Electrical Energy Audit in a Malaysian University - A Case Study

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Abstract—**In this paper, the electrical energy audit performed for the development of the electrical energy efficiency measures EEMs in Universiti Teknologi MARA (UiTM) Penang is discussed. The energy audit showed that the buildings consumed a monthly average electrical energy of 1.5 million kWh and having a potential to save 0.15 million kWh of energy, a 10% electrical energy saving potential. The energy audit was carried out on the lighting system and air conditioning system in UiTM Penang, the systems consuming 25% and 56% of total electrical energy utilized by UiTM respectively and the equipment were found to be operating at low energy efficiency. Failure to switch off electrical equipment even when not required being in operation, absence of switch signage's, inadequate effective control systems, low efficient equipments and systems were identified to be the major causes of energy losses and wastes in the buildings. To improve the electrical energy performance in buildings, an enhanced level of awareness to reduce energy waste, the use of efficient equipment and control systems is found to be the most effective energy efficiency measures strategy to improve the lighting and air conditioning system efficiency in the buildings. The benefits of implementing the energy efficiency measures in buildings are substantial both in terms of energy savings and cost savings.**

Keywords-Energy audit, energy utilization, energy efficiency, energy efficient measures

I. INTRODUCTION

Electrical energy utilization in commercial buildings is increasing rapidly with the increase in utilization of more and bigger capacity electrical equipments. Energy audit is the first step which can be conducted within an organization for the development of electrical energy efficient measures EEMs. The energy audit is carried out by collecting a simple or detailed energy data of the organization's real energy utilization which is to be compared with the normative standard energy utilization for developing the EEMs. An understanding of the organization's energy utilization is important to develop the EEMs for improving energy utilization within an organization. Developing EEMs for organizations is essential to remain competitive as the operating costs have been increasing with electrical energy tariffs and energy costs rising dramatically because of the increase in fuel costs and globally limited fuel resources. For the promotion of energy efficiency in Malaysia, the Efficient Management of Electrical Energy Regulations 2008 was introduced on 15 December 2008 which makes it mandatory for the management of large commercial and industrial electrical consumers in Malaysia to develop and implement EEMs to reduce energy losses and implement efficient utilization of electrical energy in the organization [1]. For the success of these EEMs, energy efficient awareness in the entire organization is essential. Energy audit can be successfully carried out only with the commitment of top management and involvement of the entire staff of an organization. The organization management must be committed of the importance of implementing energy management and hence energy audits [2]. The major electrical energy utilization in buildings is the lighting and air conditioning system. Lighting systems consumes approximately 25% of electrical energy utilization in buildings. The main energy waste in a building is the attitude of organization staff not switching off lighting when not required to be in operation in buildings. The use of efficiently designed lighting technology can reduce equipment energy losses with improved lifespan and lighting quality [3]. Air conditioning consumes the highest electrical energy in buildings with approximately 56% of the electrical energy utilization in buildings. The main waste is also not switching off air conditioning equipment when not required and inefficient operation of air conditioning system due to doors and windows in air conditioned spaces left open. The use of efficient air conditioning system can reduce equipment losses and improve system efficiency [4]. The development of EEMs is carried out with the aid of energy recorders to determine real energy utilization of the Lighting and Air Conditioning systems. Electrical energy audit carried out in an organization can be a low cost simple audit to develop low cost measures or a detailed audit which can develop medium and high cost EEMs but is costly and time consuming. The audit process will identify energy losses and wastes in the building and to develop the EEMs [5]. This energy audit paper focuses on the development of electrical EEMs in buildings to be implemented by organization management using IEEE Standard Practices for Energy Management [6].

II. ENERGY AUDIT

An energy audit can be defined as a systematic process to evaluate where a building uses energy and identify the EEMs to reduce energy consumption [7]. Energy audit is an essential energy management service which applies energy analysis methods to evaluate the profile of energy utilization to develop energy efficiency measures EEMs in buildings [8]. An energy audit was conducted in the UiTM Penang campus building during 2011. The energy audit established a profile of energy utilization of electrical equipment in terms of kWh consumption as shown in Figure 1, including hours of operation and costs. The audit revealed electrical energy utilized for lighting, air conditioning and other electrical equipment for a total average energy utilization of 1.5 Million kWh as shown in Figure 2. Energy utilization for lighting and air-conditioning account for a larger proportion of building energy consumption, thus having high potential of energy saving. Hence the EEMs were developed for the lighting systems and air conditioning systems to be implemented aimed at reducing energy utilization and energy costs in buildings.

