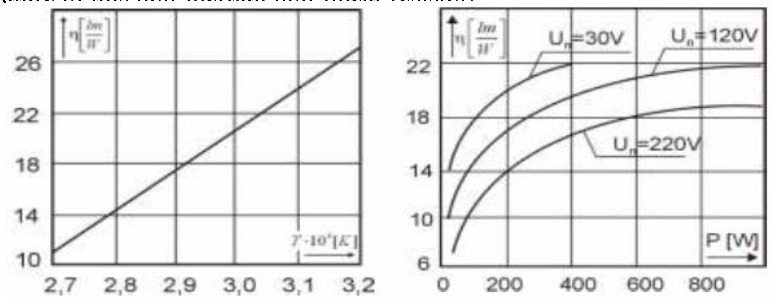


Fig.2.1. (a) The luminous efficacy variation depending on the filament temperature (b) the lamps power at different rated voltages

The low voltage lamps and the high power ones have superior luminous efficacy to those with high voltage and low power, because the first ones have a thicker filament which admits higher temperature regime (fig. 2.1-b). The intense thermal solicitation of the filament, corresponding to some increased luminous efficacy leads to the reduction of the lamp operating time. Another consequence of the high working temperature consists in intense volatilization of the filament whose particles submitted to the interior walls of the lamp leads to bulb blackening and, implicit to the diminishing of the luminous flux of the source. These inconveniences are diminishing in the case of incandescent lamps with halogen.

The incandescent lamps must be powered at the voltage for which they were designed. If the supply voltage is modified the operating parameters have variation which leads at operating characteristics whose shape (fig. 2.2) allows the following conclusions:

- ✓ The increase of the voltage above the rated value leads to the increasing of the flux, power and the lamp luminous efficacy, but diminish the operating time. The gain in the luminous efficacy, as an over-voltage result, is applied by increasing the radiated power in the visible area of the spectrum, according with the maximum displacement low.
- ✓ Lower voltages then the rated one ($\Delta u\%=-5\%$) lead to an increased operating time (with 100%) but decrease the power and luminous efficacy (both with 8%), and the luminous flux (with 18%).

Based on the operating characteristics and on the afferent price of electrical energy and of incandescent lamps, it can be analyzed if in exploitation is advantageous or not the over-voltage of the lightening system. In some situation, the increasing of the luminous flux through this method has as the result the diminishing of the lamps number in the room. Regarding the light source over-voltage to increase lamp or the access is difficult (flash lamps, signalling lamps etc.)

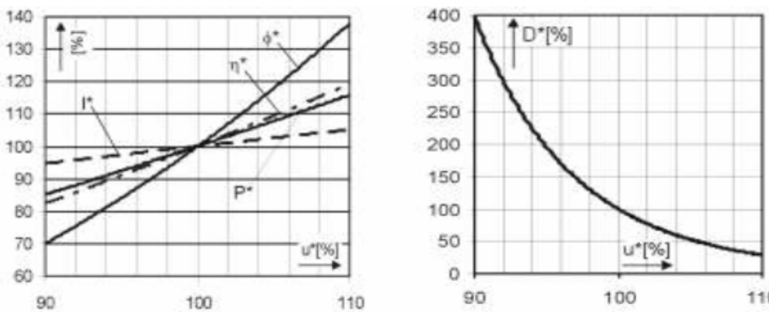


Fig.2.2. The operating characteristics of the incandescent lamps
*P**- the lamp power, *I**- The current through lamp, *Ø**- the luminous flux, *a**- the luminous efficacy of the lamp, *D**- operating time.

3. The operating characteristics of the fluorescent lamps with low pressure mercury vapors

The florescent lamps powered on voltage at industrial frequency are non-linear circuit elements with a non-inertial behaviour, which makes the light source to turn on and off on every alternation of the supply voltage. In consequence, it will appear interruptions in the current wave form, and the luminous flux will go through zero with a double frequency (100Hz) to the power grid one. The lamp flickering leads to the appearance of the stroboscopic effect, which is the apparent change of the real movement of an object situated under a variable luminous flux.

The luminous flux diminishes proportional with the operating time (fig. 2.3) as a result of the luminophore degradation under the action of the mercury vapours and due to the blackening of the tube extremities because of the filament volatilization.

In the first operating hours (around 100) the diminishing of the luminous flux is accentuated (about 10% reduction), and then it becomes much slower. Such being the case, *the rated flux*, of calculation, of a fluorescent lamp is considered after 100 hours of uninterrupted operating. In the last 100 hours the lamps needs a higher voltage because the quality of the thermo-emissivity material from the electrodes decreases. The voltage on the lamp increases to the value when the starter trigger continuously, and the lamp has a visible flickering.

