

APPLICATION OF INNOVATIVE TECHNOLOGIES FOR ENHANCING ENERGY EFFICIENCY IN HONG KONG, CHINA

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ABSTRACT

Hong Kong is a major commercial and financial centre in Asia and the energy consumption is increasing substantially over the past ten years. The electricity consumption in the commercial sector is increasing at about 7% per annum and is the fastest growing sector. The Energy Efficiency Office (EEO) of Electrical and Mechanical Services Department (EMSD) is actively exploring means to reduce energy consumption and a series of initiatives are being implemented to achieve the goal. One of the initiatives is to investigate advanced and innovative energy saving technologies via series of pilot projects in government buildings with a view to promote the wider use of these technologies in public and private sectors. The investigation covers equipment for lighting, air conditioning, lifts and escalators.

INTRODUCTION

In 1995, EEO had obtained a funding of \$6 million to carry out a 3-year Pilot Energy Management Opportunities (EMO) Implementation Programme (the Phase I Programme). The objective of this Programme was to examine the cost effectiveness of various new energy-efficient building services technologies under local conditions.

The Phase I Programme was completed in early 1999 and the report was published in the EMSD's Homepage in July 1999. The Phase I programme had successfully introduced energy efficient equipment, such as electronic ballasts, variable speed drives, high efficient motors, etc. to Hong Kong. These energy efficient products are now widely used in offices and commercial buildings and have also been included in the recently launched Demand Side Management (DSM) programme operated by the two power companies in Hong Kong.

Another two-year \$6M Phase II Programme had also been approved and started in May 1999 to study the application of innovative energy efficient equipment in Government buildings. Some pilot installations have been carried out or are being planned for all aspects of building services including lighting, air conditioning and vertical transportation. In the area of lighting, T-5 fluorescent luminaires and intelligent lighting control have been tested in Queensway Government Offices (QGO), Arsenal House and the new offices for Environment and Food Bureau (EFB)

in Citibank Plaza. As far as air conditioning is concerned, pilot projects are being planned for automatic sea water-cooled condenser tube cleaning system and indirect evaporating precoolers and heat exchangers. In the areas of vertical transportation, pilot projects for converting AC 2-speed drive to Variable Voltage Variable Frequency (VVVF) have also been carried out.

PILOT EMO PROJECTS FOR LIGHTING

Lighting consumes about 20-40% of the energy consumed in Hong Kong office buildings. There are many opportunities for energy savings in lighting, such as:

- use of more efficient lamps and ballasts;
- use of more efficient reflectors/louvers in luminaires;
- installation of dimming or on/off control systems for the maximum utilization of available daylight; and
- use of occupancy sensors to switch off or dim down lighting in unoccupied zones.

As far as energy efficiency lamp is concerned, a new generation of T5 fluorescent lamp with a diameter of 16mm (5/8") and G5 base has recently been introduced into Hong Kong. The new T5 lamps, owing to their superior luminous efficiency outputs (efficacy about 100 lm/W), represent serious competition for the classical T12 or T8 fluorescent lamps. The standard wattage of the new T5 lamps is 14W, 21W, 28W and 35W. Enhanced economy is achieved by high frequency operation with electronic ballasts, which are specified in principle for these new lamp types. Owing to their slim shape, the new T5 lamps permit innovation in luminaire design as a further reduction in luminaire casing dimensions. In addition, the lamp length of all T5 lamp types is 50mm shorter than their T12/T8 counterparts and T5 luminaires could then be dimensioned to enable them to fit exactly into the usual metric grid (600mm and 1200mm) of suspended ceilings.

For fluorescent luminaires with T5 lamps, the most effective means of optical control is parabolic reflection. The most important optical property of the parabolic reflector is that if a line source is placed at its focus a parallel beam of light is obtained. In practice the ideal line source is difficult to obtain from fluorescent tube and the shape of the distribution curve depends on the size of the source in relation to the focal length and mouth width of the reflector. As the diameter of T5 tube is much smaller than its T8 and T12 counterparts, and is more closer to a line source, optical control of luminaires with T5 lamps and parabolic reflector can be more precise and efficient.

