PEAK POWER REDUCTION STRATEGIES FOT THE LIGHTING SYSTEMS IN GOVERNMENT BUILDINGS

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ABSTRACT

Lighting systems are the second major contributor to the peak power demand and energy consumption in buildings after A/C systems. They account for nearly 20% of the peak power demand and 15% of the annual energy consumption. Thus energy efficient lighting systems and their smart operation can be very effective in reducing the national peak power and energy consumption, particularly for a country like Kuwait where power demand grew from 6750 MW in 2001 to 9075 MW in 2007 (MEW, 2002-2008).

This paper presents an approach developed to reduce the peak power demand in the lighting. The approach included optimum use of daylight, time of day control and delamping. The implementation of this approach for eight government buildings with occupancy of between 7:30 and 2:30 and peak power demand of 29.3 MW achieved a reduction of 2 MW in the peak power demand (around 7%). More importantly this 7% in peak load reduction and 10,628 MWh reduction in the annual energy consumption was achieved without any added cost. Also, the paper includes recommendations for retrofitting cost effective energy efficient lighting systems and implementation of more effective control.

Key Words: Peak power, time of day control, delamping, Building automation system.

INTRODUCTION

In Kuwait, fast economic growth and rapid urbanization over the past few decades have resulted in ever increasing demand for electricity, with an annual rate which currently exceeds 6%. During the past six years, the power demand grew from 6,750 MW in 2001 to 9,070 MW in 2007 (MOE, 2000-2007).

Lighting systems are the second major contributor to the peak power demand and energy consumption in buildings after A/C systems. They account for nearly 20% of the peak power demand and 15% of the annual energy consumption. Thus energy efficient lighting systems and their smart operation can be very effective in reducing the national peak power and energy consumption.

Smart operation strategies for lighting systems developed by the Kuwait Institute for Scientific Research (KISR) were implemented in many selected buildings jointly by the KISR and the Ministry of Electricity and Water (MEW). This paper presents an approach developed to reduce the peak power demand in the lighting system in government buildings. The scope of work was confined to: optimum use of daylight, time of day control and delamping. The implementation of this approach for eight government buildings with occupancy of between 7:30 and 2:30 and a peak power demand of 29.3 MW achieved a reduction of 2 MW in the peak power demand and 8.6 MWh reduction in the annual energy consumption.

Since Kuwait has many buildings with very high peak power demand, time of day control (TDC) for lighting systems can be an effective tool to reduce national peak power demand. However, this measure has to be implemented with utmost care to provide visual comfort.

BUILDINGS DESCRIPTION

Eight government and institutional buildings with a total air-conditioned area of approximately 439,400 m^2 were selected to implement the smart operation strategies for lighting systems. The important features of each building are as follows:

<u>Ministries Complex (MC)</u> MC, commissioned in 1981, consists of 12 identical buildings for ministries, two buildings for VIPs and four interconnecting areas. Building occupancy begins at 7:30 h and ends between 14:00 and 15:30 h. Lighting systems in MC building comprise mostly of T12 fluorescent tubes with magnetic ballasts, compact fluorescent lamps (CFLs) and incandescent lamps with a total connected load of 2,900 kW including the load of magnetic ballasts. Peak power demand in MC building is nearly 12,000 kW. A/C and lighting systems account for 73% of this demand. The

Building automation system (BAS) in MC building is equipped to control operations of air distribution and lighting systems and the complex was implementing season based time-of-day control (TDC) for the cooling production and air distribution systems.

Justice Palace Complex (JPC) JPC building, commissioned in 1985, houses judicial organs and their agencies. The building is square in plan and has a sky-lit courtyard in its center. Its walls and roof are not insulated and it has clear-single glazed windows. Although working hours are set to be between 7:30 and 14:00 h, several zones in the building, such as court rooms, are occupied after working hours. The lighting system in the interior of the complex comprises mostly of T12 fluorescent tubes with magnetic ballasts. Due to the unavailability of data, the lighting load could not be verified. JPC building has a peak load of around 3,700 kW. JPC building has a BAS that has on/off facility for AHUs, there is no specific control for lighting system.

Liberation Tower Complex (LTC) LTC, comprises of three buildings: New Main Building (NMB), Public Office Building (POB), and Communication Tower. The complex constructed in 1987 and commissioned in 1993 is an energy-efficient structure with well-insulated walls and roofs. It has different occupancy periods for different areas including zones with 24 h occupancy. Lighting systems in the interior of the complex comprise mostly of T8 fluorescent tubes with magnetic ballasts and incandescent lamps. LTC has a peak load of around 3,800 kW. The BAS has no specific control for lighting.

