High Frequency Electronic Ballast for Fluorescent Lamp Is it the Panacea?

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ABSTRACT
In developing countries electromagnetic ballasts are widely used for operation of fluorescent lamps. High frequency electronic ballasts are expensive and the ones that are available at a reasonable price suffer from disadvantages like injection of harmonics to the mains, marginal energy conservation etc. The reasons for market unacceptability of these are studied. An L-C resonant ballast is also considered in the analysis to arrive at a Figure of Merit. The alternate ballast system is suggested for a DSM programme of an utility.

Key words: High frequency ballast, L-C resonant ballast, Fluorescent lamps, DSM programme.

INTRODUCTION
Conventional core-coil ballasts are used for fluorescent lamps along with glow -type starters. High frequency electronic ballasts came into the market 4-5 years ago as they were expected to be energy conserving. Although there is a national standard on this product no manufacturer has qualified so far. Consumer acceptance has also been poor. Detailed experiments were conducted on various high-frequency electronic ballasts picked up from the market for study. A comparative assessment of their performance is made with an electro-magnetic reference ballast as well as with an L-C resonant ballast designed by the authors.

STATEMENT OF THE PROBLEM
The single phase distribution supply in India is at 240V 50Hz. There are transient disturbances in the system at any point of time. During peak load conditions in any city the voltage drops to as low as 160V. On week ends , holidays & on night shifts the voltage may touch 280V. The harmonics in the power system are on the increase because of various types of industrial loads such as steel rolling mills, scrap melting induction furnaces, d.c. traction systems etc., The T & D losses are in the range of 20-25 %, the power factor of a distribution system is poor and is in the range of 0.6-0.75. Some utilities insist on installation of capacitors at a residential p.c.c, whereas others are interested in other forms of distributive capacitive compensation. A residence or a small-scale industry faces many problems because of poor power quality. Lighting is the area which is considered for discussions in this paper as it forms an important aspect in a DSM programme and to understand the contribution of ballasts to poor power quality their susceptibility under poor power quality conditions and also to determine a viable alternative.

TYPES OF BALLASTS.
- Conventional core-coil ballasts (ccb): These are of core coil variety designed to give rated lamp parameters (Fig.1).
- Reference ballasts(refb): These are also of core-coil variety used for calibration of commercial ballasts.
- High frequency ballasts (hfb): (Fig.2.) Generally power frequency voltage is first converted to d.c and inverted to high frequency a.c output for operation of lamps. Calibration of these is carried out with a core-coil reference ballast indicated above.
- L-C resonant ballast (lcb): (Fig.3) A redesigned core-coil in series with a suitable capacitor and a triac-diac based power electronic circuit for initiating discharge at a lower input voltage of say 150V. constitutes an L-C resonant ballast wherein the power electronic circuit cuts off after the lamp lightsup. LCB operates at a leading power factor.

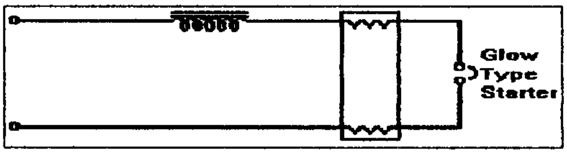
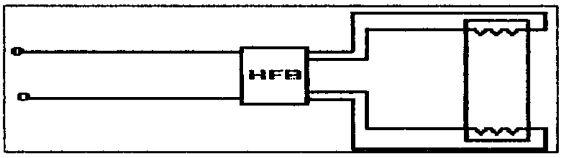


Fig.1



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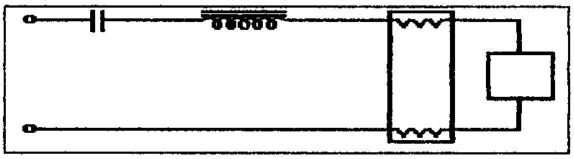

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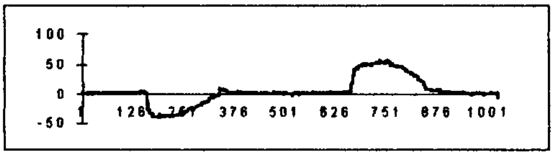

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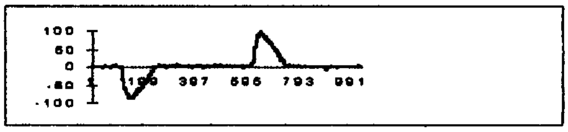

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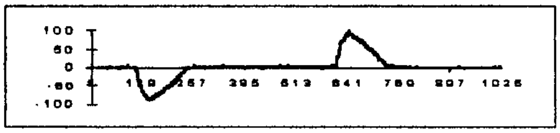

