Laboratory no. 3
FLUORESCENT LAMPS FITTINGS

3.1 General information

The fluorescent lamps powered at industrial frequency voltage act as nonlinear resistors, non-inertial, with a dynamic symmetric volt-ampere characteristic and with hysteresis (fig.3.1-a). Therefore the voltage waveforms (fig.3.1-b) of the voltage on lamp U_l and its current I_l are deformed and the power factor will be:

$$k_l = \frac{1}{\pi U_l I_l}\int_0^{\pi} u_l i_l d\omega t = \frac{\sqrt{2} U_l I_l}{\pi U_l I_l}\int_0^{\pi} \sin \omega t dt = \frac{2\sqrt{2}}{\pi} = 0.9$$

with the simplifying assumption that the lamp voltage has a rectangular variation $u_l=U_l$, and the current is sinusoidal $i_l = \sqrt{2} I_l \sin \omega t$

The fluorescent lamp behaves like a non-sinusoidal voltage generator opposite to the network and, in order to extend the life of the light source, it is necessary to reduce the percentage of harmonics in the current waveform. This is possible if the peak value (the ratio between the maximum and effective periodic signal) satisfies $f_V \leq 1{,}7$. Due to the non-inertial character of the discharge, the lamp flashes on every alternation of the supply voltage, which leads to the emission of light with a double frequency relative to the power supply.

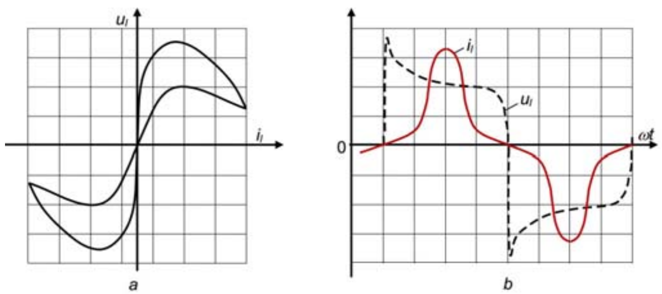


Fig. 3.1 Dynamic characteristic (a) and the waveform of a fluorescent lamp (b) u_l, i_l

The flickering of the lamp causes a stroboscopic effect, which means apparent change of the motion of an object when a variable light output falls upon it. Through analyzing the currents oscillogram the existence of some breaks can be noticed, whose duration is reduced if the inequality is satisfied $U_S/U_l \geq 1{,}5$, where U_S effective value of the main grid voltage.

Because the fluorescent lamps operate on the negative slope of the static volt-ampere characteristic of the discharge, power supply connection is made through the starting-regulating device which, in principle, stabilizes the arc mode. The lamp fitting -starting-regulating device are called the montage of the fluorescent lamp.

The fluorescent lamp fittings can be supplied with: continuous voltages or industrial or high frequency voltages and must meet the following quality requirements.

- ✓ Limiting flicker light output and reducing the percentage of harmonics in currents waveform.
- ✓ High power factor for the efficient use of the power supply
- ✓ High impedance in audio-frequency, especially if the distribution network is also use on remote controllers or on data TV transmissions.

3.2 Fluorescent lamp fittings supplied with industrial frequency voltage

In the case of industrial frequency supply voltage, start-regulation devices should ensure: the necessary fitting voltage impulse, the stabilization arc discharge with minimal loss of energy, harmonic attenuation if higher rank in the current waveform and the avoidance of the break current regime. Fluorescent lamps can connect to the grid after a variety of schemes but, ussually, fittings with starter ignition or with fast ignition, starter free, were imposed. In all cases, are used the discharge limiting-stabilizing elements using inductive or capacitive impedance. Note that the resistive ballasts are energetically inefficient and generate a discontinued current regime and the pure capacitive ballasts lead to pulsed operating of the lamp and amplifies the deforming regime.

3.2.1 Ignition starter fittings

The starter is designed to close the circuit which consists of a ballast and the lamps electrodes, and, after the preheating of the filaments, it breaks the circuit suddenly. The rapid current variation through the ballast generates through the self-inductance a voltage pulse that will ignite the lamp. Starters are of different construction types (manual, thermal, magnetic, electronic, etc.), but on the inductive fittings, conductive fittings or their combinations, were imposed a flickering starter.

The inductive ballast fitting (Fig.3.2-a) is obtained through the insertion of an cored-coil D with air gap into the fluorescent lamp, whose an high slope external characteristic. The power factor of the fitting is inductive and has a value of about 0.3 ... 0.5 that depends on the lamp power and voltage.

