

ENERGY AUDIT AND PROPOSED NEW DESIGN SCHEME FOR ENERGY SAVING IN LABORATORY BUILDING.

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Abstract

This paper presents the explanation and technical analysis of various data from the energy audit of the Electrical Laboratory building in UiTM Shah Alam. The electrical wiring installation in this building is quite old and the efficiency of energy usage is reduced by time. Energy audit is considered as one of the comprehensive methods in monitoring the energy usage and wastage in buildings.

This paper describes the process of energy audit, desktop analysis, financial tool approaches to determine worthiness of the investment on energy saving measures and proposed the ways on how to improve the energy usage. The discussion includes proposed new design scheme in order to increase the energy efficiency and achieve optimum energy saving, for the sake of energy conservation and minimize downtime.

Keyword

Energy audit, energy conservation, energy saving measures and energy efficiency.

1.0 INTRODUCTION

Energy audit is a process of examining an energy account, checking the way energy is used and identify areas where wastage can be minimized.[1]

The process of energy audit, which being describe by [1] is implied to this cases on Electrical Laboratory building.

Electrical Laboratory building noticed as Block E is located adjacent of Block A at Engineering Block. The single storey building with 200ft length (60.96m) and 40ft width (12.192m) whereby is covered by 743.2m² area. There are five rooms in this building includes:

- General Machines Laboratory (223m² area)
- Staff's Room (74.4m² area)

- Advanced Machines Laboratory (148.6m² area)
- Power Electronics Laboratory (148.6m² area)
- Fabrication Instrument Laboratory (148.6m² area)

The cubicle sub-switch board (SSB-E) is located at staff's room with incoming size 200Amperes which is laying via underground cables from the Ring 11kV Sub-station from main board MSB – Eng. 1.

Among of energy system used in this building such as air-conditioning split unit type (ACSU), lighting and general equipment (fans, computers, printers) and also from the workbench including motors during laboratory session.

2.0 ANALYSIS AND METHODOLOGY

The objective here is to study and analyzed the use of electrical energy in Electrical Laboratory building so as to identify areas to conserve energy via preliminary audit. Also to identify energy conservation and retrofit solution by implementing load management to those decided areas.

2.1 Identify areas to conserve energy.

The preliminary audit comprises of desktop analysis and physical audit of the energy system. Briefly the physical audit looks at the air-conditioning system, lighting and general equipment. The information gathered are then analyzed and potential energy savings solutions and saving quantum are respectively identified and estimated. The findings of the preliminary audit are used to determine whether to proceed with the detailed audit activities.

2.1.1 Desktop Analysis

The desktop analysis was undertaken after data collection is completed. Various data were compiled via field interviews, document reviews and physical survey of the facilities.

2.1.2 Interview

Audit interviews were conducted at Laboratory building and Sub-station Intake Eng.1. The interview provides initial understanding of current operational procedure and maintenance's crew (Laboratory staff and Electrical Charge man from Maintenance unit) opinions on the state of the energy system in laboratory building. The interview also took into consideration the current maintenance practices, historical of installation and the ongoing development activities on the energy system as a whole.

Interview with building operators provide insight into the general condition and the usage pattern of the building, its current operating and its future usage.

2.1.3 Document Review

The document review activity mainly focuses on an electrical drawing, inventories of equipment, maintenance manual as well as data on electricity bill, which are supposed to be review, but in this case, unfortunately those document unavailable. Therefore, all information on the energy usage pattern is done by physical audit to produce the electrical system layout of the building and existing electrical schematic drawing for the electrical reticulation in laboratory building. The tariff imposed to electricity billing is Tariff C1 with Maximum Demand per kW power consume is RM17.30 and energy charge per kWh is RM0.208.

2.1.4 Walk Through Audit

Each facilities energy system was examined and operating conditions recorded. During the walk through audit, the representative from the maintenance and laboratory staff explained the operating procedure of each energy system and provides brief overview of the problems that they encounter in operating the system.

The walk through audit comprises of visits to the Sub-station, each of the laboratories rooms and even the rooftop of the laboratory building whereby the name plate of energy system is located.