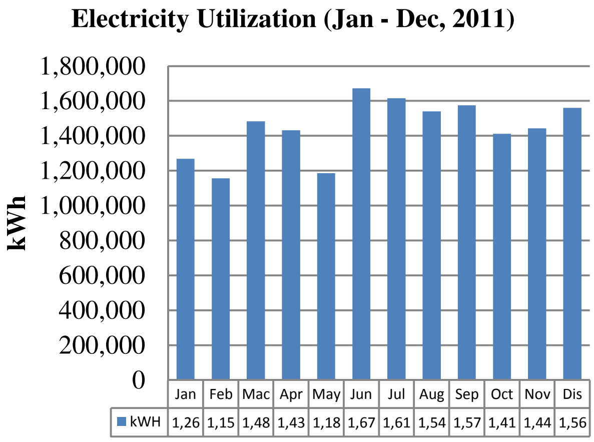

Fig. 1. Energy Consumption (kWh) and Percentage of Energy Utilization for January to December 2011

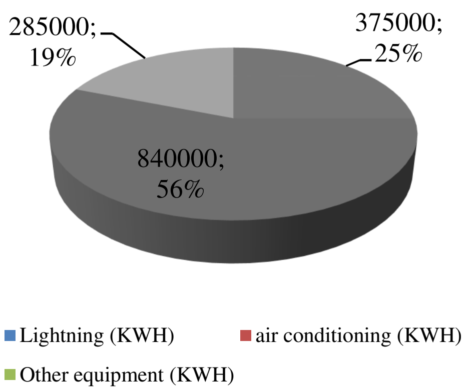

Fig. 2. Monthly Energy Utilization for Lighting and Air Conditioning System

A. *Lighting Systems Energy Audit*

The lighting system used in buildings mainly utilizes T8 fluorescent lamp tubes of 18W and 36W and the conventional inefficient high power magnetic ballasts. The lighting levels in the building were measured using lux meters for compliance with the Illuminating Engineering Society (IES) Recommended Practice Guides that provide Tables of appropriate luminance data to be used in different areas of buildings. Measurements were carried out using light meters or Lux meters for measurement to compliance with real illumination levels in buildings.

Energy audit measurements for lighting system revealed that (1) most parts of the building met lighting standards except certain open areas with sufficient natural lighting which had higher than standard illumination. (2) a lack of energy saving awareness - energy waste of lighting where lights were not turned off when area is brightly lit and nobody was in public zone, rooms and in toilets (3) the use of conventional fluorescent tubes and inefficient magnetic ballast as shown in Table 1.

TABLE 1: PERFORMANCE OF THE LIGHTING SYSTEM

Tube type	No.	Rated Power	Real power	Lumens /lamp
T8 36W Fluorescent c/w 8W ballast	1740	44W	46W	1950 lumens
T8 18W Fluorescent c/w 8W ballast	820	26W	27W	1050 lumens

B. *Air Conditioning Systems Energy Audit*

The air conditioning system consists of 30 split units for individual rooms and a central air conditioning chiller system for general areas in building. The central air conditioning system which was installed in 2001 consists of a chiller plant, AHU rooms and cooling tower floor. The chiller plant has 4 chillers with 3 units of 600 tons/385kW capacity and 1 unit of 300 ton/201kW capacity chillers, 20 units of 75kW motor-pump systems to supply chilled water to 16 units of air handling units AHUs and 4 units of 15kW cooling towers. Since the chiller system was the major electrical energy user with the highest potential of EEMs, energy measurements were carried out to identify the 4 Chillers efficiencies using electrical energy, flow, pressure, and temperature meters for comparison of the real measured data with efficient equipment efficiencies. The air conditioning audit was carried out to reduce the energy consumption of chiller plant system which consumes approximately 70% of air conditioning system load by developing effective EEMs for implementation without compromising the comfort of students and staff. The audit was carried out to ASHRAE standards, the American Society of Heating, Refrigerating and Air Conditioning Engineers that developed the standards for air conditioning industry.

The energy audit on air conditioning system identified the following energy inefficiency and wastes in the split unit air conditioning system (1) poor maintenance of filters 2) low energy efficiency ratio EER of 2.63 for split unit equipment as shown in Table 2. For high efficiency split units the EER must be greater than 3.2.