The capacitive ballast fitting (Fig.3.2 b) has the limited stabilizing element consists of the normal ballast D, and the capacitive C, which is chosen so that the lamp operates at a rated current. The power factor of the circuit is capacitive $k_m \approx 0.35$ ... 0.65 and depends on the lamp power, voltage and on the tolerance of the capacitor.

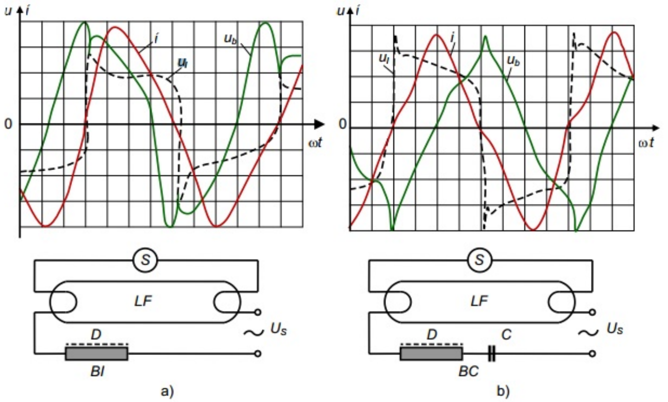


Fig. 3.2 Inductive (a) and Conductive (b) ballast fittings

The duo (dual) fitting (fig.3.3) is realized by connecting in parallel in the same luminaire of a capacitive fitting and an inductive one. In this case the stroboscopic effect is virtually eliminated due to the phase shift of 120° (electrical) between the lamps currents and the emitted lighting flux. Another solution to reduce the stroboscopic effect is to use the existing phase difference (lagging) between the phases voltages of the main grid, when there are connected successively to the three phases a number of 3 lamps, in inductive or capacitive fittings. The power factor of the duo fitting is $k_m \approx 0.95$ (inductive or capacitive depending on the value of the capacitive ballast). If the luminaire has four light sources, a *double duo* fitting is used, obtained by connecting in parallel two duo fittings. If in the same luminaire there are three sources of light, two will be connected using the duo scheme and the other one in an inductive or capacitive fitting.

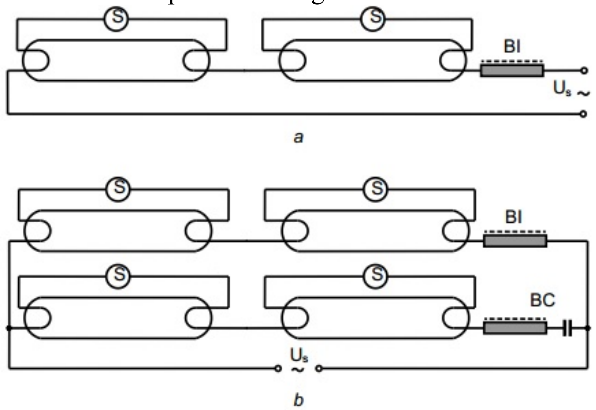
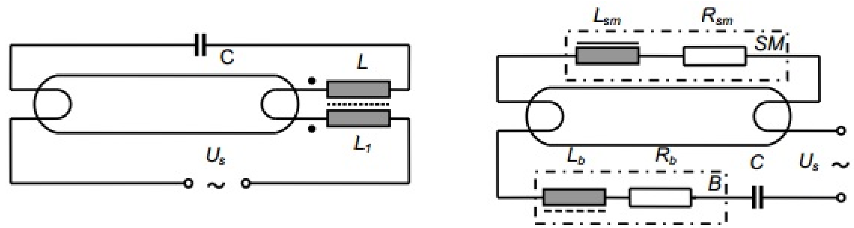


Fig. 3.3 Dou (a) and tandem (b) fittings

In the tandem fitting (Fig. 3.4-a) two series lamps of 20 W are supplied via an inductive or capacitive ballast. The fitting operates at a power factor of about $k_m \approx 0.4 ... 0.5$ and is frequently used in luminaires equipped with two lamps LFA 20. The double tandem fitting (Fig. 3.4-b) results from connecting in parallel on the same luminaire of two tandem fittings, one with inductive ballast and the other with capacitive ballast. The fitting has the advantages presented on the duo fittings and operates in $k_m \approx 0.95$.