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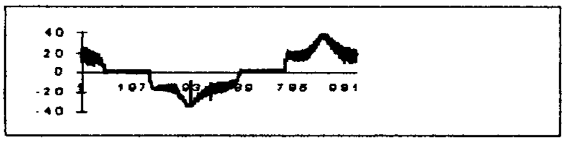
Fig.7



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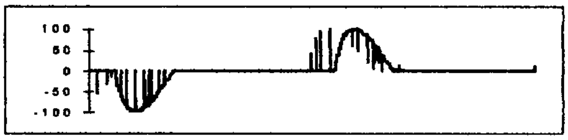

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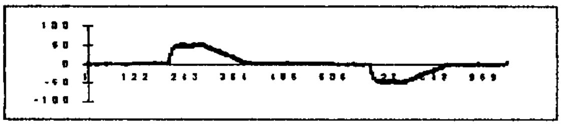

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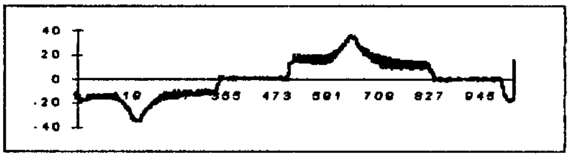

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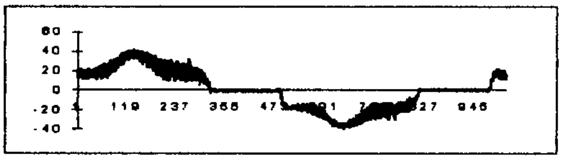

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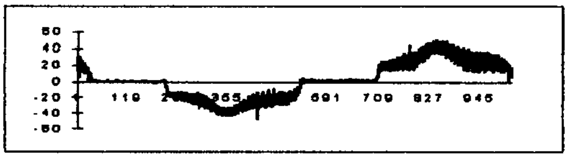

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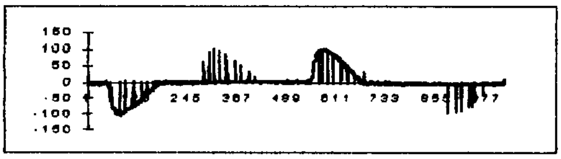


Fig.14

EXPERIMENTAL METHODOLOGY.

Several high frequency electronic ballasts were picked up from the market and comparative analysis has been made on various parameters such as input current, wattage, power factor, THD, illumination etc. on varying input voltages, Experiments were conducted on reputed core-coil ballasts and reference ballasts. Comparison has also been made with a typical L-C resonant ballast. The input electrical parameters were measured with INFRATEK 100 KHz power meter. The out-put voltage, frequency and crest factor of current were measured using KEITHLEY -DMM 2001. The illumination was measured with TEKTRONIX-J17 photometer. Harmonic analysis was made with FLUKE-41 power meter. Non-sinusoidal power supply was generated using HP 6813-A power source & analyzer.

OBSERVATIONS.

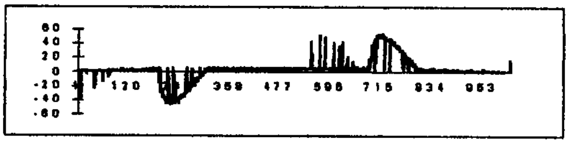
The wave shapes of input current for different makes of hfb are shown in figures 4 to 16 and for ccb, refb and an lcb is shown in figures 17-19 respectively.

A. *Lumen per input watt (LIW) v/s Voltage*

CCB has a higher value of LIW at lower voltages say 160-180V and reduces at increasing voltages whereas hfb has a higher value at about 200-220V falling off on either side of this voltage. LCB has a fairly constant value over a wide range of voltage. In India the typical values of LIW at rated voltage are shown in table 1:

B. *Crest factor of current:*

CCB indicates a lamp current crest factor of about 5.70



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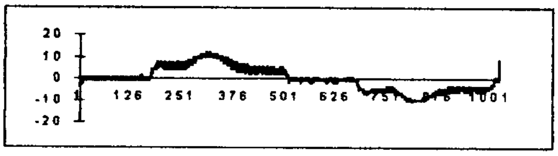

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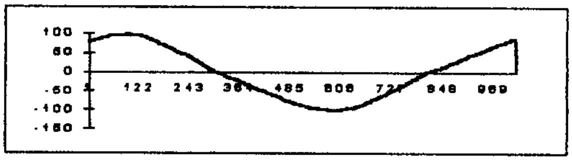

