"ELECO'99 INTERNATIONAL CONFERENCE ON ELECTRICAL AND ELECTRONICS ENGINEERING"
E01.100/A7-69

EXPERIMENTAL STUDY FOR DETERMINING EFFECTS OF DIMNESS LEVEL

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ABSTRACT

In this study, a sèries of experiments has been made for searching effects of dimness level of electronic ballasts on light and electrical characteristics of fluorescent lamp. Five different dimmable heigh frequency electronic ballasts are used in the experiment. Adjustment of dimness level is made by varying the control voltage. It is seen from this experimental study that power drawn and luminous flux do not change directly proportional to voltage level applied. Therefore, it would not be possible to make definite commentary about illumination levels in the environment illuminated by different systems at varying dimness levels.

1. INTRODUCTION

Use of fluorescent lamps for artificial lighting in places like trade buildings, school and similar constructions during the day time is more or less mandatory. Fluorescent lamps are considered among top usage items for interior lighting due to their high luminous efficacy, different colour temperatures and good colour rendering index. However, use of auxiliary elements like "ballast" has become mandatory in order to stabilize the current and to provide operating voltage in fluorescent lamps in which light is produced predominantly by fluorescent powders activated by the ultraviolet energy of the discharge.

Electronic ballasts items, are preferred more and more during the recent years over chock ballast, because of their advantages. Regulating luminous flux of fluorescent lamps is made easy by use of special type of electronic ballast, which enables lighting control systems adopted for adjustment of artificial lighting according to daylight hence, provide economy in terms of electrical consumption [1].

On the other hand, catalogues do not seem to comprise detailed information regarding light and electrical characteristics of ballast and fluorescent lamps under varying dimness levels. Available information and values are only pertaining nominal operating conditions [2,3].

A series of experiments has been made in the Lighting Laboratories of the Electrical and Electronics Faculty of Istanbul Technical University for searching effects of dimness level of electronic ballasts on light and electrical characteristics of fluorescent lamps.

2. THE ADVANTAGE AND STRUCTURE OF DIMMABLE ELECTRONIC BALLAST

High frequency electronic ballasts which are widely used during recent years for providing economy on electrical consumption and comfortable atmosphere at indoors, offer important advantages over conventional chock ballasts, such as [4]:

- Improve lamp and system efficacy, i.e. reduce ballast loss,
- No flicker or stroboscopic effects,
- Instantaneous starting without the need for a separate starter,
- Increased lamp life,
- Elimination of supply current harmonics and provision of unity power factor without use of correction capacitor,
- Light-regulation possibilities,
- Less temperature increase (due to lower losses),
- No hum or other noise,
- Lower weight, especially for big lamp sizes,
- Can also be used on DC.

A popular approach is to rectify the current drawn from the main supply and convert it in to a high-frequency square-wave signal in the range 20 kHz to 100 kHz. For control of lamp current an electronics stabilization circuit is used. Light regulation is simply achieved by increasing the frequency.

The main elements of the electronic ballasts for light regulation (dimmable electronic ballast) may be listed as follows;

- A low - pass filter,
- A rectifier,
- A buffer capacitor,
- A high frequency power oscillator,
- A high - frequency stabilizer coin,
- A light regulation circuit.

Figure 1 shows the general circuit of the dimmable electronic ballast.

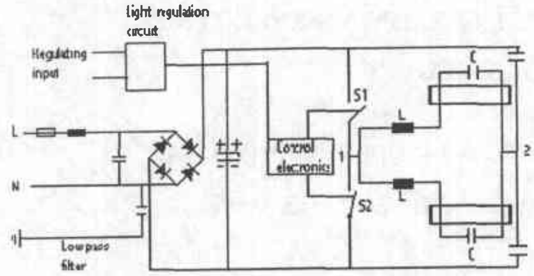

Figure 1. General circuit diagram of a dimmable electronic ballast

According to the working principle of the dimmable electronic ballasts the AC supply voltage mostly used for the fluorescent lamps must first be converted into a DC voltage. This voltage is than converted into a high frequency AC voltage, which is the supply for the lamp. The rectifier charges a capacitor to 280 V. This DC voltage is transformed into a high-frequency square - wave voltage of 280 V by to electronic semi conductor switches (S1 and S2) operating at a frequency of 28 kHz. This HF square-wave voltage is the supply source for two lamp systems in parallel, each consisting of an HF stabilizer coil and a HF fluorescent lamp in series.