Besides the energy system, the usage pattern of the building was also observed. The usage pattern was obtained generally via interviews with relevant personnel handling the building.

The general thread is then reclassified into a few categories of energy use. For this particular site, the energy use is classified into the following:-

- Air Condition Split Unit System
- Lighting System
- General Equipment (such as fan, computers, printers, laboratory equipment etc.)

2.2 Identify energy conservation and Retrofit solution.

The effort to date on energy conservation has been rather lethargic and sporadic at best. Turning over energy responsibility to an employee without defining specific energy reduction goals through a comprehensive energy audit is a most common and unfortunate practice. It is often though that energy conservation is related to some design or operating problem that can be remedied.

Retrofitting can and does have different meanings for the various engineering disciplines as employed in construction, bring the meanings for "The modification, rearrangement, removal or addition to existing (building or process) energy consuming systems of components and or controls so that the energy use profile of systems operations, utilizing the existing energy demand, is substantially reduced without sacrifice of prior comfort and productivity standards for the maintained environment".[2]

The lighting and air condition retrofit toward energy conservation can be achieved through managed by objectives.

2.2.1 Load Management System

Load management is the control of usage of electrical or other form of energy by reducing or optimizing the amount of such usage and the rate of such usage (demand)[3]. Basically, the energy saving can be obtained either by using expensive capital equipment/ exotic technology or utilized existing energy system via managing current load efficiently.

A) Managing Load of an Air Conditioning system.

In the audits session, first identified sources of heat gain and loss and quantified each, then cooling temperature is controlled at 23 deg. Centigrade. The ventilation e.g proposed rooftop ventilation and existing sidewall at the top ventilation by controlling the exhaust fan therefore allows hot air to escape.

The most common factor to regulate temperature in the building via-

- i) Prevent heat gain
 - Hot air infiltration via open doors and windows.
 - Solar heat via glass windows.
 - Reduce internal heat generating equipment.
 - Switch OFF unoccupied areas.
- ii) Controlling of parameters.
 - Control systems operating times.
 - Regulate space temperature.

- Installed ultrasonic occupancy sensor for auto switch OFF unoccupied area.
- iii) Maintenance
 - Regular maintenance for efficiency of air distribution system and clog outside air intake (air filter).
- iv) Modify
 - Modify cooling and ventilation system by introduced efficiency improvement retrofit.

B) Managing Load of Lighting system.

During audit session, via visual inspection on the illumination level and fittings layout, there are various technique can be applied, in order to achieve energy savings. Among of the technique being proposed are:

- Manually switch OFF the light while not in used.
- Minimize the numbers of lighting per switch.
- Rearrange the lighting point circuit accordingly with workbench working plane.
- Use low loss ballast 5W rather than standard ballast 10W.
- Install infrared occupancy sensor for auto switch OFF unoccupied areas.
- Use compact fluorescent with electronic ballast.

C) Operational initiatives.

Managing the operational practices is useful for maximum demand saving purposes. Firstly, identify the peak load from monthly usage pattern, then initiate better starting schedule of the enormous energy equipment. The analysis focus on:-

- Impact of simultaneous starting of all air condition units. Sample calculation of maximum demand (MD) charge for simultaneous starting of all ACSU with starting current assume to be six times full load current:-
 $MD1 = 6 \times 46.555kW \times RM17.3/kW$ MD1 = RM4,832.41
- Impact of staggered starting of each air condition unit via schedule starting. Sample calculation of maximum demand (MD) charge for schedule starting with starting current assume to be six times full load current :-
 $MD2 = 6 \times 3.7kW \times RM17.3/kW$
 MD2 = RM384.06

3.0 RESULTS

Based on the finding of an energy audit conducted, various important information are compiled and presented in the following manners:

3.1 As-built Drawing

Prior to the actual electrical installation and equipment layout in the building, all energy equipment and electrical wiring system being studied then produced the as-built drawing of electrical layout and schematic.(Appendix 1).