Public Institution for Social Security (PIFSS) PIFSS building, commissioned in 2005, consists of a 24-storey office tower and an adjoining 3-storey podium block for the public with a total air-conditioned area of around 58,000 m^2. The majority of the building occupants vacate the premise at 14:00 h. PIFSS lighting systems mostly consist of energy-efficient T8 fluorescent tubes with electronic control gears (ECGs), compact fluorescent lamps; incandescent and high intensity discharge lamps. Due to the unavailability of data, the lighting load could not be verified. The building has a peak power of 2,600 kW. BAS monitors and controls the lighting system.

Ministry of Health (MOH) MOH building was commissioned in 1988. It has 4 levels of occupied space including basement, and a small single-storey building. The total air-conditioned area is 29,000 m^2. The working hours for MOH building are from 7:30 to 14:00 h. The lighting systems inside the MOH building comprise mostly of T8 fluorescent tubes with magnetic ballasts, compact fluorescent lamps and incandescent lamps. The building peak power is about 2,200 kW. The lighting load alone is 736 kW, which is more than a third of the peak load. MOH building has no BAS.

Kuwait Chamber of Commerce and Industry (KCCI) KCCI building, commissioned in 1999, consists of a 16-storey office tower and an adjoining 5-storey podium block with a total air-conditioned space of around 36,400 m^2. It has considerable utilization of day-lighting. Starting from 07:30 h, most areas of the building are occupied until 22:00 h. The lighting system inside the building mostly consists of energy-efficient T8 fluorescent tubes with magnetic ballasts, compact fluorescent lamps and incandescent lamps. KCCI building has a peak power of 1,800 kW. There is no control for the lighting system through the BAS.

State Audit Bureau (SAB) SAB building was commissioned in 2007. It has three towers each with nine levels including two levels basement and a big atrium. It is covered with a double-glazed argon charged glass envelope and has lots of indoor plants. SAB building has many features of smart building for energy efficiency, safety and security. General working hours for SAB building are between 07:00 and 14:30 h, although it differs from floor to floor. Lighting systems inside the SAB building comprise of energy efficient T8 specially designed fluorescent lamps with ECGs, CFLs, incandescent lamps and light emitting diodes (LEDs). The building has a peak load of around 2900 kW and it is mainly shared by A/C and lighting. Lighting system is controlled by DELMATIC software which controls individual lamps, and fully implements TDC by closing indoor lights between 16:00 and 04:00 h, car parking lights between 15:00 and 07:00 h and outdoor lights between 22:00 and 17:00 h.

Public Authority of Youth & Sports (PAYS) PAYS building, commissioned in 2004, has 9 levels of occupied space, with a well day lit atrium, a basement and an adjoining 2 story building. The total air-conditioned area is 25,000 m^2. The working hours are from 7:30 to 14:00h. The lighting systems inside the building comprise of energy-efficient T8 fluorescent tubes with a mixture of electronic control gears (ECGs) and magnetic ballasts. Building peak power is about 1,000 kW. The lighting load alone is 307 kW, which is 30.7% of peak power of the building. BAS can monitor and control important parameters such as supply air and supply water temperatures and the on/off status of AHUs.

APPROACH AND METHODOLOGY

Approach adopted for peak load reduction was based on KISR’s previous experiences related to the implementation of smart operation strategies in governmental and institutional buildings for peak power reductions and energy savings (Maheshwari et-al, 1997; Al-Ragom et-al, 2002; Al-Ragom et-al 2005 and Hajiah et-al, 2007). More importantly, identification and evaluation of additional opportunities for peak power reduction in governmental and institutional buildings were carried out with a special thrust.

Study Operation Features of Buildings Walk through surveys were carried out for all of the buildings. The main focus was to study the lighting load, operation, schedule and maintenance of the lighting systems. Meetings with the building operators were held to familiarize with the buildings and find out measures to apply peak power reduction without compromising the visual comfort.

Development and Implementation of Peak Power Reduction Strategies Peak power reduction strategies were developed and finalized in consultation with the facility managers and their technical team. Prior to that, critical areas were identified in consultation with the facility managers. Critical areas are the zones in the building where the comfort quality, has to be maintained at constant level for most of the day. This requirement could be due to their occupants, such as ministers and other top executives.

Time-of-Day Control Time-of-Day Control (TDC) for lighting systems along was applied at 14:00 h, after the end of work. TDC implementation was carried out through the BAS except for MOH and PAYS buildings, details of the TDC schedule is detailed in Table 1.