3.2.2 The fast ignition fittings

The fittings with fast ignition, without starter, use lamps with electrodes heated or preheated permanently. The filaments are triple wounded to ensure a faster heating and are placed inside the anode rings, which protects them from electronic bombardment during the normal operational regime of the lamp. The fittings are designed to provide a high enough ignition voltage in order to ignite the lamp in adverse conditions. During operating, the current through the filament is diminished if the preheating circuit is not interrupted. If the ambient temperature is low or the main grid presents voltage fluctuations, the quasi-resonant circuit schemes are recommended for ignition. One of the most used schemes of this type (Fig. 3.5) includes two inductors L and L_1 arranged on a common magnetic circuit with air gap cored-coil.



When the fitting is under voltage, the total inductance of the coil is reduced (the windings L_1 and L are differentially connected). Through the series capacitor C, a current resonance occurs leading to intense preheating of the filaments. Since the resonant frequency of the circuit is slightly less than 50 Hz an overvoltage occurs at the C capacitor terminals which, applied to the lamp, will lead to its ignition. The advantages of the *presented* fitting consist of a high power factor km ≈ 0,93...0,95 Since the resonant frequency of the circuit is slightly less than 50 Hz an overvoltage occurs at the C capacitors terminals which, applied to the lamp will lead to its fuse. The advantages of the presented fitting consist of a high power factor $k_m = 0.93 ... 0.95$ inductive, safe ignition for variations of ± 10% of voltage supply and for temperatures up to -15 °C, a high impedance audio-frequency and a higher harmonics filtering. Permanent heating of the filaments involves additional consumption of electricity and a reduction of the luminous flux. If the lamp is of normal construction, operating time decreases by accelerating the consumption of thermo-emissive material caused by a too high temperature of the filaments.

In order to reduce the time of ignition without affecting the operating parameters of the light source or of the fitting, in the laboratory of UEE, of the UAAI department, a magnetic starter was designed and built for ignition of the fluorescent lamps with capacitive ballast (Fig. 3.6). The operating principle of the magnetic starter SM is based on the variation of the LSM inductance of a nonlinear magnetic circuit, saturable coil type, connected in a RLC circuit (with $R = R_b + R_{SM}$, $L = L_b + L_{SM}$, where indices b, SM refer to ballast or magnetic starter). The rapid and cyclical variation of the LSM inductance (the magnetic circuit saturation-desaturation) leads to the apparition of the resonance phenomena in the circuit by changing its frequency of oscillation, which generates overcharged voltages at the BC capacitive ballasts terminals and implicitly, across the lamp. Magnetic starters, recommended for temperatures $\theta_a \geq +5$ °C, assure a short start time ($t_a \approx 0.7 ... 1.1$ s) and supply voltage variations in the range of 180 ... 260 V, regardless of the type and power of the lamps used.

3.3 Power factor compensation for the fluorescent lamps fittings

The study of fluorescent lamps fitting is difficult due to the lamps nonlinearities and ballast. Currents and voltages in the circuit are not sinusoidal quantities, which do not allow their representation through factors and complex analysis. If there are electro-dynamic measurement tools then we can estimate the active power, the current I and the voltage U of the fitting, and so its power factor $k_m = P / (UI)$. The low value of this parameter requires measures to reduce the consumption of reactive power that, in the case of inductive ballast fittings, consists in connecting the capacitor in parallel with the fitting (Fig. 3.7-a). It is noted that this solution increases the percentage of harmonics in the current waveform and disturbs the operating of the remote-control systems in the area.

The value of the C capacity can be determined with sufficient approximation if one considers that the current waveform is sinusoidal and the power factor is equal to the cosine of the phase angle between the circuit current and the supply voltage. In this context, if φ_1, φ_2 are voltage-current phase shifts before and after compensation with $\varphi 1 > \varphi 2$, from the current phase diagram of the fundamental harmonic (Fig. 3.7-b) it results that:

$$\underline{I}_c + \underline{I}_2 = \underline{I}_1 \Rightarrow I_c = U_S C\omega = I_{r1} - I_{r2} \Rightarrow I_c = U_S C\omega = I_1 \sin$$

In the event of an ideal capacitor $P_d \approx 0$, without loss, the active component of the current is: preserved and therefore:

$$I_{a1} = I_{a2} \Rightarrow I_1 \cos\varphi_1 = I_2 \cos\varphi_2 \Rightarrow I_2 = I_1 \cos\varphi_1 / \cos\varphi_2$$

which leads to:

$$I_c = I_1 \sin\varphi_1 - I_1 \cos\varphi_1 \sin\varphi_2 / \cos\varphi_2 \Rightarrow I_c = I_1 \cos\varphi_1 (tg\varphi_1 - tg\varphi_2)$$

$$C = \frac{I_1 \cos\varphi_1}{\omega U_s}(tg\varphi_1 - tg\varphi_2) = \frac{P_1}{\omega U_s^2}(tg\varphi_1 - tg\varphi_2)$$

where P_1 is the active power required by the fitting from the power supply.