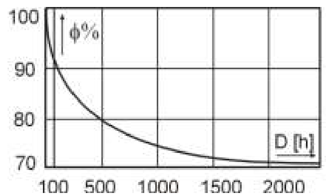


Fig.2.3 The luminous flux variation of the for fluorescent lamp during operating

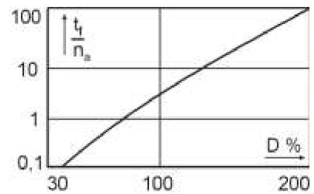


Fig.2.4.The dependency $t_f/n_a=f(D)$

The operating time of the fluorescent lamps depends, especially, on the pre-heating current and the regime one, also and on the number of operating hours t_f [h] considering to one of the n_a ignition numbers of the lamp (fig. 2.4).

The operating regime of the fluorescent lamps is strongly influenced by the temperature of the environment, by atmospheric conditions and the type of the lamp, which may be closed (A) or open (B) (fig. 2.5). The maxim luminous flux is obtain when the coldest part temperature is around 40 [^0C], which correspond to the environment temperature of $Ø_a$=25[^0C]. In this situation the pressure of the mercury vapors is optimal for the UV radiation of 253,7 [nm].

When the temperature decreases the mercury is vaporized in insufficient quantities, the discharged UV radiations are decreasing and the lamp luminous flux will decrease.

At temperature below zero Celsius degree it starts the condensation process of the mercury vapours and the light source performance is considerable diminished. When the environmental temperature exceeds 25^0C, the partial pressure of mercury vapours increases. Also the UV radiation percentage increases, which leads to the decreasing of the luminous efficacy.

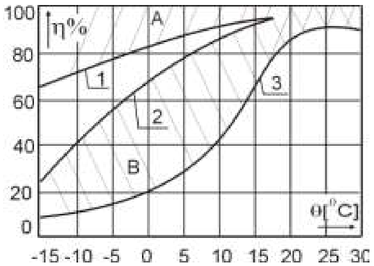


Fig.2.5. The luminous efficacy variation depending on the environment temperature: 1- closed lamp exposed to wind; 2-open lamp in windless environment; 3-open lamp in windy environment

The operating characteristics of the fluorescent lamps fittings obtained by modifying the voltage supply are presented in fig.2.6. Examining the graphical dependencies it results:

Most of the operating parameters are modified in the same sense with the supply voltage; exception is the fitting luminous efficacy which decreases when the voltage increase. This behaviour is a consequence of the different increasing speeds of the power and the luminous flux.

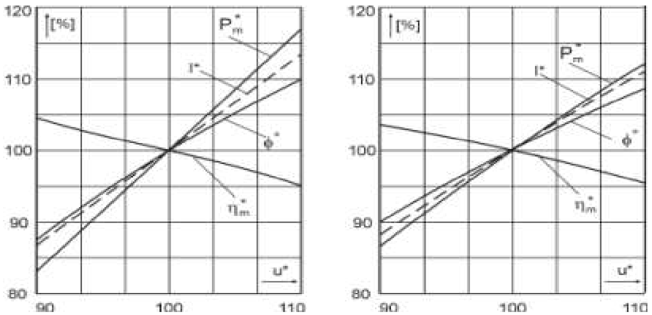


Fig. 2.6. The operating characteristics of the fluorescent lamps in an inductive ballast fitting (a) and capacitive, I^*- the current in circuit, P^*_m- the power of the assembly, $Ø^*$-the luminous flux, μ^*_m- the assemblies luminous efficacy (the operating parameters in percent).

- he operating time is diminished for voltages different by the rated one. Thus, at the lamp over-voltage the current through filament increases, and at its low voltage increases the ignition time. Both situation leads to a premature run-out of the thermo-emissive material submitted on the double wounded filaments. The medium decrease of this operating parameter is obtained when the supply voltage deviation is bellow ±6...7%.
- The capacitive ballast fittings, comparative with the inductive ballast ones, have a lower dispersion of the operating parameters for the same variation of the power grid voltage.

This behaviour is a consequence of the external shape characteristics of the ballasts (fig.2.7) according to:

$$U^2_{be}=U^2_s-U^2_b=f(I_s)$$

where:

U_s=0.9 U_n U_s=1,1 U_n - the limit voltages of the power supply.