On top of that, undesirable load from old installation are justified to be demolishes. Under these circumstances, several lighting fixture and air condition which are over sizing and not utilize being determined. As a result some profit can be generated from this energy saving measures.

In order to obtain long term and reliability energy saving and high efficiency usage of energy, some of up to date protection equipment are proposed to be used and shown in the proposed new design of schematic and layout. (Appendix 2)

3.2 Usage Pattern

From the physical audit, the information obtain from the personnel and measurement done elaborate by the following graph in Figure 1 and Figure 2.

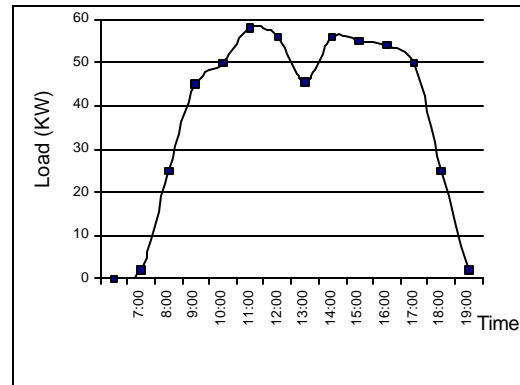


Figure 1 : Usage pattern – Load without Laboratory Operation

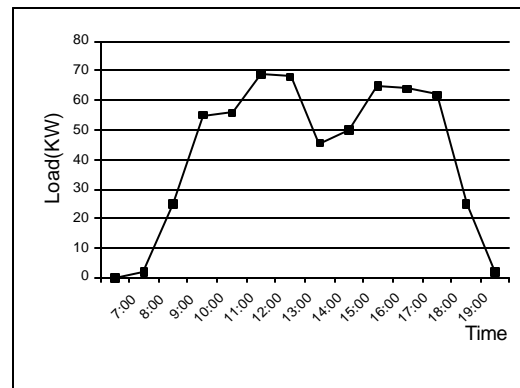


Figure 2 : Usage pattern – Load with Laboratory Operation

The graph above shows the daily energy consumption pattern in laboratory building for different occasion, which Fig. 1 load during semester break and Fig. 2 load with full running of laboratory session during lecturing season. According to the operational, load continuously increased by the year, because of increasing number of equipment and duration of usage, also due to inefficiency in using of equipment with no control over usage parameter.

3.3 Load Apportioning

Below is the result, which indicated by Table 1 and Figure 3. The result described the load apportioning for the electrical laboratory building, with major load disseminated through ACSU (80%), lighting (11%) and general equipment (9%) of the total energy usage. The laboratory operating hours is from 8:00a.m in the morning until 6:00p.m about 10hours operation basis.

Location : Electrical Laboratory Building

Energy equipment	Description	Qty. (nos.)	Load (kW)	Usage Schedule
ACSU	3.7kW	8	29.6	8:00am - 6:00pm
	3.0kW	2	6	
	2.985kW	3	8.955	
	1kW	2	2	
			46.555	
Lighting System	2 x 36W (F)	72	5.184	8:00am - 6:00pm
	3 x 36W (F)	8	0.864	
	1 x 36W (F)	6	0.216	
	2 x 18W (F)	6	0.216	
			6.48	
General Equipment	250W	12	3	8:00am - 6:00pm
	120W	12	1.44	
	60W	10	0.6	
			5.04	
TOTAL			58.075	

Table 1 : Load Apportioning

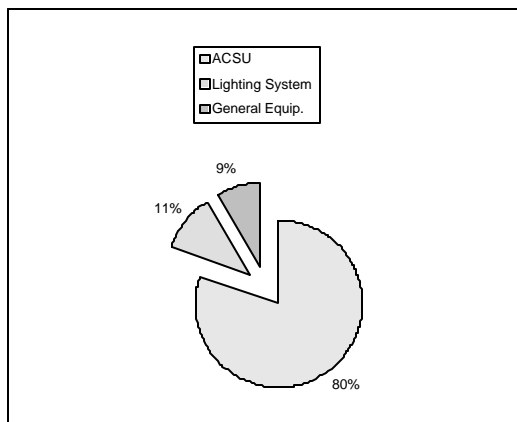


Figure 3 : Load Apportioning

3.4 Energy savings opportunities and results

The main components to be concentrates, in order to increase utilization of electricity usage, which may bring significant electrical energy conservation and cost saving are:

3.4.1 Increase Awareness through education programs

Through out continuous and frequently education programs, the management should educate the operational staff about the efficient ways and awareness of energy wasted resulting from inefficient usage of energy. The awareness of energy conservation method can be obtained via attending the energy efficiency seminar, which conducted by government agencies, energy efficiency consultant and the expertise.

Information on energy strategies and results must be made known throughout the entire building users to motivate people to maintain the level of efficiency already reached and to improve it in the future.

The daily operating hours of the energy equipment can be reduced up to two to three hours per day. As a results, the saving can be achieve about 20% to 40% of the total energy consume.

3.4.2 Installation of energy saving equipment

Since the areas to be conserve of energy are substantially determine, some of the innovative technology are available in the market, which help to increase the energy efficiency and improve energy usage. For ACSU application (46.555kW), 2nos. of Power Boss 30h.p, which is cost about RM6415 per unit, with saving of 15% up to 35% of power.

In Lighting application (6.48kW), use 1 no. Matrix energy termination unit, implementation cost RM600/.kVA. Saving of 15% from the electrical power.

3.4.3 Installation of occupancy sensors

Using occupancy sensors is economically feasible for larger circuits controlling more than 500W of controlled load for infrared sensors and 1700W of controlled loads for ultrasonic sensors, especially in areas occupied intermittently.

The occupancy sensors can be used to control air-conditioning split and fan units. A cost of RM330/= is allocated for each infrared occupancy sensor and RM580/= for ultrasonic occupancy sensors, inclusive of cost of wiring and contactor to control the fan or air-conditioning units. The savings are based on 30% of normal operating hours. The lightings, air-conditioning and fans are auto turned OFF when the area is unoccupied.

3.4.4 Proposed new design scheme

By looking at the existing system, some improvement technically can help in reducing energy consumption are determined. Those proposal such as:-

- Introduce new circuit arrangement to suit with working zone.
- Use efficiency control equipment

- Use MCB (Miniature Circuit Breaker) to replace fuse link.
- Use MCCB (Moulded Case Circuit Breaker) to replace switch fuse and fuse switch.
- Use new cable wiring as some of the wiring installation is more than 15 years.
- Replace 6nos. 3 x 36W (F) diakon diffuser with 6nos. 2 x 36W (F) with aluminium parabolic reflector and louvre.
- Remove 4nos. 2x36W (F) in fabrication room, which is not in use.
- To check the air-conditioning compressor capacity for fabrication room, change from 3.7kW to 3.0kW.

3.5 Economic Analysis

The economic analysis of investment is a critical step in an energy conservation program because monetary saving is generally the main factor leading to a decision. The same analysis can conveniently be used to choose among possibilities, which may be equivalent from a technical point of view.

The main elements of an investment are ; the initial investment cost or implementation cost, interest rate, the payback period or the return on the investment and the life of the investment.

The payback period is the time required to recover the capital investment from net cash flow[4].

$$\text{Payback} = I / S \quad \text{-----} \quad (1)$$

where;

I = Investment i.e the total capital cost or Implementation cost

S = Saving cost or Net Annual Cash Flow i.e {annual energy saving + other cost saving – annual additional costs} referred to the year of the investment.

Return on Investment (ROI) is the reciprocal of the payback and it is generally expressed as a percentage.

$$\text{ROI} = 1 / \text{Payback} \quad \text{-----} \quad (2)$$

The followings are shown samples of calculations for an existing system and the proposed systems with various techniques implied, in order to

utilize energy usage and increase energy efficiency.

3.5.1 Existing System

Using Tariff C1

Maximum Demand Charge=RM17.3/kW

Energy charge=RM0.208/kWh

Annual Operating hours =10hrs/day x

20days/mth x 12 mths/yr = 2400hrs/yr.