Regulation takes place by changing the frequency of the control electronics, depending on the variable DC voltage applied. Light regulation between 100% and about 1% can be achieved by opening and short-circuiting the two connection terminals of the regulating input. The voltage at these terminals called control voltage, is varied between 10 V and 1 V. By inserting a potentiometer between these terminals, the regulating range from 100% to 1% can be covered in a continuous manner. On the other hand, by using remote control, it is also possible to regulate the lighting from various points in the room. If the circuit is supplemented by an automatic cut-off circuit, the lighting installation can be switch off automatically and the lighting level is obtained with daylight [5,6].

3. EFFECTS OF DIMNESS LEVEL ON LIGHT AND ELECTRICAL CHARACTERISTICS

In this study, the changes occurring on the power drawn, power factor, luminous flux and the luminous efficacy according to dimness level on fluorescent lighting systems with dimmable electronic ballasts have been determined experimentally. Adjustment of dimness level is made by varying the control voltage between 10V and 1V. Five different dimmable high frequency electronic ballasts used *in the experiment are*: 2 x 18W; 1 x 36W; 2 x 58W; 1 x 26W and 2 x 26W. Effects of these ballasts operating at variable dimness levels, hence different control voltage on the light and electrical characteristics of fluorescent lighting systems are inspected.

3.1. Changes in Power Factor According to Dimness Level Variation

Power factor is expressed as the cosine of phase difference between voltage and current. It is desirable to have this value close to "1" as much as possible in order to prevent useless loading of the system.

In order to examine the changes in the power factor at various levels of dimness, current and power values according to control voltage are measured and shown in Table1. Voltage is kept stable at 220V throughout the experiments. Power factors of the systems are calculated by placing measured values within formula given by equation (1).

$$\cos\varphi = \frac{P}{U \times I} \tag{1}$$

Changes in power factor, calculated in various dimness levels for five lamp-ballast systems, according to control voltage are given in Figure 2 in graphical form.

3.2. Changes in Luminous Flux and Luminous Efficacy According to Dimness Level Variation

Measurements of luminous flux are made by Ulbricht Sphere for each lamp-ballast system by altering the control voltage. By the help of the luminous flux values measured and power values corresponding to the same control voltage, changes in luminous flux according to power are drawn in Figure 3. Figure 3 also indicate the relationship between the power drawn and the control voltage, as well.

The luminous efficacy of fluorescent lamps which need to be used together in accordance with their working principles, are calculated by:

$$e = \frac{\Phi_L}{P_L + P_B} \tag{2}$$

Where,

Φ_L : luminous flux of lamp,
P_L : power of lamp,
P_B : loss of ballast.

Luminous efficacy for each lamp-ballast system is calculated at various control voltages by equation (2) by using luminous flux and power values measured. Changes in luminous efficacy according to control voltage are given in Figure 4 in graphical form.

Table 1. The values of current and power drawn according to control voltage

Type of the lamps and ballast	Control voltage (V)	1	2	3	4	5	6	7	8	9	10
2x18W	Current (A)	0.05	0.062	0.074	0.086	0.099	0.115	0.129	0.146	0.162	0.175
	Power (W)	8	11	14	17.4	20.7	24.3	27.5	31	35	38
1x36W	Current (A)	0.043	0.048	0.06	0.073	0.088	0.103	0.12	0.138	0.156	0.173
	Power (W)	5.5	7.2	10.4	14.2	17.6	21.5	25.5	29.3	33.4	37
2x58W	Current (A)	0.078	0.103	0.151	0.209	0.269	0.328	0.39	0.453	0.493	0.51
	Power (W)	14.8	20.3	32	45.3	58.8	72	85.5	98.3	106	106
1x26W	Current (A)	0.03	0.039	0.053	0.068	0.081	0.092	0.103	0.113	0.121	0.128
	Power (W)	5.8	8	11	14.5	17.3	19.8	22.2	24.2	26.2	27.5
2x26W	Current (A)	0.068	0.076	0.098	0.125	0.146	0.168	0.186	0.205	0.223	0.24
	Power (W)	14	16	21	27	32	36.5	40.8	45	48.7	52.8