U_b - the drop voltage on the ballast coil, whose value is extracted from the volt-ampere static characteristics $U_b=f(I_s)$.

From the figure 2.7 it can be observed that the variation range of the current through the lamp on the capacitive ballast assemblies (ΔI_c) is more limited then the inductive ballast ones (ΔI_b). The tangents slope for the external characteristics corresponding to the operating stable point, is grated on the capacitive ballast fittings and so those have better stability dynamical proprieties.

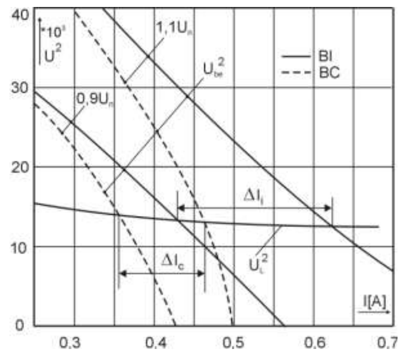


Fig.2.7. The stabilization of the lamp operating point when the supply voltage is modified for the inductive ballast fittings (BI) and capacitive (BC).

4. The operating characteristics of high pressure lamps with discharge in metallic vapours

The light sources that operate in arc regime on high pressure (lamps with vapors of mercury, sodium, metal halides etc.) have a transitory regime that depend both the type and the power of the analyzed light source. Since the operating parameters have specific variation and values on ignition regime time, the existing norms recommends the raise of both transitory regime characteristics, and the operating (stationary) regime described by

$x^*=F(t)$ and $x^*=F(u^*)$

where t is the necessary time, measured from the connecting moment, after what the analyzed parameter reach a stabilized value.

For the fluorescent lamps with mercury vapours of high pressure, the transitory regime characteristics and the operating one have the shape in the figure 2.8. During the ignition, the current is about 40% higher than in the regime one, and the power is modify between 40% and 100%. The luminous flux and the voltage on the lamp terminals (U_{aL}) have about the same variation law, with the observation that the ignition voltage (U_{aL}) depends nonlinear by the temperature $\O_a$ of the ambient environment (fig.2.9). The operating characteristics are modified in the same sense with the supply voltage and because the luminous flux and the fitting power have the variation speed approximate equal, the fitting luminous efficacy is less dependent on the supply voltage fluctuation.

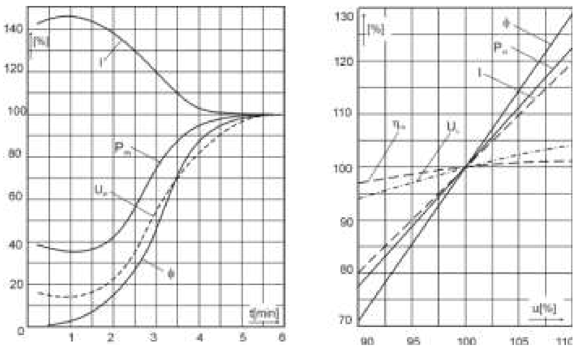
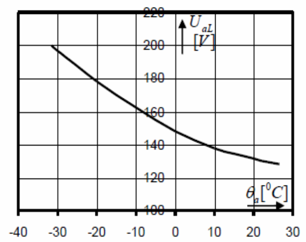


Fig.2.8 The transitory regime characteristics (a) an the operating one (b) of the fluorescent lamps fittings with high pressure mercury vapors

The high pressure lamps with mercury vapors, with black light or with mixed light have similar characteristics with the one previously presented. Exception make the lamps with mixed light where the luminous flux for transitory regime is superior to the stationary regime one, because the used ballast is with metallic filament, whose resistance is nonlinear modified with temperature.



The transitory regime characteristics (fig. 2.10a) of the high pressure lamps with sodium vapor have, basically, the same aspect as in the case of the high pressure fluorescent lamps with mercury. The essential difference is that the ignition voltage U_{aL} is basically independent of the environment temperature, because is supplied by igniters of diverse constructive types (impulse transformer, thyristor etc.)

Fig. 2.9. The dependence between the lamp ignition voltage LVF and the environment temperature

The operating characteristics (fig. 2.10.b) are linear, are modified in the same sense with the supply voltage and the luminous efficacy of the lamp is less influenced by the supply voltage. The statement stays true and for the luminous efficacy of the assembly because the power losses on the ballast (ΔP_b) although are parabolic modified with the mains voltage, have a constant weight (8..12%) in the absorbed power P_m.