The latest development of digital technology in electronic ballast and lighting sensors design has also made the control and dimming of fluorescent lighting more easily. Intelligent lighting control with integrated sensor to detect daylight and occupancy is also available to enhance further energy saving in T5 lighting system.

Several pilot projects in office lighting using the above-mentioned technologies have been tried out recently in the following Government buildings.

T5 Luminaires Retrofit at Arsenal House

The pilot project included the replacement of the existing 320 sets 3 x 18W T8 600mm x 600mm recessed modular fluorescent luminaires in the office areas on 27/F, Arsenal House, with new 3 x 14W T5 600mm x 600mm recessed modular fluorescent luminaires (Fig. 1), complete with electronic ballasts (1 for 3 lamps type) and parabolic reflectors designed to CIBSE LG3, Cat. II.

The performance of the new T5 lighting installation as compared with the old lighting system is summarised in Table 1. The total installed lighting power reduced from 28kW to 16kW while the average illumination on the working plane was improved from 450 lux to 600 lux.

T5 Luminaires Retrofit at New EFB Offices

As part of the Phase II EMO Implementation Programme, the new EFB offices in Citibank Plaza have been selected to try out the latest T5 fluorescent lighting technology in their lighting installations. The adoption of the new generation of T5 fluorescent lamps together with appropriate T5 electronic ballasts in the specially designed air-handling fluorescent luminaires (Fig. 2) have provided many energy efficiency features. The new lighting installations increased illumination at the working plane from 500 lux to 700 lux and at the same time consumed 38% less energy than their T8 counterparts with conventional lamps and electromagnetic ballasts. Intelligent lighting control has also been included in some offices along the perimeter with digital control technology for dimming and occupancy sensing.

The performance of the new T5 lighting installation as compared with the old lighting system is summarised in Table 2. The major energy efficient and environmental features of the refurbished offices are highlighted as follows:

- ✧ Original circuit power per luminaire (2x36W T8 with conventional ballasts) is 98W
- ✧ New circuit power with 1 electronic ballast driving 2 T5 28W lamps is 60W
- ✧ Annual cost saving per luminaire based on 3000 hours/year and \$0.9/kWh will be HK\$103
- ✧ Additional material cost for T5 luminaire is about HK\$200. Simple payback is approximately 2 years.
- ✧ The average lifetime of T5 lamps is 15,000 hours (T8 lamps is 8,000 hours)
- ✧ Average measured illumination level is 700 lux (+40% as compared with the original 500 lux lighting scheme)
- ✧ The new T5 lamps use less glass, less mercury and less packaging materials
- ✧ The new T5 luminaires use less metal for their casing and reflectors

T5 Luminaires Retrofit and Intelligent Lighting Control at QGO

A typical floor of QGO has an office area of 1390 m² and is illuminated by about 500 recessed single-lamp 300x1200 mm luminaires. The existing 1x36W T8 luminaires was controlled by conventional electromagnetic ballast and starter switch. Before the retrofit, the average illuminance on working plane was about 460 lux with an installed lighting power density of about 22 W/m².

This pilot project was a complete replacement of the original luminaires on 35/F with new T5 luminaires designed to CIBSE LG3, Cat. II (Fig. 3). Each new luminaire was fitted with a digital dimmable ballast, a 28W T5 fluorescent lamp and anodised aluminium reflectors and louvers. The 500 luminaires were divided into about 150 groups, each group consisting of two to four luminaires. The luminaires in a group are linked to an integrated sensor, which detects illuminance, occupant presence and the signal from a remote control.

The sensor is a constant light system with integrated light level detection, presence detection and infra-red remote control. With a wireless programmer, the following operating parameters can be programmed: light level (1-100% or max), time delay (30s-60min or continuous), Passive Infra Red (PIR) activation (active or inactive or off), bright-out (yes or no), state if vacant (off or dimmed to low level), state at power up (on or off), 10% start (on or off), hold override (on or off). An infra-red remote controller can also be used to turn the lights on or off, or dim the lamps up or down manually and temporarily overridden the automatic functions.