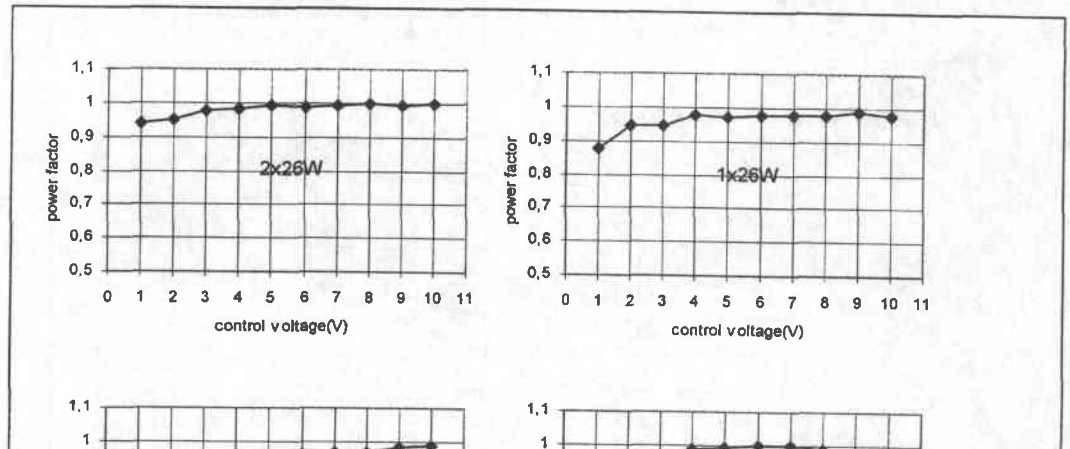

Figure 2. Relationships between the control voltage and the power factor for five lamp-ballast systems