TABLE 2: PERFORMANCE INFORMATION OF THE 30 UNITS OF SPLIT UNITS AIR CONDITIONING SYSTEM

Equipment	Capacity	Real KW	EER	Running hours/year
Split Unit 3 Hp	10000BTUH	1.5	2.63	5000

The energy audit on chiller air conditioning system revealed (1) a lack of energy efficiency awareness – energy wastes with room doors and windows left open when air conditioning are working (2) a simple audit showed the specific power consumption SPC of the chiller equipment 1, 2 and 4 were operating at a good performance based on ASHRAE efficiency recommendation of SPC below 0.8 kW/ton at rated load however Chiller 3 was operating at a low SPC of above 0.8 kW/ton at rated load which could be due to a lack of essential maintenance of chillers leading to a low heat exchange in chiller tubes being not cleaned regularly hence reducing heat exchange efficiency or due to the centrifugal compressor operating inefficiently as shown in Table 3. A detailed audit measurement of SPC at various load as shown in Figure 3 and 4 showed that the chiller performance of Chiller 3 needed improvement due to operational problems or plant requiring correctable design whereas Chiller 1, 2 and 3 was of fair performance consistent with older chiller plants. The chiller plant equipment is more than 10 years old.

TABLE 3: PERFORMANCE INFORMATION OF THE 4 CHILLERS IN AIR CONDITIONING PLANT

Equipment	Rated Capacity	Rated power	Rated SPC KW/ton	Real kW/ton	Running hours/year
Chiller 1	600 Tons	385kW	0.64	0.76	5000
Chiller 2	600 Tons	385kW	0.64	0.77	5000
Chiller 3	600 Tons	385kW	0.64	0.89	5000
Chiller 4	300 Tons	201kW	0.67	0.75	2000

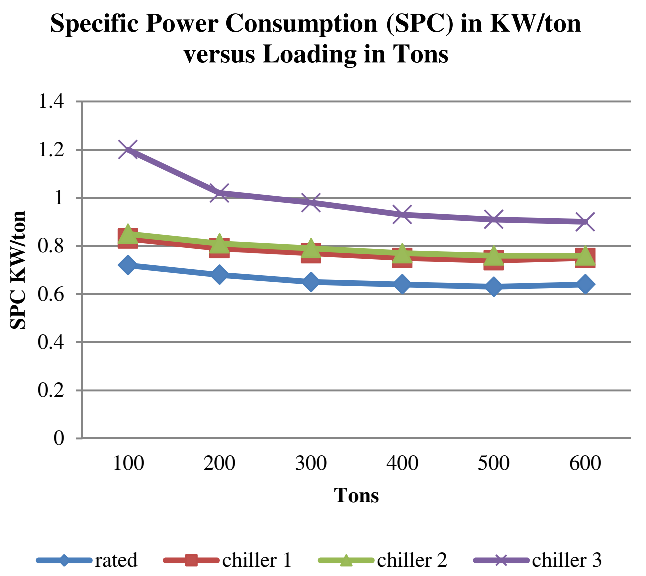

Fig.3. Specific Power Consumption SPC for Chiller 1, 2 and 3 from low to rated load

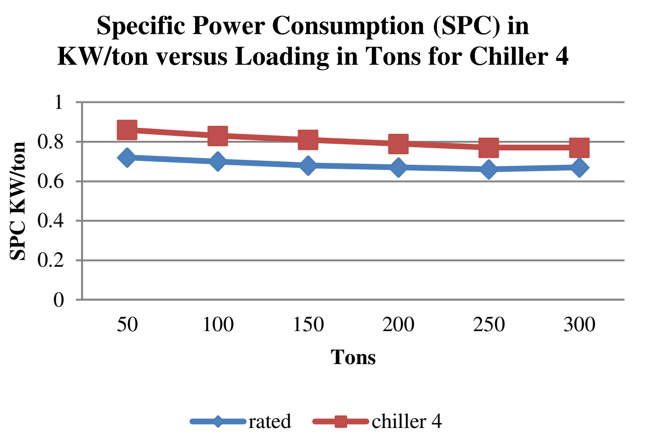

Fig.4. Specific Power Consumption SPC for Chiller 4 from low to rated load

III. ENERGY AUDIT EEMS

A. *EEMs for Lighting System*

The building's interior lighting is using fluorescent tubes T8 of 36W and 18W equipped with electromagnetic ballasts. Hence to improve the lighting system efficiency, the EEMs proposed are low cost measures of (1) delamping and (2) using signage's and automatic control systems including sensors and for medium cost measures (3) relamping by replacing T8 fluorescent lamps by high efficiency lamps and electronic ballast for different spaces as shown in Table 4.

i. Delamping: In open areas with sufficient natural which had higher than standard illumination, removing 1 tube each from approximately 300 fittings using 2x36W tubes operating approximately 5000 hours per year could save 54000 kWh of electrical energy per year.

ii. Use of signage's and automatic lighting control systems such as sensors for areas where lights were not turned off when area is brightly lit and nobody was in public zone, rooms and toilets. Hence by installing signage's to create awareness and remind users to switch of lights, sensors and automatic control systems which automatically switch off lights in unused areas substantial electrical energy can be saved.