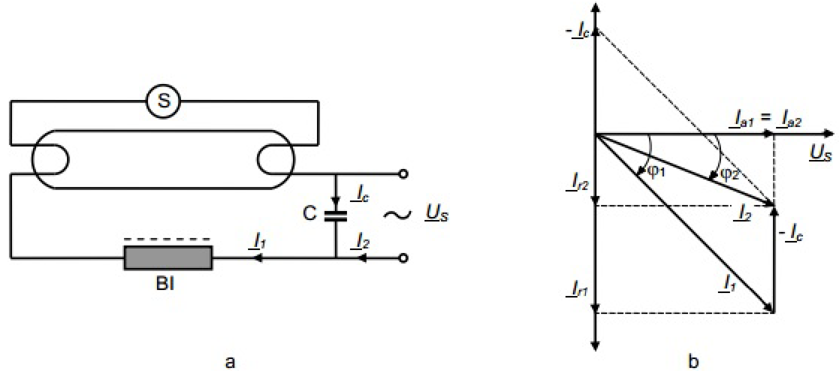


Fig 3.7 Power factor compensation for inductive ballast fitting

3.4 Utilization of the fluorescent lamps fittings

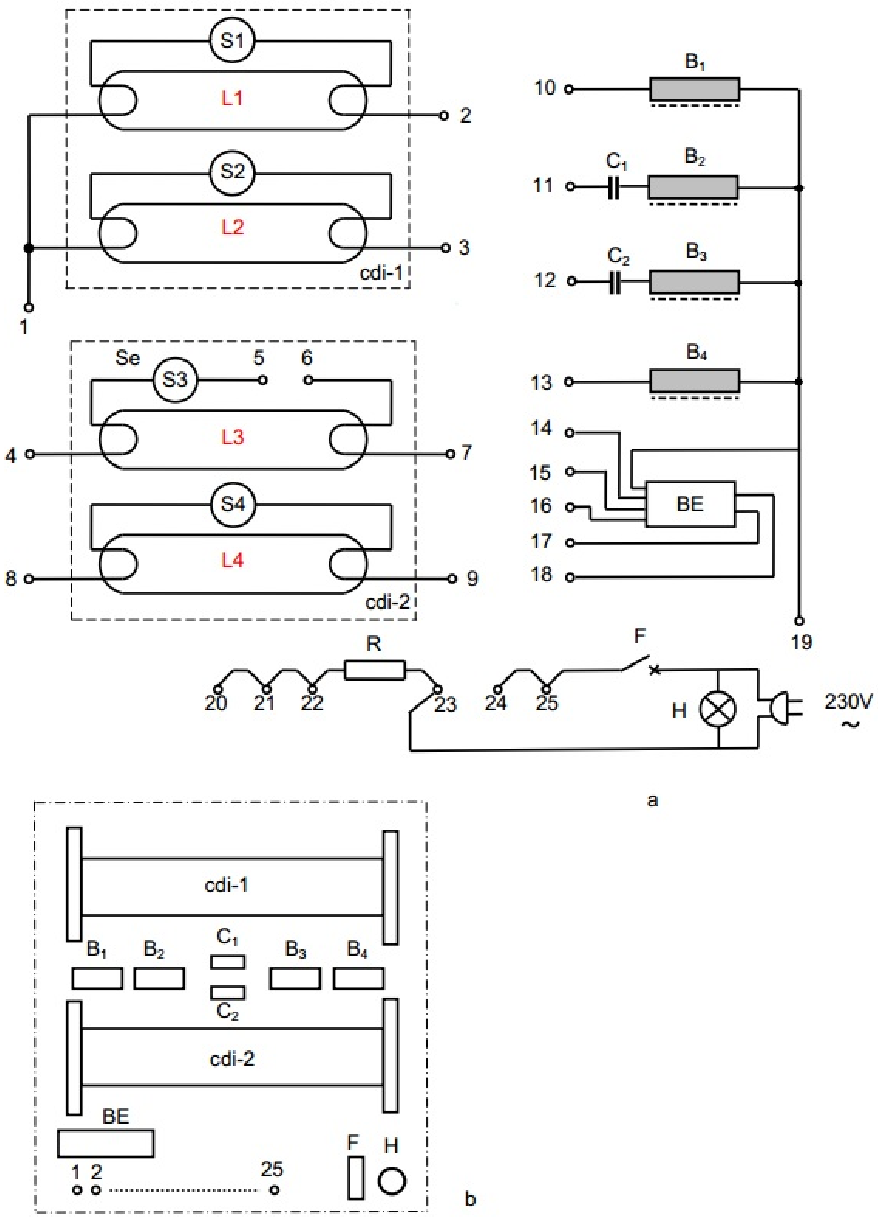
Exploitation of fluorescent lamps and of their fittings, presents a series of particularities compared to that of the incandescent lamps due to the start-control devices. The construction and operation of lighting installations with fluorescent lamps requires compliance with the following requirements:

-The lamps are mounted in series with the appropriate power voltage ballasts supply;

-If at the connection to the grid of the fitting it does not illuminate, they can be situations as: imperfect contact on lamp socket or on starter, interrupt power conductors, faulty starter (decalibrated bimetal), penetration of air in the lamp;

- If you notice blackened areas at the ends of the tube or if it flashes during the operation (the termoemisiv material of the filament was consumed), the lamp should be changed for it is worn out;

- If at the time of a grid connection the lamp shows a helical lumen variation in the tube (due to the material expelled from the filament which moves in an electric field), then it will disconnect-connect the light source successively until the phenomenon disappears;

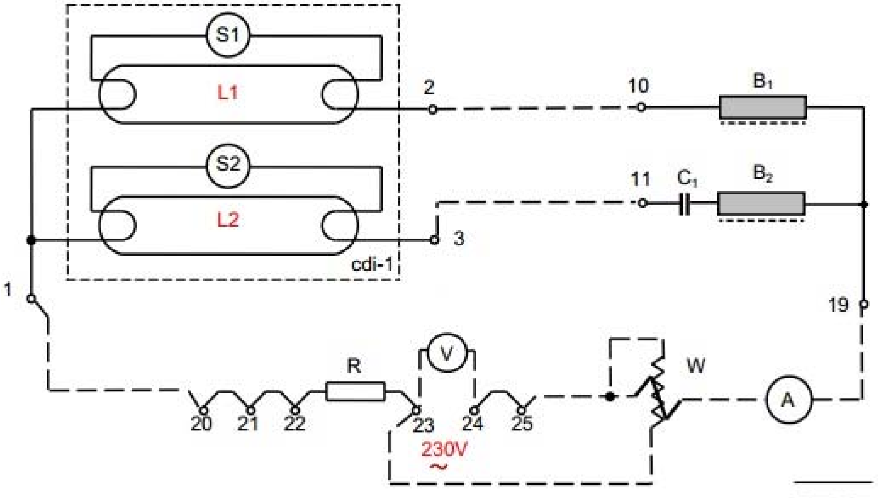


- If only the ends of the lamp light up then the starter electrodes are short-circuited, or the starter capacitor is cracked, in both cases the installation will be immediately disconnect from the grid;
- If the the ballast is heated excessively during the operation, this indicates a short circuit between windings and it is recommended its replacement.