- Lighting (6.48kW)
Energy cost per annum = RM 3234.82

- ACSU (46.555kW)
Energy cost per annum = RM 23240.26

- General Equipment (5.04kW)
Energy cost per annum = RM 2515.97

- Maximum Demand Charge
MD = 58.075kW x RM17.3/kW
MD = RM1004.70

Total Energy Cost Per Annum (TECPA)

TECPA = RM 29995.75

Total Energy Cost Per Month (TECPM)

TECPM = RM 2499.65

3.5.2 Proposed System

Option 1 – Manually switch OFF the light and ACSU if not in used.

Saving in term of hours perform per day will be reduce to 8hrs/day instead of 10hrs/day, Therefore:

Annual Operating hours = 8hrs/day x 20days/mth x 12mths/yr = 1920 hrs/yr.

Lighting; (20% saving)

Saving per annum = RM646.97

ACSU; (20% saving)

Saving per annum = RM4548.06

General Equipment; (20%sving)

Saving per annum = RM503.19

Total Saving per annum for Option 1

= RM5798.22

Payback Period = Immediate.

ROI = maximum

Option 2 – Installation of energy saving unit.

ACSU; (15% saving)

Price RM6415/unit

Implementation cost = RM 12830

Saving per annum = RM 3486/=

Payback Period = 3.7 yrs.

ROI=27.03% per year.

Lighting; (15% saving)

Price RM600/kVA

Implementation cost = RM 4574

Saving per annum = RM 485.23

Payback Period = 9.4 yrs.
 ROI=10.6% per year.

Overall cost for Option 2:
 Total Implementation cost=RM 17404
 Total Saving per annum= RM 3971.10

Overall Payback Period = 4.4yrs.
 Overall ROI=22.73% per year.

Option 3 – Install infrared occupancy sensors, 500W per circuit RM330/pcs and ultrasonic occupancy sensors, 1700W per circuit RM 580/pcs.

Lighting; (30% saving)
 Implementation cost = RM 4290
 Saving per annum = RM970.45
 Payback Period = 4.4yrs.
 ROI=22.73% per year.
 ACSU; (30% saving)
 Implementation cost = RM 16240
 Saving per annum = RM 6972.08
 Payback Period = 2.3yrs.
 ROI=43.48% per year.

Overall cost for Option 3;
 Total Implementation cost=RM20530
 Total Saving per annum = RM7942.52

Overall Payback period = 2.6yrs.
 Overall ROI=38.46% per year.

Option 4 – Proposed new design scheme

Lighting (5.566kW); - 15% saving
 Saving per annum= RM 456.27
 Implementation cost;
 Ballast = 82pcs x RM12 = RM 984/=
 Fittings = 2x36W(F)=6pcs x RM90
 Fittings = RM 540/=
 Implementation cost = RM 1524/=
 Payback Period = 3.3yrs.
 ROI=30.3% per year.
 ACSU (45.155kW) – 5% saving
 Saving per annum =RM 698.88
 Implementation cost = RM7500/=
 Payback Period = 10.7yrs.
 ROI=9.35% per year.

Overall cost and Payback Period;
 Total Implementation cost=RM 9024/=
 Total Saving per annum = RM 1155.15
 Overall Payback Period = 7.8yrs.

The summaries of every particular energy saving opportunities calculations for the lighting and air conditioning are describes by Table 2 and Table 3.