TABLE 4: ENERGY EFFICIENCY MEASURES FOR LIGHTING SYSTEM

NO.	Energy Efficient Measurement	Annual Energy savings kWh	Annual Cost Saving RM	Investment Costs RM	Payback period
LOW COST MEASURES					
1.	Delamping 100 lamps	54000	15000	Nil	Instant
2.	Use of Signage's, sensors and automatic control systems	150000	45000	60000	1.3 years
MEDIUM COST MEASURES					
1.	Replacing fluorescent tube T8 (36W) with T5 (25W)	95700	28710	52200	1.8 years
	or/and Replacing fluorescent tube T8 (36W) with LED (18W).	156600	46980	208800	4.4 years
2.	Replacing conventional ballast (8W) with electronic ballast (3W).	43500	13050	13920	1.1 years

iii. Relamping : Replacing T8 lamps with T5 or/and LED lamps including electronic ballasts. The use of T5 and LED lamps of same or equivalent efficacy with electronic ballast can greatly reduce electricity consumption. Lamp selection is based on several factors, such us efficacy (lumens per watt), color temperature, color rendering index, life and lumen maintenance, availability and cost. The application of this measure will involve the replacement of the existing T8 lamps of 18W and 36W by lamps of equivalent efficacy of different technology types: T5 and LED tube. The replacement of existing electromagnetic ballasts by electronic ballasts present advantages of high frequency operation which eliminates flicker and hum; they are lightweight; they have better energy efficiency using less energy and they can be built dimmable, enabling users to adjust light levels resulting in electricity savings.

The low and medium cost EEMs for lighting systems shows implementing the measures has a potential of substantial annual cost savings with a payback period of less than 2 years by replacing T8 lamps with T5 and 4.4 years by replacing with LED lamps. The annual energy saving for LED is 60% more than T5 tube. Even though the payback period for LED is higher, LED is fast becoming a preferable choice due to fast declining LED costs.

B. EEMs for Air Conditioning Systems

i. EEMs for Split Unit Air Conditioning System: To improve energy efficiency of the split unit air conditioning system, the proposed EEMs are (1) replacing air conditioning refrigerant from R22 to Cold*22 and (b) replacing low efficient air conditioning unit with high efficient unit. Cold*22 is an environmentally friendly refrigerant which can save up to 20% of electrical energy usage. Replacement of existing split units of low EERs with high EER of greater than 3.2 can produce substantial cost savings with a payback period of 3.6 years as shown in Table 5.

ii. EEMs for Chiller Plant Air Conditioning System: To improve energy efficiency of chiller plant air conditioning system, the proposed EEMs are (1) maintenance of chiller evaporator and condenser piping (b) Replace inefficient compressor with high efficient compressor. The first step is to improve the SPC in KW/ton to a good rating is by cleaning the dirty chiller and evaporator. However, if maintenance fails to improve chiller efficiency to a good rating, retrofitting with a high efficient compressor even though of high cost should be able to improve the chiller SPC to a good rating with a payback period of less than 3 years as shown in Table 6.

TABLE 5: ENERGY EFFICIENCY MEASURES FOR SPLIT UNIT AIR CONDITIONING SYSTEM

NO.	Energy Efficient Measurement	Annual Energy saving kWh	Annual cost saving RM	Investment cost RM	Payback period
MEDIUM COST MEASURES					
1.	Replacing Refrigerant R22 with Cold*22	24000	8000	10000	1.25 years
HIGH COST MEASURES					
1.	Replace the split unit of EER 2.63 with energy efficient unit	150000	50000	180000	3.6 years

TABLE 6: ENERGY EFFICIENCY MEASURES PERFORMANCE FOR CHILLER PLANT AIR CONDITIONING SYSTEM

NO.	Energy Efficient Measurement	Annual Energy saving kWh	Annual cost saving RM	Investment cost RM	Payback period
MEDIUM COST MEASURES					
1.	Maintenance of chiller evaporator and condenser piping	72000	24,000	40,000	1.7 years
HIGH COST MEASURES					
2.	Replace inefficient compressor with high efficient compressor	1200000	40000	100000	2.5 years

IV. CONCLUSION

Electrical energy utilizing in buildings is continuously increasing and will continue to grow in the foreseeable future as more high power electrical equipment are installed. Energy audit identifies several energy saving measures which can be undertaken within an organization to reduce electrical energy utilization by reducing wastes and improving energy efficiency. To achieve optimal energy performance in buildings, energy audit is able to reduce energy wastes and improve the energy efficiency of the lighting and air conditioning equipment. Finally, electrical energy audit will develop the EEMs and only if management of organizations implement these EEMs measures in the buildings, they will be able to achieve the benefits of energy and cost saving.

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