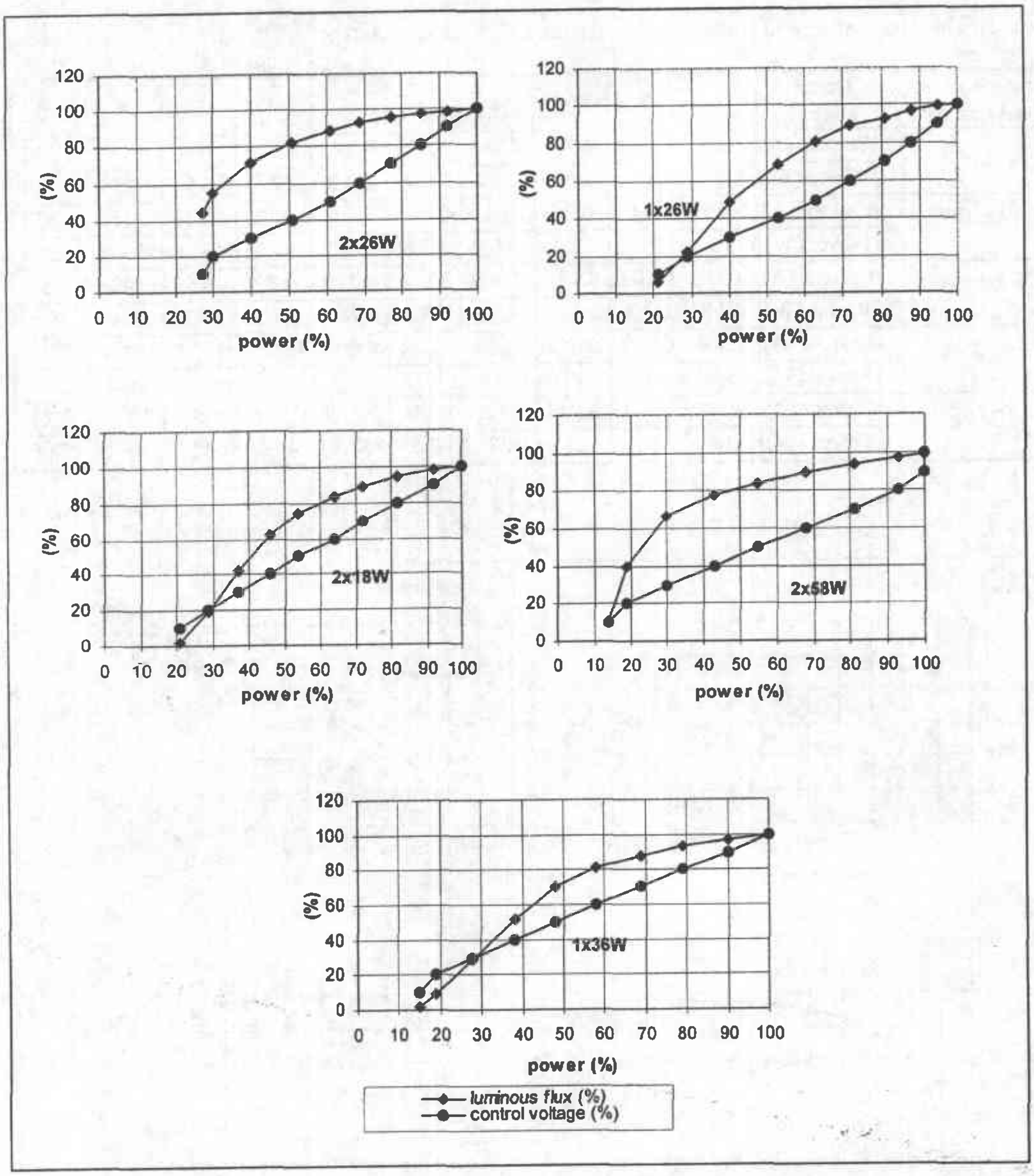

Figure 3. Luminous flux and control voltage as a function of power drawn for five lamp-ballast systems

4. CONCLUSION

It can be seen from careful inspection of Figure 2, there are sudden drops of power factor values in 2 x 18W and 1 x 36W systems under 50% control voltage. If power factor falls down to 0,6 - 0,7 value, the complimentary compensation precautions should be taken considering reactive power drawn. A decrement is also observed in power factor when control voltage drop below 50% in the 2 x 58W system, as well. This decrement however is not significant enough for taking additional precautions. On the other hand, 1 x 26W and 2 x 26W compact fluorescent lamp systems have revealed power factor values falling within acceptable limits to consider "constant" at all voltage levels.

Drawn power values do not diminish at the same rate as control voltage decrease in all tested lamp-ballast systems. Luminous flux of all lamps are observed not to diminish at the same rate with power drawn (Figure 3). Therefore, luminous efficacies of all systems are not maintained stable at all control voltages (Figure 4). Luminous efficacy rises above nominal value when the control voltage dropped to 50% from 100% value. On the other hand, decrease is observed in luminous efficacy when the control voltage drops below 50% where further drop below nominal value is observed under approximately 30% voltage levels.