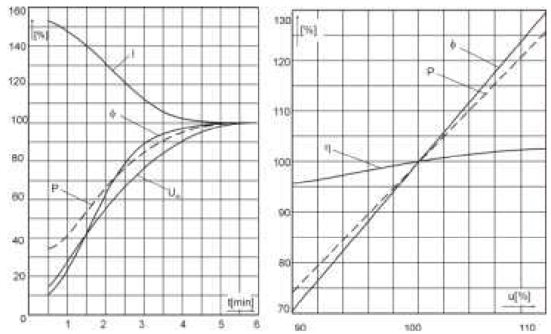


Fig.2.10. The transitory regime characteristics (a) and the operating one (b) of the assemblies with high pressure sodium vapors lamps

5. The laboratory operating mode

In the laboratory theoretical and practical problems will be taken into consideration.

- To know the operating principle of the incandescent lamps, of the fluorescent lamps and of the high pressure arc discharge lamps.
- To draw operating characteristics of the classic incandescent lamps and the iodine regenerative cycle one.
- To draw the operating characteristics of the fluorescent tubes in the inductive ballast assembly, and in capacitive ballast assembly.
- To draw the operating characteristics of the compact fluorescent lamps.
- To draw the transitory regime characteristics for the fittings with high pressure mercury fluorescent lamps, as for the mixed light lamps.
- To record the conclusions from the performed study.

The experiments are made on the laboratory installation whose module is powered from the power grid, successively, through a autotransformer (fig.2.11). The nominal values of the operating parameters are considered for U_n=230 V, and the variation range of then supply voltage will be about ±10%, with a 5 V gap between readings.
The transitory regime data are read from 30 to 30 seconds for rated supply voltage (230 V) and will have a total time of 5…10 minutes depending on the tested lamp. On the luminous flux estimation it will be determined a proportional measure with this one and the illumination E on the surface S of the luxmeter photocell, on a given distance of the light sources.
If E and En are the illumination at U and U_n voltages then:

$$Ø^* = Ø/Ø_n = E*S/E_n*S = E/E_n = E^*$$

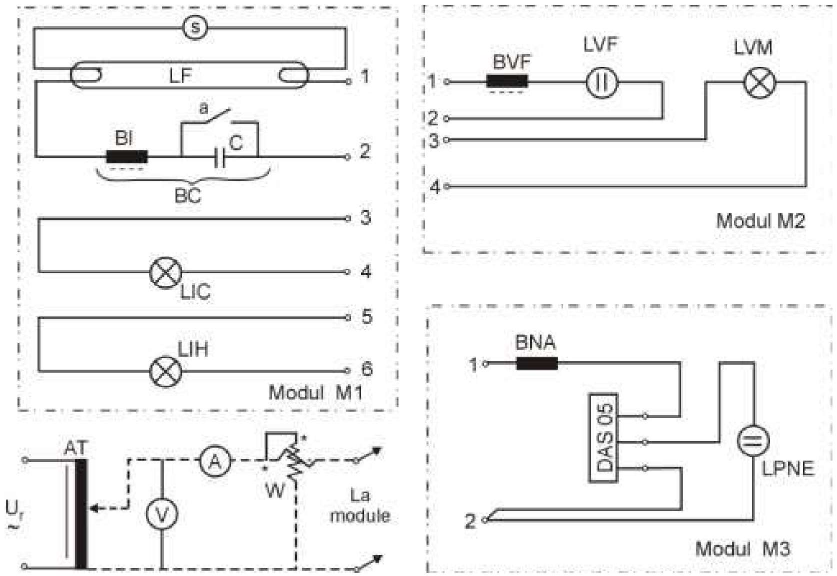


Fig.2.11. Assembly for the determination of transitory regime parameters and the operating one of the light source.

M1 Module: S – starter, LF – Fluorescent lamp, BI – Inductive ballast, BC – Capacitive ballast, a – Switch, LIC – Classic incandescent lamp or compact fluorescent lamp,
LIH – Halogen incandescent lamp.
M2 Module: LVF – Fluorescent lamp with high pressure mercury vapors, BVF – Ballast for the lamp LVF, LVM – Lamp with mixed light.
M3 Module: LPNE – Lamp with sodium steam with oval frosted bulb, BNA – Ballast for the lamp LPN, DAS05 – Ignitor with impulse transformer,
AT – Autotransformer, A – Ammeter, V – Voltmeter, W – Wattmeter,
1, 2 … - Clamps series connector
——— Existing connections.
-------------- Connection to be realized.