Existing System	Proposed System	Savings / Payback / ROI
Fluorescent: 86 Fixtures 2x18W - 4nos. 1x36W - 4nos. 2x36W - 72nos. 3x36W - 6nos. 6.48kW 2400hours/year Energy cost per annum : Cost = 0.208 x 6.48 x 2400 Cost = RM 3234.82 /year	Fluorescent: Option 1 86 Fixtures 2x18W - 4nos. 1x36W - 4nos. 2x36W - 72nos. 3x36W - 6nos. 6.48kW 1920hours/year Implementation cost = Nil. Cost = 0.208 x 6.48 x 1920 Cost = RM 2587.85 /year	Saving RM 646.97 / year Payback Immediate ROI Maximum
	Option 2 86 Fixtures 2x18W - 4nos. 1x36W - 4nos. 2x36W - 72nos. 3x36W - 6nos. 5.508kW 2400hours/year Implementation cost = RM 4574. Cost = 0.208 x 5.508 x 2400 Cost = RM 2749.59 /year	Saving RM 485.23 / year Payback 9.4 yrs. ROI 10.64% per year
	Option 3 86 Fixtures 2x18W - 4nos. 1x36W - 4nos. 2x36W - 72nos. 3x36W - 6nos. 4.536kW 2400hours/year Implementation cost = RM 4290. Cost = 0.208 x 4.536 x 2400 Cost = RM 2264.37 /year	Saving RM 970.46 / year Payback 4.4 yrs. ROI 22.73% per year
	Option 4 2x18W - 4nos. 1x36W - 4nos. 2x36W - 74nos. 5.566kW 2400hours/year Implementation cost = RM 1524 Cost = 0.208 x 5.566 x 2400 Cost = RM 2778.55 /year	Saving RM 456.27 / year Payback 3.3yrs ROI 30.3% per year
	Combination 2x18W - 4nos. 1x36W - 4nos. 2x36W - 74nos. 4.7311kW 1344hours/year Implementation cost = RM 10388 Cost = 0.208 x 4.7311 x 1344 Cost = RM 1322.59 /year	Saving RM 1912.23 / year Payback 5.4 yrs ROI 18.52% per year

Table 2 : Energy saving opportunities with Lighting

Existing System	Proposed System	Savings / Payback / ROI
ACSU 15 Fixtures 3.7kW - 8nos. 3.0kW - 2nos. 2.985kW - 3nos. 1.0kW - 2nos. 46.555kW 2400hours/year Cost = 0.208 x 46.555 x 2400 Cost = RM 23240.26 /year	ACSU : Option 1 15 Fixtures 3.7kW - 8nos. 3.0kW - 2nos. 2.985kW - 3nos. 1.0kW - 2nos. 46.555kW 1920hours/year Implementation cost = Nil. Cost = 0.208 x 46.555 x 1920 Cost = RM 18592.20 /year Option 2 15 Fixtures 3.7kW - 8nos. 3.0kW - 2nos. 2.985kW - 3nos. 1.0kW - 2nos. 39.57175kW 2400hours/year Implementation cost = RM 12830 Cost = 0.208 x 39.57175 x 2400 Cost = RM 19754.22 /year Option 3 15 Fixtures 3.7kW - 8nos. 3.0kW - 2nos. 2.985kW - 3nos. 1.0kW - 2nos. 32.5885kW 2400hours/year Implementation cost = RM 16240 Cost = 0.208 x 32.5885 x 2400 Cost = RM 16268.18 /year Option 4 15 Fixtures 3.7kW - 6nos. 3.0kW - 4nos. 2.985kW - 3nos. 1.0kW - 2nos. 45.155kW 2400hours/year Implementation cost = RM 7500 Cost = 0.208 x 45.155 x 2400 Cost = RM 22541.38 / year Combination 15 Fixtures 3.7kW - 6nos. 3.0kW - 2nos. 2.985kW - 3nos. 1.0kW - 2nos. 38.38175kW 1344hours/year Implementation cost = RM 36570 Cost = 0.208 x 38.38175 x 1344 Cost = RM 10729.69 / year	Saving RM 4648.06 / year Payback Immediate ROI Maximum Saving RM 3486.04 / year Payback 3.7 yrs. ROI 27.03% per year Saving RM 6972.08 / year Payback 2.3 yrs. ROI 43.48% per year Saving RM 698.88 / year Payback 10.7 yrs. ROI 9.35% per year Saving RM 12510.57 / year Payback 2.9 yrs ROI 34.48% per year

Table 3 : Energy saving opportunities with Air Conditioning

4.0 DISCUSSION

The existing energy consumption was studied carefully. The lighting load consists of 86 fixtures fluorescent fitting with ten hours daily operation, contributes energy cost RM3234.82 per year. The biggest energy contribution are from ACSU load, which is from 15 fixtures ACSU load with different capacity from 1.0kW up to 3.7kW and with similar operating hours consume of energy cost about RM23240.26 per year.