3.5. Conducting the laboratory work

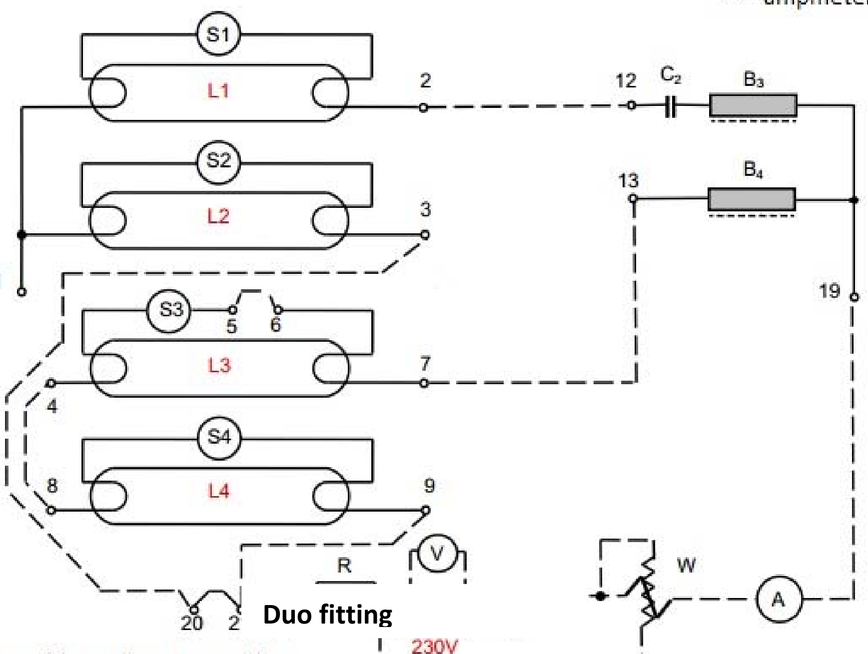
In the laboratory classes there shall be consider the following theoretical and practical issues:
- Study the schematic layout of the laboratory (fig.3.8);
- Fittings to be achieved: inductive ballast, capacitive ballast, duo, tandem inductive and capacitive, doubles tandem;
- Power factor will be calculated for every fittings made;
- Compensate the power factor of the inductive ballast fittings and determine the value of the condenser capacity;
- Calculate and check the experimental current after compensation, if the capacitor is necessary;
- Draw oscilloscopes and waveforms of u_l, u_b, i, $u_l - i$, $u_b - i$, $u_s - i$ for fittings with capacitive and inductive ballast;
- Determine the peak factor of the current for the fittings made;
- Record the conclusions for the study conducted.

Fig.3.8 Electrical diagram of the installation of laboratory (a) and layout of the system (b)
cdi-1, cdi-2 – luminaires; L1...L4 fluorescent lamps LFA18/1x= F18/54; B1, B2 – coil ballast type BIA18; B3, B4 – coil ballast type BIA36;, S1 .. S4 – glow starter type SLU 4..20W; C1 = 3µF, C2 = 3,75µF; BE – electronic ballast; R = 0,62Ω/5W; F – automated safety 6A; H – indicator lamp; Se – starter fitting with BE (makes short circuit it the classic starter socket)



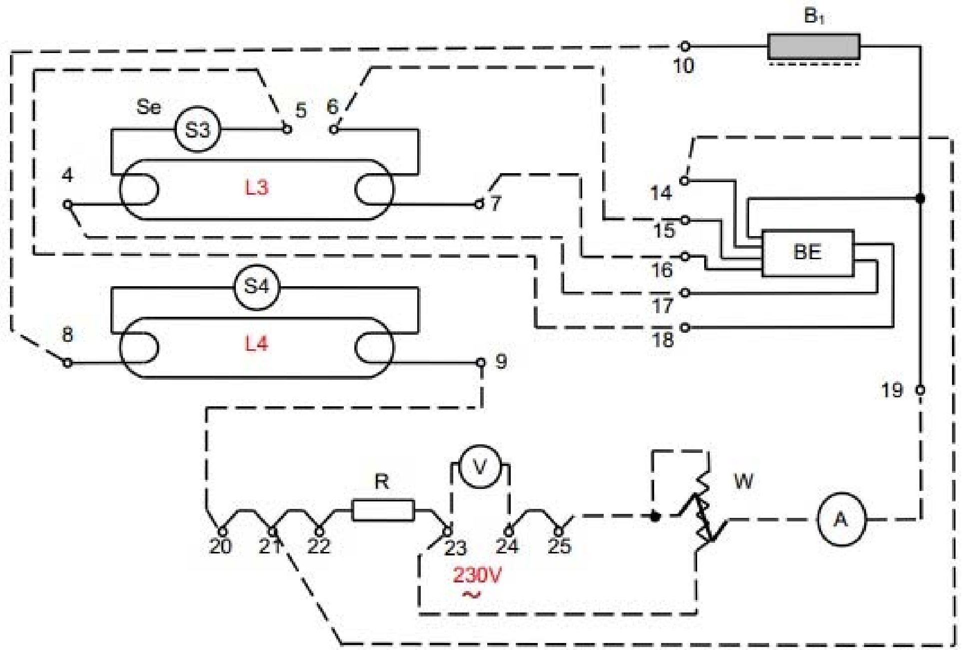
V – voltmeter
W – wattmeter
A - ampmeter

Duo Assembly



Double tandem Assembly

Double tandem fitting



L3 lamp fitting with electronic ballast and L4 lamp fitting with inductive ballast