Table 1. Operation Schedules for the Lighting System Before and After TDC Implementation

Building	Before Implementation			After Implementation		
	Full Capacity (h)	Partial Capacity (h)	Complete Closure (h)	Full Capacity (h)	Partial Capacity (h)	Complete Closure (h)
MC	05:00-17:00		17:00- 05:00	06:00-13:00	13:00-15:30	15:30-06:00
JPC	00:00-24:00			06:00-14:00	14:00-06:00	
LTC	00:00-24:00			00:00-24:00		
PIFSS	05:00-17:00	17:00- 05:00			00:00-24:00	
MOH	06:00-14:00	14:00-06:00		06:00-14:00	14:00-06:00	
KCCI	06:00-15:00	15:00-06:00			00:00-24:00	
SAB	*			06:00-18:00	18:00-21:00	21:00-06:00
PAYS	05:00-14:00	14:00- 05:00		05:00-14:00	14:00- 05:00	

*Building under commissioning.

Identification and Evaluation of Additional Opportunities While implementing well established operation strategies, special interest in identifying additional opportunities (AOs) for peak power reduction in these buildings were put into consideration. AOs that were studied and explored were the additional operation strategies that could be implemented with or without minor modifications, and by correcting the design deficiencies that could be rectified easily and economically. Interaction with technical teams in these buildings realized the implementation of additional peak power reduction strategies that could further reduce the peak power demand and achieve additional energy savings.

Delamping and rewiring were found to be effective tools to correct the design deficiencies in the lighting system of these buildings for additional peak power reduction.

Delamping: Delamping refers to removing extra lights from their fixtures. This is an excellent way to rectify the over sizing of the lighting equipment. This is costless procedure can be undertaken during the time of system maintenance.

In areas where light switches control more than one fixture and where the light levels exceed the recommended values, delamping is the most suitable remedy. To correctly reform the over utilization of lights by delamping, site measurement data for light levels for different tasks areas are collected using a lux meter, lamps in areas where the illumination levels exceed the recommended ones are removed. It is recommended to remove the ballasts along with the lamps and keep them for future use, since ballasts may consume energy.

It was found that the illumination levels in many areas in these buildings were higher than those recommended by MEW through the Energy Conservation Code of Practice (MEW/R-1, 1997). The recommended illumination levels for corridors, lobbies and offices are 100, 150 and 500 lux, respectively. However, in the offices, it can be ranged between 300 and 500 lux depending on the visual task. The only building that adheres to the recommended illumination levels was SAB. Delamping was suggested in some buildings as an opportunity to reduce the building's load and maintain the illumination levels as per the recommendation of MEW through the Energy Conservation Code of Practice. Figures 1 and 2 show the effect of delamping in some buildings. The values of measured lux levels and their potential savings are listed in Table 2 for offices, lobbies and corridors for each building.

(a) (b)

Figure 1. A corridor at LTC building (a) before (b) after delamping.

(a) (b)

Figure 2. A corridor at MOH building (a) before (b) after delamping.

Table 2. Measured Lux Levels and Their Respective Saving Potential for Each Building through Delamping

Building	Lux level measured			Saving Potential (%)			Savings Achieved					
							Offices		Lobbies		Corridors	
	Office	Lobby	Corri-dor	Office	Lobby	Corri-dor	%	New lux level	%	New lux level	%	New lux level
MC*	526	473	328	5	68	70	-	-	100	352	33	230
JPC	-	465	385	-	68	74	-	-	33	235	50	220
LTC	-	-	300	-	-	67	-	-	-	-	33	220
PIFSS	-	-	170	-	-	41	-	-	-	-	50	110
MOH	720	435	260	31	65.5	62	25	590	50	165	50	165
KCCI	-	350	350	-	57	71	-	-	50	280	50	280
SAB**	360	120	270	-	-	-	-	-	-	-	-	-
PAYS	900	550	488	44	73	80	50	560	50	176	50	264

* Experiment was carried out, but not implemented.
** Illumination levels in this building falls within the specified range.

Rewiring the Lighting Systems: It was observed that TDC for lighting can be made more effective for peak power demand reduction by making minor adjustments through rewiring while maintaining the recommended values of illumination levels in different locations in the building. At PIFSS, It was noticed that at the staircase 17 floors have enough daylight during the day, while the BAS controls the lights in the staircase including the basement area. Switching off these lights did not affect the illumination levels in the daylit area of the staircase. In addition, re-wiring the lights in the elevator lobby from the 3rd floor up in the office building, where the illumination levels were found to be excessive due to sufficient daylight was also implemented. Minimum required illumination level in the staircase and the elevator lobby was maintained after re-wiring. Based on KISR's recommendations, rewiring of lighting systems was made while the BAS centrally controlled on/off operations of the lighting systems and switching off these lights between 05:00 and 18:00 h.

