A PRACTICAL INVESTIGATION FOR REASSESSING THE PERFORMANCE OF ELECTRONIC BALLASTS COMMERCIALLY AVAILABLE ON THE MARKET IN EGYPT

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ABSTRACT

In this study a practical investigation to the electrical and optical performance of the electronic ballasts and compact fluorescent lamps commercially available on the Egyptian market is conducted. The study includes 18 different cases of fluorescent lamps driven through magnetic and electronic ballasts. The outcome of this study was made to encompass all relevant circuit particulars. The conclusive remarks confirms the superior performance of the electronic ballasts but find it with the relatively high level of harmonic order present in the current waveform thus impairing the lamp efficacy, true power factor, THD and crest factor resulting in an a discomforting impact on the low-voltage networks.

INTRODUCTION

In most areas of domestic, residential, commercial and industrial application of lighting systems *fluorescent tube* fixtures are extensively made-use-of. This is due to the fact that they consume less active power and cause a more prolonged operating lifetime of the tube than their counterpart the incandescent lamp.

The superior performance of the fluorescent tubes are sometimes outweighed by the mandatory presence of the magnetic ballast and its companion the starter as means to start the arc and maintain the lamp in a stable operating state. Since the early 1990's the recent developments in the technology of power electronic devices made it possible the manufacturing of the electronic ballast as a direct replacement to the combination of the magnetic ballast/starter on one hand and also to develop the compact fluorescent lamp as a direct replacement to the filament lamp on the other hand. Now, after two decades of operation with the electronically-based ballasts, and considering their ever-growing field of utilization, it is useful to re-evaluate their impact on the field of illumination and on other relevant fields, mainly the power quality of the low voltage networks.

It is the purpose of this paper to carry out a practical investigation to the electrical and optical performances of selected sample of the electronic and CFL commercially available on the Egyptian market. To assess its ever growing effect on the low-voltage distribution network, their low power factor and the interference problem they may produce.

TESTING SYSTEM SETUP

The practical setup used to perform to this study is shown in fig.(1) and an illustration to this setup is given in fig.(2).

A computer software program was developed to generate other relevant deductible results from the measured ones through the use of the fast Fourier transform technique (FFT) of the MATLAB software version 7.0.

Eighteen cases of ballasts and compact lamps available on the local market are carefully selected so as to cover a broad area of ballasts types as shown in table 1.

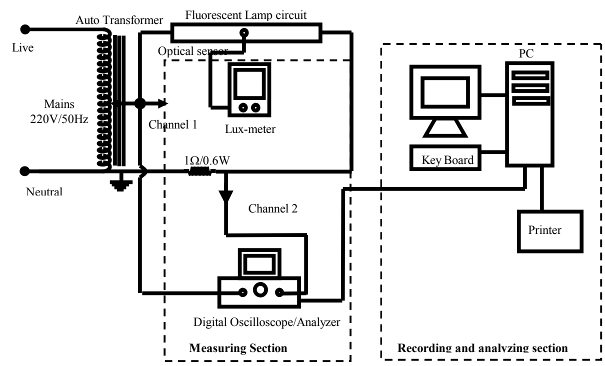


Fig.(1) Testing system set up

Fig.(2) Illustration of the testing system in use

Table 1 listing of cases under study

Case No.	Type	Power Rating in W	Nominal Power Factor	Fluorescent Tube
1	Mag.	20	0.35	60/19W
2	Mag.	36	0.5	120/38W
3	Elect.	20	0.56	60/19W
4	Elect.	40	0.65	120/38W
5	Elect.	40	> 60%	60/19W
6	Elect.	40	> 60%	120/38W
7	Elect.	40	-	60/19W
8	Elect.	40	-	120/38W
9	Elect.	40	-	60/19W
10	Elect.	40	-	120/38W
11	Elect.	36	-	60/19W
12	Elect.	36	-	120/38W
13	CFL	12	-	Half Spiral
14	CFL	15	-	Spiral
15	CFL	20	-	3U
16	CFL	23	-	3U
17	CFL	26	-	Half Spiral
18	CFL	26	0.92	Half Spiral

