ENERGY CONSERVATION IN AN INSTITUTIONAL CAMPUS: A CASE STUDY

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ABSTRACT

An educational complex consumes electricity for the purposes of lighting, air conditioning and computer loads. To practice energy conservation in such a building enclosure warrants, switch off policies, which has limited results. A probable energy saving and demand reduction opportunity in lighting load in a typical institution campus was found out. An experiment was conducted in a residential educational complex. The interventions considered were fluorescent lamp with magnetic ballast, with electronic ballast and with a power factor improvement capacitor, in addition to the magnetic ballast. Experiments have shown that, fluorescent lamps emit almost same quantity of luminous flux (lumens) with all of these configurations. The salient results of the study reveal that energy demand can be reduced by about 40%, with a very short payback period for the said interventions.

KEYWORDS: *Demand Reduction, Power Factor Improvement, Magnetic Ballast, Electronic Ballast, Harmonic Distortion.*

I. INTRODUCTION

The gap between supply and demand of energy is continuously increasing despite huge outlay for energy sector since independence. Further, the burning of fossil fuel is resulting in greenhouse gases, which are detrimental to the environment. The all India annual requirement of electricity during year 2010-11 was 861,591 Million Units (MUs) and availability was 788,355 MUs, resulting in shortage of 73,236 MUs (8.5%). During year 2011-12 the all India annual requirement was 933,741 MUs and the availability was 837,374 MUs, resulting in shortage of 96,367 MUs (10.3%). The all India annual peak requirement during 2010-11 was 122,287 MW and availability was 110,256 MW, resulting in shortage of 12031 MW (9.8%). During year 2011-12 the all India annual peak requirement was 136,193 MW and availability was 118,676 MW, resulting in a shortage of 17,517 MW (12.9%) [1]. The conservation of energy is important, as it can reduce peak and average demand. Investment in energy efficiency/energy conservation is highly cost effective, can be achieved in less than Rs.10 Million/MW and it also avoids investment in fuel, mining, transportation etc. The Government has taken many steps to save energy [2].

Lighting industry in India is seven decades old and has gone through a period of transition and growth. The share of lighting load in the total connected load of India is about 100000 MW (17 %) in year 2010 [3]. Since, the share of lighting load is significant, there is an urgent need to take care of this. There are many ways available for the conservation of energy like switch off lights when not required, use automatic devices, infrared sensors, motion sensors, timers, dimmers, use task lighting as far as possible, regular dusting of the light sources, replacing ordinary bulbs with efficient one, de-lamping, day light harvesting, using light colors for wall painting, selecting ballasts with higher power factor and long term efficiency in mind, etc [4].

Lighting is a very important part of every business. The lighting load of the business, accounts for 20% to 50% of total electricity consumption. This means that a realistic cost savings can be achieved with energy-efficiency improvements, and because of continually improving equipment, lighting provides the highest return-on-investment. The technologies available are incandescent lighting, compact fluorescent lighting, improved halogen system, fluorescent lighting, high-intensity discharge lighting, quality of fixtures, day lighting, light emitting diode lighting and induction or electrode less fluorescent lighting. The controls available for these systems are bi-level switching, dimmers, occupancy sensors, and daylight sensors. Few steps for efficient lighting technology are replacing T8 fluorescent lamps with T12 lamps, replacing incandescent lamps with compact fluorescent lamps, installing fluorescent lighting systems in place of incandescent lighting systems, installing metal halide / high-pressure sodium vapor lamps in place of mercury vapor lamps [5].

Compact fluorescent lamps (CFL) have come up as a strong alternative of incandescent lamps due to their quality of lower power consumption and longer life. However, CFL produces distorted currents with THD>100% and low power factor 0.47-0.67, resulting in excessive utility losses [6]. Experimental results have shown that, operational costs of LED lamps are many times smaller than other types of lighting sources. However, LEDs, CFLs and fluorescent lamps worsen power quality of low voltage networks due to high current harmonic distortions (THD) and lower power factor [7]. There is a common misunderstanding, that energy saving is always equivalent to environmental protection. Compared with magnetic ballasts, electronic ballasts have a much shorter lifetime and are not recyclable. This brings new concerns about their environmental impacts due to the addition of a huge amount of toxic and/or non-biodegradable electronic waste components and materials [8].