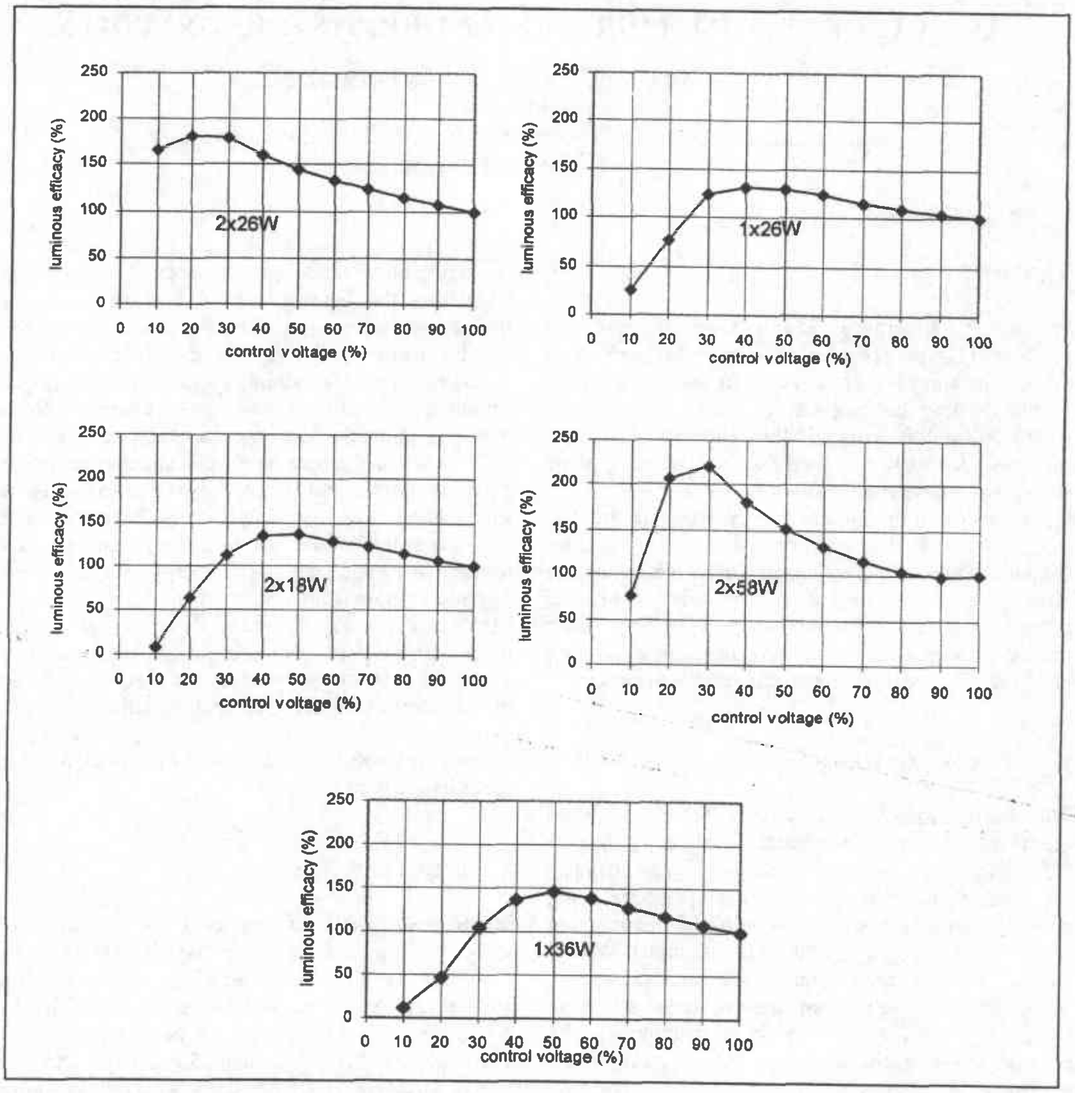

Figure 4. Relationship between the control voltage and the luminous efficacy for five lamp-ballasts systems

It is seen from this experimental study for five different lamp-ballast systems, that power drawn and luminous flux do not change directly proportional to voltage level applied. The above results have shown that it would not be possible to make definite commentary about illumination levels in the environment illuminated by different systems at varying dimness levels. Experimental results verify that structure and working principles of dimmable electronic ballast systems do not conform any specific standard, what so ever. Nevertheless, it becomes obvious to have these experiments repeated with numerous different type and marks of lamp-ballast systems for enabling more definite conclusion.

REFERENCES

[1] RUBINSTEIN, F. M., SIMINOVITCH, M., VERDERBER, R., "Fifty Percent Energy Saving With Automatic Lighting Controls", IEEE Transactions on Industry Applications, Vol. 29, No. 4, p. 768 - 773, July- August (1993)

[2] Philips Lighting, "General Technical Manual for HF Ballasts", Product Information, July, 1990

[3] Osram, "Electronic Control Gear' 97/98, April, 1997

[4] ONAYGIL, S., GULER, O., "High frequency Electronic Ballasts", I. National Lighting Congree, p. 200-207, Istanbul, 1996

[5] MEYER, Chr., NIENHUIS, H., "Discharge Lamps", Philips Technical Library, Kluwer Technishe Boeken B.V., Deventer – Antwerpen, p. 115-122, 1998

[6] COATON, J.R., MARSDEN, A.M., "Lamps and Lighting", John Wiley&Sons, Inc., New-York, 4.edition, p. 303-335, 1997