Retrofitting of lamps: In KCCI building, all incandescent lamps were replaced with their equivalent energy efficient compact fluorescent (CFL) lamps. Due to the limited number of these lamps, the saving came to 6.5 kW.

RESULTS AND DISCUSSIONS

Delamping for the lighting systems was the major contributor to the peak power reduction, it was carried out as an additional activity which also contributed to the overall peak power reduction.

Delamping was implemented in the corridors, lift lobbies and car parks of some of the eight buildings. It proved to be a successful solution for peak power reduction, besides minimizing the building's lighting energy consumption. All time savings of 228 kW was achieved in peak power reduction due to delamping.

Delamping was applied in all buildings except MC and SAB buildings. The only building that adheres to the recommended illumination levels was SAB and the management of MC building did not allow the team to carry out delamping in their building.

Table 3 summarizes the peak power reductions realized in different buildings between 14:00-15:00 h due to the implementation of TDC and delamping for the lighting systems. Switching off a lighting unit not only reduces its direct power demand, it also has an important indirect effect. Switching off a lighting unit results in eliminating its heat emittance; leading to a reduction in the cooling demand of the building. In the eight buildings, the direct reductions in power demand due to TDC implementation of lighting systems were 1,680 kW.

Table 3. Breakdown of Peak Power Reduction for Different Components for Each Building at 14:00 – 15:00 h.

Building	Delamping	TDC Lighting	Total
	kW	kW	kW
MC	0	1,378	1,378
JPC	37	27	64
LTC	20	-	20
PIFFS	2.7	31	33.7
MOH	121	-	121
KCCI	27.5	19	46.5
SAB	-	225	225
PAYS	21	-	21
Total	**228**	**1,680**	**1,909.2**

Delamping was not applied in all areas of the buildings to the full extent such as the offices because of the variations of the visual tasks carried out in these offices. Furthermore, even after delamping was applied in areas such as corridors, lift lobbies and car parks the measured illumination levels were mostly higher than the recommended ones. This proves that office buildings' lighting systems are over designed, and there is a great potential for more savings in power demand if delamping was applied in all the over lit areas.

The savings in energy consumption that leads to significant financial benefit to MEW and the environmental benefit to the nation was an additional major achievement. The total reduction in lighting energy consumption for the eight buildings for a typical day was 29 MWh and the annual energy savings for the lighting systems was 10,628 MWh.

CONCLUSIONS AND RECOMMENDATIONS

Peak power reductions strategies for lighting systems proved its feasibility. Also, the clear guidelines that have been developed can be used by facility operators to execute similar strategies effectively and independently. Conclusions and recommendations can be summarized as follows:

1. The implementation peak power reduction strategies for the lighting systems in the eight governmental and institutional buildings with a total peak demand of 29.3 MW achieved a reduction of around 2000 kW. Furthermore, reduction in peak power demand is associated with reduction in energy consumption which leads to a substantial reduction in fuel consumption and CO_2 emissions. This low-cost and extremely effective measure saves around $ 85,000 for MEW based on 1.2 cents/kWh for the cost of the production of energy. Therefore, MEW should consider implementing peak power reduction strategies in all the governmental and institutional buildings in Kuwait at the earliest.
2. Delamping was identified as an additional power and energy saving scheme. It contributed to an all time savings of 228 kW. Delamping is rather a rectification of design deficiency in the lighting system and not an operation strategy. Most of the buildings were found to have higher illumination levels which were corrected through delamping. It is recommended to enforce delamping in existing buildings to reduce the illumination levels as recommended by MEW Energy Conservation Code of Practice. Likewise, for the new buildings, illumination levels should be an integral feature in the lighting system design.
3. The connected lighting load in the buildings (excluding LTC), ranging between 17 and 33% of the total connected load of A/C and lighting systems combined, is considered high. Also, it was observed that many buildings use non-efficient lighting systems such as incandescent and T12 fluorescent lamps, and magnetic ballasts. The present Energy Conservation Code of Practice, which allows Lighting Power Density (LPD) of 30 W/m^2, is responsible for excessive lighting loads in buildings. It is recommended that the code should be modified limiting the LPD to 10 W/m^2 as recommended by ASHRAE/IESNA standard. This can be achieved by using more energy efficient lamps, luminaires and ballasts.
4. Most of the governmental and institutional buildings are equipped with state-of-the-art building automation systems (BAS). However, the BAS in these buildings were not adequately utilized to implement energy efficient operation strategies such as TDC for lighting systems. It is recommended that energy inefficient operation practices should be rectified to ensure full benefit of these capital intensive devices through proper education and training of maintenance engineers, technicians and building operators.

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