The objective of the paper is to find out the probable energy savings and demand reduction in lighting load in a typical institution campus. An experimental study was carried out at Tolani Maritime Institute (TMI), Indori, Pune, India. The campus of TMI is spread over an area of over 100 acres of land. The connected load of the campus is 1193 kW and the contract demand is 750 kVA. The lighting load of the campus is about 35 % (the potential of saving energy in lighting is about 15 %). For this a comparative study of fluorescent lamps with different configurations of ballasts was carried out. We compared the results and concluded that the fluorescent lamps with magnetic ballasts are to be used with power factor correction capacitor.

The paper discusses rationale of said study methodology, results and their discussions. The probable energy saving and demand reduction is also discussed.

II. METHODOLOGY

Tolani Maritime Institute is located at Pune, in the state of Maharashtra of India. It offers Marine Engineering and Nautical Technology degree programs. The campus of the institution is spread over an area of over 100 acres.

The engineering systems of the campus are a 0.8 MW coal fired power plant, modern vapor absorption chiller, water treatment plant and effluent treatment plant.

The academic facilities includes air conditioned classrooms (50), workshops (2), laboratories (20), a library (7,000 sq. ft.), an auditorium (300 seated), a functional ship-in-campus, simulators and faculty offices for over 100 faculties.

The residential facilities include 3 hostels accommodating over 1500 students, town styled apartments over 125 for families of faculty and an executive residence for the persons enrolled in advanced courses.

In addition to these, different sports facilities, 24X7 medical facilities, canteens, shopping complex and a laundry.

The TMI campus is a High Tension (HT) Consumer and is fed by a 22 kV line from Maharashtra State Electricity Distribution Company Limited (MAHADISCOM). It has connected and sanctioned load of 1193 kW, the contract and the sanctioned demand of 750 kVA, and the average of monthly units consumption is 172000. The details of the sub-station are number of incoming feeder/s 1, the outdoor plinth mounted type, 1000 kVA, 22 / 0.415 kV, Delta/Star connected. The campus has a backup supply of two diesel generator sets of 500 kVA each.

The various types of loads are lighting, air conditioning, computer and uninterrupted power supply load and 3 phase motor load. The contribution of these loads is as shown below (fig. 1).

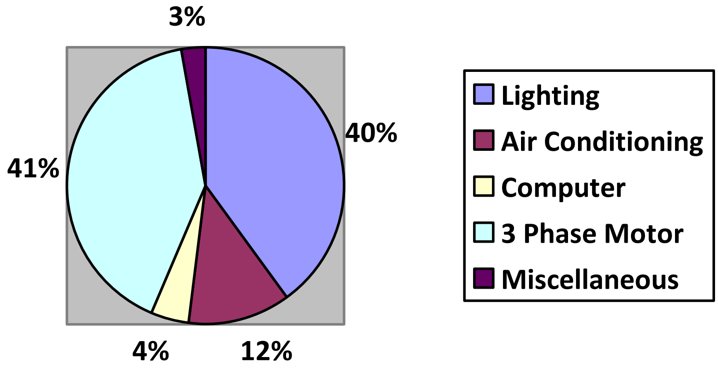


Fig. 1 % Share of different types of loads.

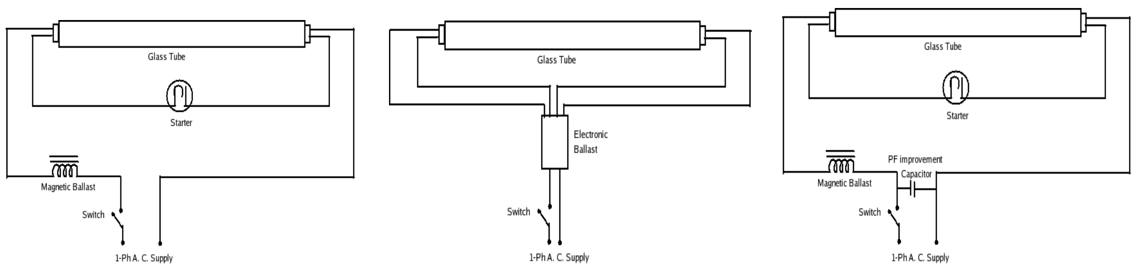
Since the second highest contribution of the total load is shared by lighting, it prompts us to think for the energy conservation opportunities in this area.