The luminaire consists of a white powder coated metal casing with a 30-cell aluminium louver/reflector for optical control of the light so that the luminaire belongs to category 2 luminaire as defined in CIBSE LG3 (CIBSE 1993).

Data measured by the energy meter were analysed to give daily profiles of lighting power consumption. The power profiles for all working days in the two months before and the two months after the retrofit were reviewed. The lighting power profiles for two typical (cloudy) working days, one before the retrofit and one after the retrofit, are plotted in Fig. 4.

There is an average reduction of 6.5 kW in lighting power after the retrofit and calculation from the daily consumption values shows a 35% energy saving. The occupancy detection was normally set between 5 and 10 minutes and contributes significantly to energy savings in this floor.

The project summary is shown in Table 3. The test results found in this pilot project revealed that, other than those similar advantages found in the previous two projects, the intelligent lighting control would also enhance further energy saving when the rooms are well lit by daylight or areas are not occupied during the office hours. The new lighting system would also be able to provide flexibility in setting the illuminance required to suit individual need for various tasks and functions.

ENERGY OPTIMISER FOR ESCALATOR

The energy optimiser is a solid-state voltage controller that reduces losses in AC induction motors by way of voltage reduction and soft starting capability. It is not a variable speed drive and does not change the frequency of the motor. When at idle or during the low load condition, induction motors operating at full supply voltage have very low power factor and are less efficient. Motors running at low load are inefficient because the fixed losses are disproportionately high. Lowering the voltage across each of the motor windings can reduce the iron loss, which is proportional to the voltage squared. The energy optimiser could provide the required motor

operating voltage to suit various loading conditions, resulting in power factor improvement and reduction of motor losses. The other benefit of the energy optimiser is its soft starting property that reduce motor starting current and excessive tear and wear in mechanical gears, chains, belts etc. associate with the mechanical transmission system. The energy optimiser could be used for any ac motor application with constant speed and variable load. Best applications are those motors with substantial variation in loading such as escalator and passenger conveyers, which could run the majority of the time less than 50% of their rated capacity.

Energy Optimiser Installation at NPGO

The ascending (UP) escalator at ground floor level of North Point Government Offices (NPGO) was selected for trial in 1999. The escalator is mainly used for public access to the first floor Eastern Sub-Treasury Office and Civil Service Training and Development Institute. The escalator is driven by a 7.5kW 3-phase induction driving motor equipped with a direct-on-line starter operating on a 3-phase 380V power supply. According to site inspection, the escalator concerned was not always loaded. A 7.5kW energy optimiser was installed adjacent to the escalator control panel inside the upper service pit as shown in Fig. 5. A separate cubicle equipped with changeover contactors, selector switch, kWh meter and hour meter, has also been installed to facilitate testing and performance analysis of the energy optimiser. The escalator has been running with the energy optimiser ON and OFF alternatively every week and the measurement records have been taken for energy consumption and performance analysis.

Site Measurements

The measurement data was recorded from January to March 2000. The result indicates an average energy consumption of 1.763 kWh per hour with the energy optimiser OFF. The information could also be interpreted as the average escalator input power of 1.763 kW even though the motor rating is 7.5 kW, i.e. the motor is at light load condition at most of the time. The average hourly energy consumption decreased when the device was gradually fine-tuned to manufacturer's recommendation. The average hourly energy consumption was found to be 1.586 kWh with the energy optimiser ON.

The electrical characteristics and parameters of the escalator running at no-load conditions were also measured using a Power Harmonic Analyser both with and without the energy optimiser. Summary of the energy performance and electrical parameters of the escalator running at no load with and without the energy optimiser connected are shown in Table 4.

Project Summary

The 7.5 kW 3-phase induction motor for the escalator under tested at NPGO was designed to handle its full load UP condition. However, the full load condition occurred not very often and it was found from site measurement that the average input power drawn by the escalator motor was only 1.586 kW and 1.763 kW with and

without the energy optimiser respectively. The 7.5 kW motor is in fact running at light load condition all the time, with very poor power factor and energy performance.