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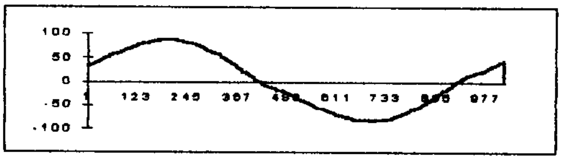

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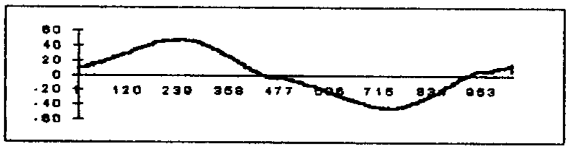

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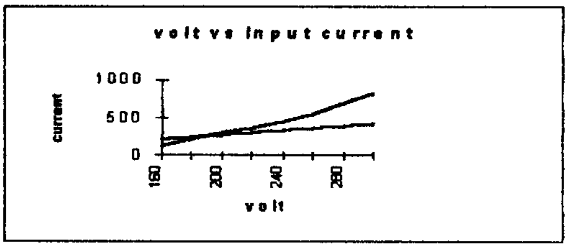

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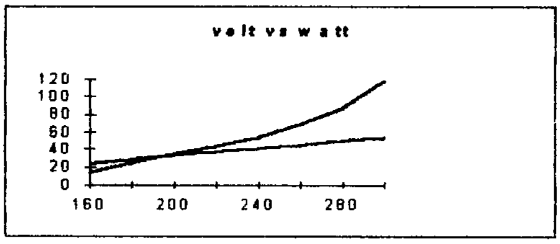

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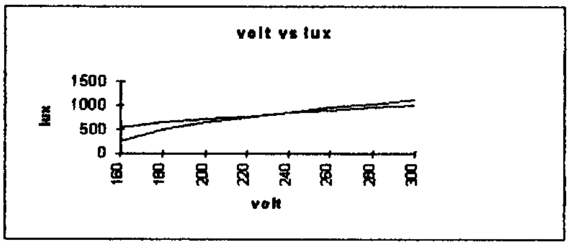

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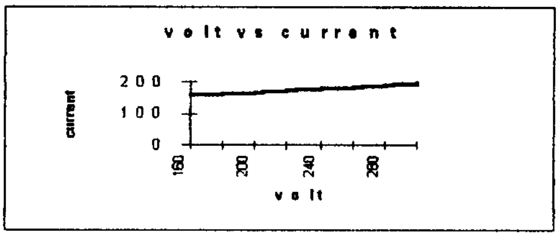


Fig 23

Table 1.

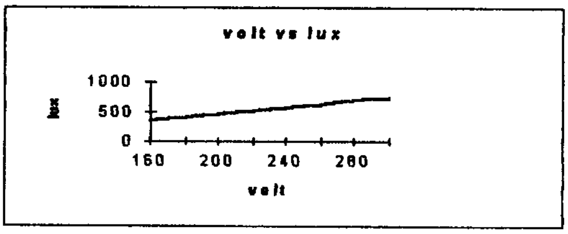
Sl no.	Ballast Type	LIW	Crest Factor	THD	PF	Cost
1.	ccb	26-28	1.62	9.7%	0.59	$4.5
2.	refb	29	1.53	7.2%	0.53	$50
3.	hfb	37	1.8-3.5	28-80%	0.5-0.9	$10-$15
4.	lcb	32	1.65	18%	0.46	$7-$8

Table 2.

V THD	I THD		
	CCB	HFB	LCB
0	9.8	24.6	19.8
42.8	24.4	44.3	46.5

Table 3.

CCB			LCB			HFB		
I	W	Lx	I	W	Lx	I	W	Lx
11	14	7	5	5	4	1.5	5	5



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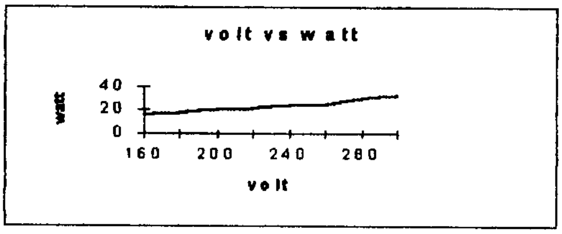

Fig. 25

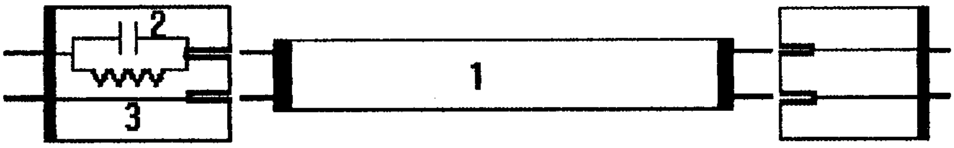

Fig. 26

during the initial starting phase at the rated voltage of 240V whereas this figure for lcb is 1.70. However during operation the crest factor for different ballasts at rated voltage are shown in the table 1. From the figures 1-15 it may be seen that the crest factor of input current for hfb is highly varying from 1.8 to 3.5.