THE ANALYTICAL PROCEDURE

The output traces of the digital/analyzer oscilloscope provide the mains voltage and current waveforms; fed to a personal computer through the SX-Metro software to produce 100,000 readings/cycle corresponding to a sample rate of 5MS/sec. A sample of these results are shown in fig.(3.a) for the case No. 9 of the electronic ballast and in fig.(4.a) for the case of CFL. These results are fed to the FFT technique of the MATLAB version 7.0 where the harmonic content in both voltage and current are computed the results are shown in fig.(3.b) and fig.(4.b) respectively. The normalised values of the harmonic content of all cases under stuffy based on the magnitude of the fundamental for each case is shown in fig.(5). The value of the instantaneous power is generated from: $p(t) = v(t) \cdot i(t)$, and consequently the average power is calculated, the true RMS voltage and current are evaluated and thereafter the THD, crest factor and true power factor are calculated according to the relation:

$$V_{TRMS} = \sqrt{\sum_{n=1}^{\infty} V_n^2} \qquad I_{TRMS} = \sqrt{\sum_{n=1}^{\infty} I_n^2}$$

$$V_{THD} = \frac{V_{TRMS}}{V_{fRMS}} \times 100 \qquad I_{THD} = \frac{I_{TRMS}}{I_{fRMS}} \times 100$$

The results of the THD is depicted in fig.(6).

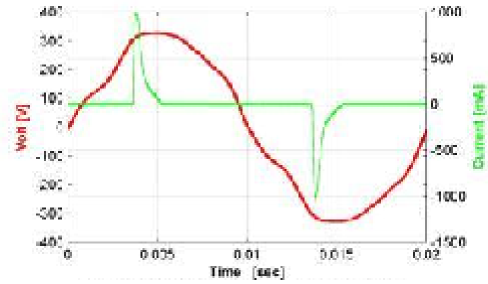


fig.(3.a) Voltage and current traces for case No.9

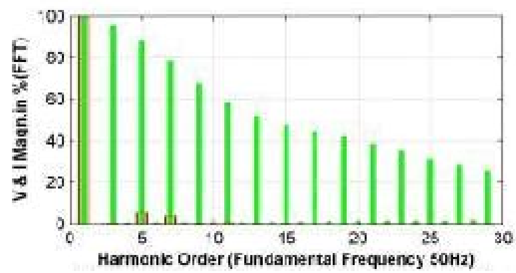


fig.(3.b) Harmonic contents in voltage and current traces for case No.9

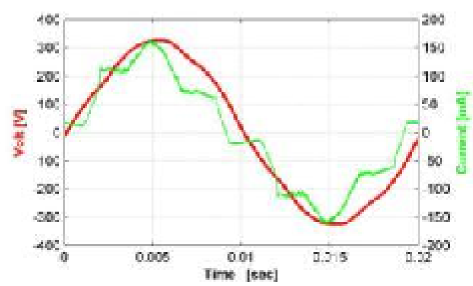


fig.(4.a) Voltage and current traces for case No.15

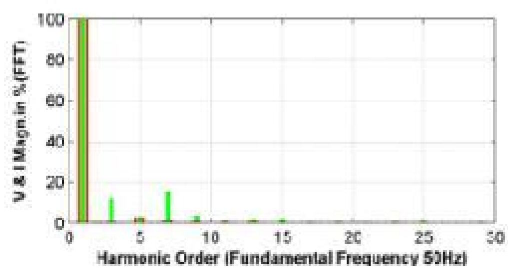


fig.(4.b) Harmonic contents in voltage and current traces for case No.15

$$V_{CF} = \frac{V_{Peak}}{V_{TRMS}} \qquad I_{CF} = \frac{I_{Peak}}{I_{TRMS}}$$

Fig.(7) shows the crest factor of both voltage and current. The true power factor is computed from the relation

$$TPF = \frac{\text{Average Power}}{\text{V}_{\text{TRMS}} \times I_{TRMS}}$$

This result is conflicting value with the displacement power factor defined as:

$$DPF = \frac{\text{Average Power}}{V_{fRMS} \times I_{fRMS}}$$

Where V_{fRMS} and I_{fRMS} are the RMS of the fundamental component of the voltage and current waveforms respectively. The results of the calculated true power factor are shown in fig.(8). For each case under study the radiating light is measured using a luxmeter and the lamp efficacy is calculated, the results obtained are shown in fig.(9) for all cases where solid lines denotes the lumen/W while the hatched bars denotes the lumen/VA. As all industrial light tariffs include both the active and reactive power components, thus the saving for these applications are reduced.