The performance of the energy optimiser can be summarised as follow:

- (a) The energy optimiser lowered the average motor power by 10% - from 1.763 kW without the optimiser to 1.586 kW with the optimiser.
- (b) The anticipated annual energy saving is about 506 kWh (i.e. 10%)
- (c) The reduction of active power at no load condition was 15%
- (d) Both displacement and total power factor were improved with the energy optimiser at no load. However, there was a substantial increase of Total Harmonic Distortion (THD) due to this non-linear nature of this solid-state device (Fig. 6). The THD of current at no load condition is found to be 38% and does not comply with the 35% requirement in the Lift Energy Code. The harmonic reduction devices need to be redesigned to comply with the Code.
- (e) The simple payback period for this pilot project is very long (about 32 years). This is mainly because of the high installation, instrumentation and modification works required for the project. The payback period could be much shorter if only the motor starter was replaced with the energy optimiser or the device is included in the package of escalator for new project.

CONCLUSION

It could be seen from the results above that office lighting using T5 lamps and luminaries has proved to be more energy efficient and has performance improvement in other electrical parameters, such as power factor, total harmonic distortion, etc. Escalator equipped with an energy optimiser has slight improvement (i.e. 10%) in energy efficiency.

There are many opportunities for reducing losses and consumption of electricity in buildings. It is the aim of the SAR Government to improve, in long term, the use of energy in buildings through energy efficiency and conservation measures. Other than office lighting and vertical transportation, we have also carried out energy efficient pilot projects in other areas, such as air conditioning (e.g. automatic tube cleaning in water-cooled chiller, integrated Fan Coil Unit and lighting control, indirect evaporating heat recovery) and power quality improvement, etc. Reports for these pilot projects will be prepared in separate issues. Recommendations will also be made for the wider application of those energy efficient equipment and systems if they were found to be effective.

REFERENCE

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- [2] "Code of Practice for Energy Efficiency of Electrical Installations", 1998 Edition, EMSD..
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- [4] L.T. Lee and K.T. Wu, "Electronic Ballasts for Fluorescent Lamps", Symposium on tall Building and Construction Technology, Beijing 1999.

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Table 1 Summary table for the lighting retrofit at 27/F Arsenal House

	Existing T8 Lighting System	New T5 Lighting System	% Improvement
Active Power (kW)	28 kW	16 kW	- 42%
Power Factor.	0.53	0.99	+ 87%
T.H.D.	11%	8.6%	- 21.8%
Apparent Power (kVA)	52.8 kVA	16.2 kVA	- 69%
Average Illuminance	450 lux	600 lux	+33%
Lighting Power Density	30 W/m ²	18 W/m ²	-40%

Table 2 Summary table for the lighting retrofit at the new EFB offices

	Existing T8 Lighting System	New T5 Lighting System	% Improvement
Active Power (kW)	34 kW	23 kW	- 32%
Power Factor.	0.89	0.99	+ 11%
T.H.D.	23%	10%	- 56%
Apparent Power (kVA)	38 kVA	23 kVA	- 39%
Average Illuminance	500 lux	700 lux	+40%
Lighting Power Density	27 W/m ²	17 W/m ²	-37%

Table 3 Summary table for the lighting retrofit at 35/F, QGO

	Existing T8 Lighting System	New T5 Lighting System	% Improvement
Active Power (kW)	24 kW	16 kW (Max.)	- 33%
Power Factor.	0.89	0.95	+ 6.7%
T.H.D.	23%	14%	- 39%
Apparent Power (kVA)	27 kVA	17 kVA	- 37%
Average Illuminance	460 lux	730 lux	+59%
Lighting Power Density	22 W/m ²	13 W/m ² (Max.)	-41%

Table 4: Summary table for the Escalator running at no load condition at NPGO

		Energy Optimiser OFF	Energy Optimiser ON	% Change
1	Supply Voltage	376V	376V	---
2	Line Current	8.3A	5.4 A	- 35%
3	Active Power	1.72 kW	1.46 kW	- 15%
4	Apparent Power	5.4 kVA	3.54 kVA	- 34%
6	Displacement Power Factor	0.32	0.45	+ 40 %
7	Total Power factor	0.32	0.42	+ 31 %
8	THD Voltage	3.3 %	3.4%	---
9	THD Current	5.4 %	38%	+ 600%