For this purpose an experiment was carried out, to compare the performance of a 36W, 230Volt, fluorescent lamp operating with different configurations of ballast. The different configurations studied were, lamp with only magnetic ballast, with electronic ballast and with a capacitor for power factor improvement in addition to magnetic ballast. The test of these three combinations was carried out in a residential room after complete sun set. All these lamp sets were used for 15 minutes and the performance was monitored using the load analyzer Yokogawa CW240 Clamp-On Power Meter [9].

The figure 2 (a) shows a 36W, 230V, fluorescent lamp with magnetic ballast only. The magnetic ballasts are free of harmonic, have long life, can be recycled and are environment friendly. Because of these properties the magnetic ballast was considered for the test.

The figure 2 (b) shows the same fluorescent lamp with electronic ballast. The electronic ballasts operate with an improved power factor, their demand (VA) is less, they draw less current, their I^2R losses are less, they start instantly and they operate even at lower voltages. Because of these properties electronic ballast was considered for the test.

The figure 2 (c) shows the fluorescent lamp with a capacitor for power factor improvement in addition to magnetic ballast. A fluorescent lamp with this arrangement improves the operating power factor, their demand (VA) reduces, draw less current, hence the reduced I^2R losses. Because of these properties this arrangement was considered for the test.



(a) (b) (c)

Fig. 2 Fluorescent lamp with different configurations of ballasts.

III. RESULTS AND DISCUSSIONS

After conducting the above said tests, different parameters were studied and compared. The details of the study is as under,

3.1 The active power

The following graph shows the active power of all the three combinations.

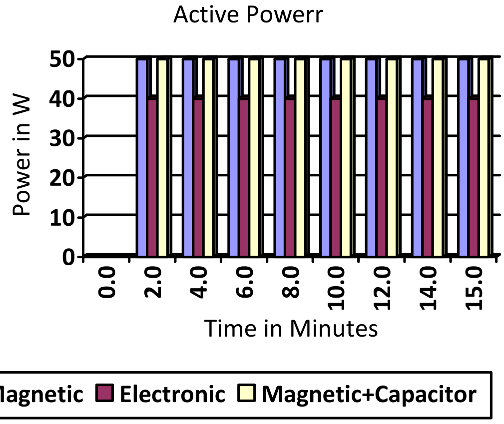


Fig. 3 Active power of a fluorescent lamp with different configurations of ballasts.

The active power consumed by a fluorescent lamp with first and third configuration, is 50W. That is 36W for lamp and 14W for the ballast. The power consumed by a fluorescent lamp with second configuration is 40W. That is the power is consumed only by the fluorescent lamp. From this we can conclude that the fluorescent lamp with electronic ballast is efficient.

3.2 The reactive power

The following graph shows the reactive power of all the three combinations.

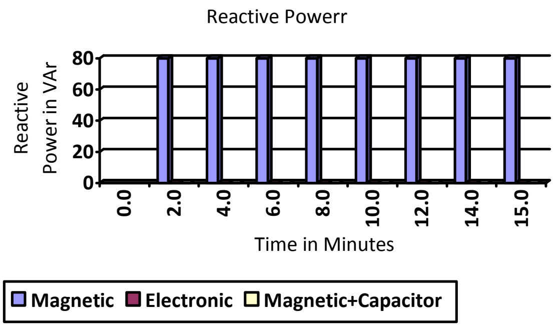


Fig. 4 Reactive power of a fluorescent lamp with different configurations of ballasts.

The reactive power consumed by a fluorescent lamp with first configuration is 80VAr, whereas, it is zero by a fluorescent lamp with both the second and third configuration. That is the second and third configurations are good.

3.3 The apparent power

The following graph shows the reactive power of all the three combinations.

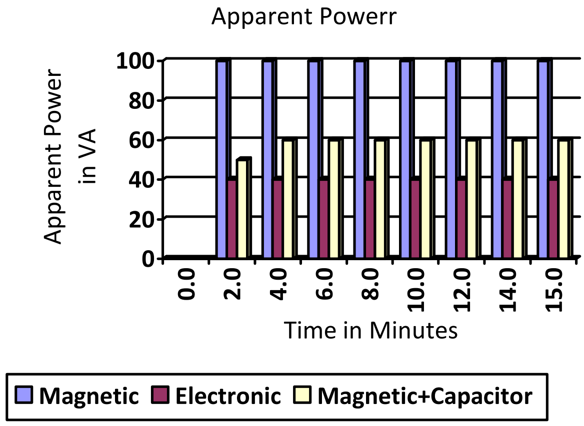


Fig. 5 Apparent power of a fluorescent lamp with different configurations of ballasts.