HARMONIC EFFECT ON LOW VOLTAGE NETWORKS

The heavy presence of harmonics in relatively large proportion of the total power delivered will produce, among other effects, two most detrimental ones; the first is that of impairing the power quality of the distribution network[1,2], while the second is that of overloading on the current flowing in the neutral wire in a four wire distribution network. The general rule is to select the size of the neutral wire equal to the phase wire or sometimes even lower in size. The summation of the multiples of the third harmonics given by :

$$I_{neutral} = I_f + \sum_{n=1}^{\infty} I_{3n}$$

Flowing in the neutral wire will cause the current in the wire to exceed its rated value or another way to look at it is to de-rate the system rated load to allow for this contingency. Needless to say that this will increase the voltage at the load neutral point[3,4], and consequently impair power quality again.

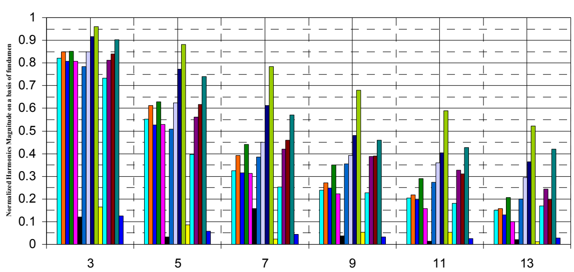


Fig.(5) Normalised magnitude of harmonic content

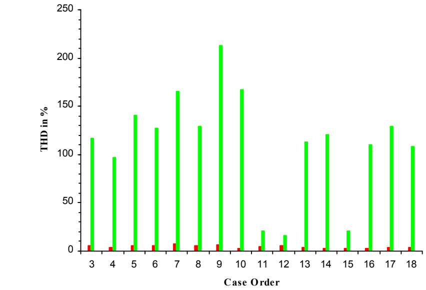


Fig.(6) shows % of THD for each case under study

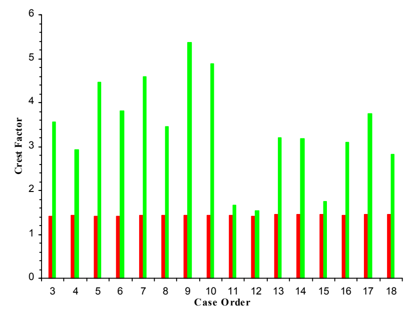
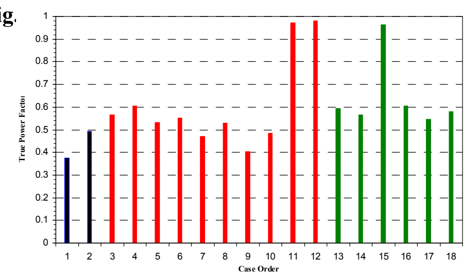


Fig.(7) shows crest factor for each case under study

Fig. 

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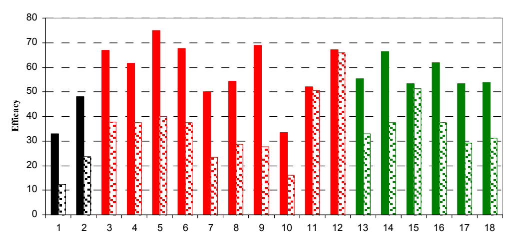

Fig.(9) shows the efficacy for each case under study

CONCLUSION

The results presented in fig.(5) to fig.(9) respectively depict the relative performance among 16 types of electronic ballasts and CFL ballasts. The major drawback of this type of ballasts is the heavy, undamped, presence of harmonics causing a large THD, crest factor and finally true power factor. The need is to provide the Egyptian market with electronic ballasts provided with filters to damp away all high order harmonics. Once this is achieved then the true power factor may converge to a value near the displacement power factor. When comparing electronic ballasts to the magnetic ballast on a technical basis, we must side the former. On the other hand this comparison when effected on a long term economical basis the magnetic ballast will be favored. The reason resides in its reliability and average life time duration [ ].

One may suggest the implementation of a microcontroller chip to discipline the operation of the electronic ballast; which may provide a possibility to change the operating frequency so as to overcome the tube aging effect and/or may be reduce the harmonic content or even optimize the tube operation.

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