C. *Power Factor:*
Input power factor of ccb varies from 0.55 to 0.61 from 160 to 240V. HFB generally operates at a distortion power factor of about 0.50-0.9. LCB operates at a leading power factor of 0.4 to 0.6.

D. *Lamp Frequency:*
Obviously the lamp operating frequency in case of ccb and lcb is the line frequency. Most of the hfb's operate at about 20 to 35 KHz at rated voltage. The operating frequency increases with decreasing voltage with about 20% of the ballasts tested operating at about 60 to 65KHz.

E. *Total harmonic distortion:*
From the figures it can be seen that the wave shape of the input current for all hfb's tested indicated severe distortion. The THD for all ballasts is shown in the table 2.

F. *Regulation:*
Experiments were conducted to determine the regulation of light output, input watt and input current of different systems of ballasting by varying input voltage from 160 to 300V. The comparative results are shown in figures 20 to 22 for ccb and lcb. The steeper curve is for ccb. Figures 23 to 25 indicate similar graphs for hfeb.

G. *Susceptibility under PQF:*
Experiments were conducted to determine the impact of line voltage harmonics on the ballasts. In order to do this H.P 6813 A Power source & analyzer was used to generate a square wave of 240 V r.m.s and applied to ballasts. The THD is noted and compared with corresponding figures for a sine wave input. The results are shown in table 2.

H. *Cost:*
The cost of ballasts in India in dollar terms in shown in table 1. However some hfb's purported to be of international design cost around 30 $ which were not available for our analysis.

STRATEGY FOR SELECTION OF A BALLAST SYSTEM:

A ballast system cannot be selected based on any single parameter namely energy conservation. A preferable Figure Of Merit (FOM) appears to be: (Lux/Va)*(Cost/Watt)*Pf*Thd*CF/K assuming equal weightage to all the parameters. K is a factor which takes care of the regulation of input parameters determined from figures 20 to 25 and its values normalised to rated voltage are shown in table 3.A weightage can be given if the operation is at a leading power factor.

DSM PROGRAMME IN INDIA

Lighting is one of the important areas of a DSM programme. One of the utilities in Western India has considered installation of lcb's in a city selected for the research programme. They have selected an ESCO for this project. It is proposed to be implemented in the residential sector initially under a leasing programme. The specification of the lighting system is as follows:

Luminaire	1200 mm for 36 w / 40 w;
Input wattage	38–40 W
Power factor	0.5-0.6 leading,
Minimum striking voltage	150 V
Operating voltage	150-300 V
Illumination	90-95 % normal.

There will be two types of the ballasting system i as a stand alone luminaire with ballast and ii as a retrofit in a domestic luminaire. Many consumers desire that the the existing ccb be utilised so as to give them a flexibility that in case the new ballast fails for whatever reason, there would be a facility to revert back to the earlier configuration easily. In the retrofit model it is contemplated to use a special tri-band phosphor lamp of 1100 mm length with ballast mounted at one end achieving a length of 1200 mm for the retrofit. The conventional starter would be replaced by an electronic starter. The schematic is shown in fig 26 wherein 1 is a special lamp, 2 is a capacitor and 3 is the end cap assembly.

CONCLUSIONS

We recognise that there may be a few high freqency electronic ballasts which are indeed as per national / international specifications However in a developing country there will be a number of manufactures in the small scale industrial sector. Our conclusions are limited to the ballasts obtained from these manufacturers for our experiments.

- Line currents of hfb's are distorted. Extensive use of these would cause severe power quality problems in an already strained power system.
- Although low voltage lightup is a boon for developing countries other systems of ballast such as lcb should be considered.
- HFB'S generally create EMI problems which is absent in other systems.
- Any system of ballasting should be considered based on its FOM.
- The response of ballasts to voltage harmonics indicate that ccb behaves better whereas hfb and lcb contribute to increased THD of line current. In all the cases the illumination drops in the presence of voltage harmonics.
- For the DSM programme in India one of the utilities has opted for lcb's for the residential lighting as a retrofit or independent lamp / ballast fitting.

ACKNOWLEDGEMENT

The authors would like to thank Director National Physical Laboratory New Delhi, 110012, India for the financial support given for Research and Development. ●

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