The apparent power drawn by a fluorescent lamp with first, second and third configuration is 100W, 50W and 40W respectively. The apparent power drawn is twice of the useful power in case of magnetic ballast. This puts an unwanted additional burden on the supplier to have additional capacity. The apparent power for second and third configuration is exactly the same as of their active power, which is a good characteristic. It shows that the second and third configurations are good.

3.4 The power factor

The following graph shows the power factor of the fluorescent lamp with all the configurations.

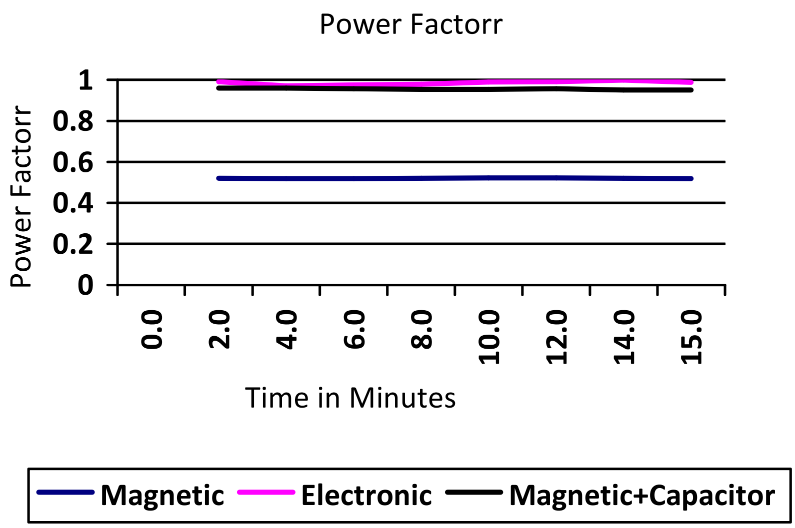


Fig. 6 Power Factor of a fluorescent lamp with different configurations of ballasts.

The power factor of a fluorescent lamp with first configuration is 0.5. It is very poor and is not a good sign, which needs to be improved. However, it is very much close to unity by second and third configuration. It shows that second and third configurations are good.

3.5 The percentage total harmonic distortion in current (%THDi)

The following graph shows the percentage total harmonic distortion in current of the fluorescent lamp with all the configurations.

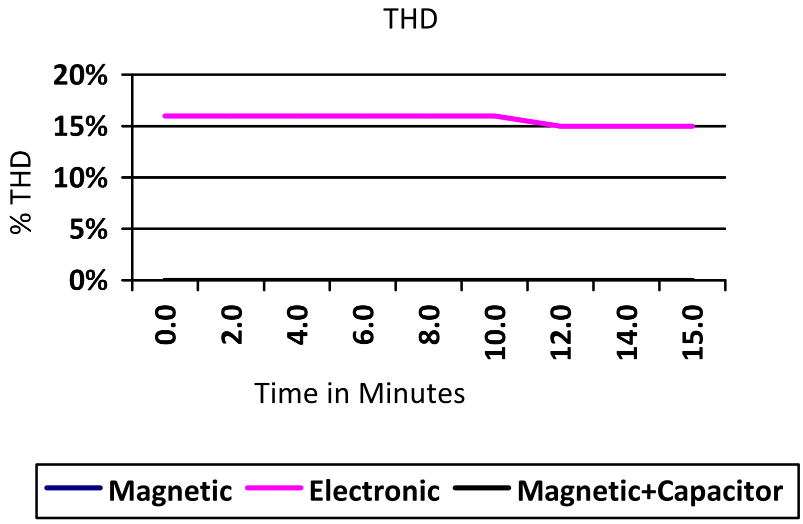


Fig. 7 % THD of a fluorescent lamp with different configurations of ballasts.