Fig. 1: New 3x14W T5 Luminaire used at Arsenal House

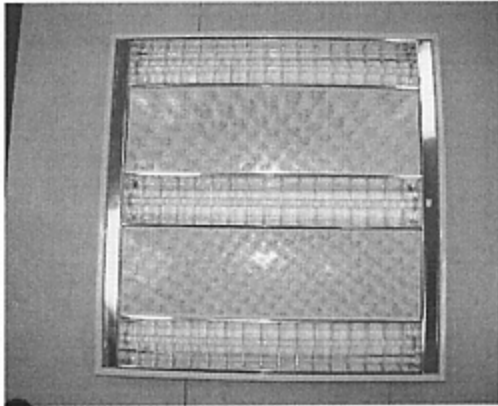


Fig. 2: New 2x28W T5 luminaires installed at EFB offices

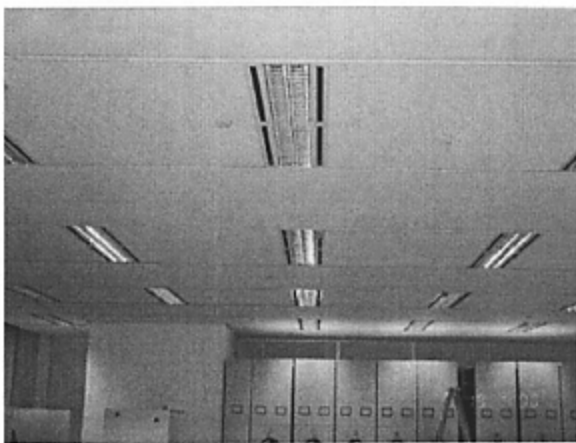


Fig. 3: T5 28W luminaire installed at 35/F, QGO

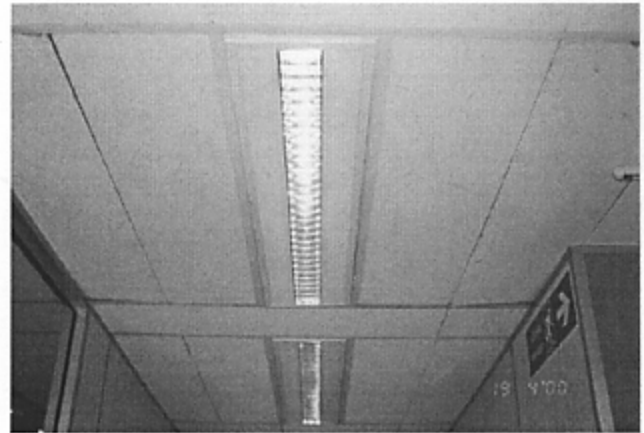


Fig. 4: Typical daily load profile before and after the retrofit at 35/F, QGO

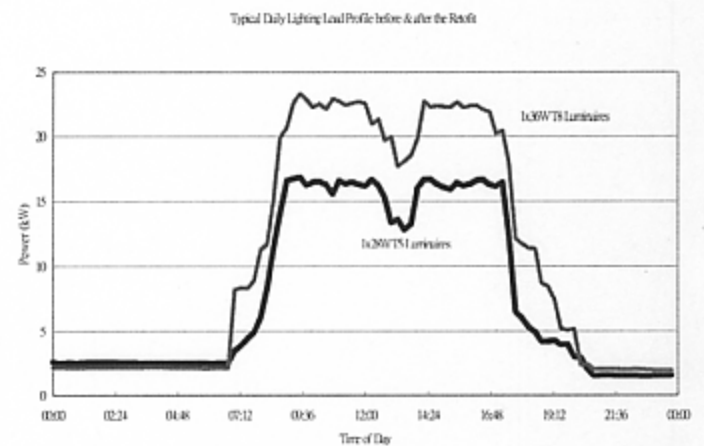


Fig. 5: Energy optimiser, energy meter and hour meter installed at NPGO



Fig. 6: Escalator Motor input voltage & current waveforms with energy optimiser ON