The harmonic distortion of the fluorescent lamp with first and third configuration is absolutely zero, this is very good characteristic. But with second configuration the current distorting harmonics are present. From this we can conclude that the fluorescent lamp with first and third configuration are good.

The observations of this study are as tabulated under,

Table 1 Comparative result of the test

Sr. No.	Parameters	Magnetic Ballast	Electronics Ballast	Magnetic Ballast + P.F. Capacitor
1.	Current drawn	0.39 A	0.25 A	0.22 A
2.	Active Power	50 W	40 W	50 W
3.	Reactive power	80 VAr	0 VAr	0 VAr
4.	Apparent Power	100 VA	40 VA	50 VA
5.	Average Power Factor	0.52	0.95	0.96
6.	Harmonic content	Absent	Present	Absent

The following data shows some facts, if we start using the third configuration at the TMI campus.

The total number of fluorescent lamps in campus is 3378.
Total Current drawn (0.39A/lamp) is 1317.42 A
The total current with a capacitor of 5µF (0.22A/lamp) is 743.16 A
Total reduction in current would be 574.26 A
This will result in reduction in I^2R losses.

Additionally, as there is reduction in demand by 40%, there will be a reduction in monthly demand charges.

In a magnetic ballast, apart from its advantages there are some disadvantages also, like they have a very poor power factor, the demand (VA) is more, draws more current, hence more I^2R losses, does not operates at lower voltages, humming noise and are flicker start.

In electronic ballast, apart from its advantages there are some disadvantages also like presence of harmonic contents, they are costlier, they have short life and are not environment friendly.

In addition to the advantages of magnetic ballast, the third configuration has few more advantages and has no additional disadvantages.

Lagging PF loads are a trouble. Utilities often try to maintain system PF from 0.85 to 0.95. Low PF loads require utility increasing apparent power to be able to supply small real power loads. Term PF reflects efficiency of an electrical power distribution system. Loads that cause poor power factor include induction motors, arc furnaces, machining, stamping, welding, variable speed drives, computers, servers, TV, fluorescent tubes, compact fluorescent lamps. Utility charges industries for poor factor but exempts houses and offices. Facility can reduce electricity costs, increasing kW capacity from the same kVA transformer, improve voltage regulation, reduce cables, transformers and switch gear sizes by improving power factor.
A customer with 100 kVA load can light seven hundred 100W bulbs at 0.7 PF and nine hundred 100W lamps at 0.9 PF. A customer using 100 kW load at 0.7 PF needs 142 kVA apparent power (wasting 100 kVAr reactive power) but the same load would require only 125 kVA capacity (wasting 75 kVAr) at 0.8 PF.
Total harmonic distortion (THD) IEEE Std.519 (1992) recommends keeping voltage THD 5% and current THD 32% in utility power distribution network <69 kV [11]. ANSI C82.77 (2002) recommends all commercial indoor hard wired ballasts >28W maintain 0.90 PF with maximum 32% current THD [12]. Current THD and PF are two different phenomena coming from entirely different situations. One of the impacts of current THD is to increase magnitude of RMS current that (I^2R) increases power system losses. Distortion factor lowers overall power factor. Reducing harmonics or improving power factor reinforces each other but PF cannot be unity in the presence of harmonics. As the PF reflects overall losses, therefore, harmonics contribute to power loss. Harmonics affect displacement factor so the total kVA demand increases.

IV. CONCLUSION

Thus, we can conclude that introducing an appropriate capacitor in the existing fluorescent sets with magnetic ballast is extremely useful. This change will not result in any reduction of the power consumption, but will definitely help in reducing the demand. The results have shown a reduction in demand by 40%. As there is reduction in demand, the demand charges will also be reduced. Additionally, as the current is reduced by about 50%, the I^2R losses will also reduce by 75%.
The fluorescent lamp sets with magnetic ballasts are available in market are of both types, i.e. with and without capacitor. It is observed that, the fluorescent lamp sets, with capacitors are used only in industries and without capacitor are used at residential loads. The Central or State Regulatory Commission (REC) must make it mandatory for all manufacturers of fluorescent lamp set, to provide a power factor improvement capacitor with every set they produce.
Further the fluorescent lamp with magnetic ballast and power factor improving capacitor can be compared with CFLs, LEDs, ELFLs, incandescent bulbs, photovoltaic and fiber optic lighting system.

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