There are four options of energy saving opportunities are being proposed to be used in this case study. The first option, by implementing manually switch OFF the energy equipment whenever unoccupied. This saving opportunity, become first priority to be implemented and ensure immediate profit generated from simple commonsense. The amount of cost saving per year for ACSU and lighting are RM4648.06 and RM646.97 each, which is 20% saving of the existing energy consumption or reduction of two hours in daily operation.

Second option, proposed energy saving equipment being installed to the incoming of lighting load and ACSU load termination, which is available in the market. This method required some capital cost to be implemented. For ACSU, as previously mentioned in 3.4.2, which will control the voltage by using HVAC (High Voltage Alternative Current) technology and involved of the power electronic devices. Saving of 15% up to 35% energy consumption are expected from this method. Based on 15% saving, the payback period of 3.7years and ROI of 37.04% per year. For lighting load, the use of energy saving unit with similar expected saving(15%), give payback period of 9.4years and ROI of 10.6% per year. The shorten payback period will covered the burden of the longer payback period, for the combination of the both energy saving equipment installed, the overall payback period will shorten to 4.4years and ROI of 22.73% per year.

Third option of energy saving opportunity is via proposed installation of occupancy sensor for the lighting load and ACSU load as per described in paragraph 3.4.3. Expected saving are 30% of the daily operating hours. For the ACSU, there are 28 pieces of ultrasonic occupancy sensors required which cost about RM16240. The payback period for the ACSU is 2.3years and ROI of 43.48% per year. For the lighting load, 13 pieces infrared occupancy sensor required and cost about RM4290. The payback period for the lighting application is 4.4years and ROI of 22.73% per year.

Finally, the fourth option is through out proposed new design scheme, in order to optimize the energy consumption. The load, which are not in used is clearly determined and standardize the type of lighting and ACSU fixtures in the similar application and circumstances.

For ACSU load, changed the capacity of ACSU in the fabrication laboratory from 3.7kW to 3.0kW due to the occupied area is reduced by partitioning of two separate rooms. The payback period is 10.7years and ROI of 9.34% per year. In lighting application, at fabrication laboratory, 4 fixtures of 2x36W fluorescent removed due to not utilized since the two separate room ceiling block them. Also in Power Electronic laboratory, will proposed to change 6 fixtures of 3x36W to 6 fixtures of 2x36W for standardization of light fitting. By this proposed saving opportunity, the payback period for lighting application is 3.3years and ROI of 30.3% per year.

Overall payback period by combination of all energy saving opportunities is 2.9years for ACSU and 5.4years for lighting application. The return on investment (ROI) is then to be 34.48% for the ACSU and 18.52% for lighting.

5.0 CONCLUSIONS

The analysis and calculation of electrical energy conservation of the electrical laboratory building were carried out, even though the amount of electrical energy used was low (58.075kW), remarkable energy cost saving were demonstrated, for ACSU (46.2%) and lighting (41%) of the total energy cost per annum.

As mention earlier, the implementation cost are the most important factor and it is affected from the top management decision whether to allocate the budget for the study or not. Priority should be given to the methods which is do not contribute much cost to be implemented, then follows by the methods which give less payback period and high return on investment. Therefore, Option 1 must be implemented first and together follows by Option 2, 3 and Option 4. For Option 4, it is recommended to do with a proper manner and in order to have a sustainable electrical power system for the future consumption and also to increase the reliability of the system.

Some recommended practices guided by [3], [4], [5], [6] and [7] can be considered as an approaches strategy in typical building audit session, developed existing as-built drawing and justification of the investment worth for the various energy saving opportunities.

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REFERENCES

- [1] H. K. Wong, C. K. Lee, "Application of Energy Audit in Building and a Case Study", IEEE 2nd International Conference on Advances in Power System Control, Operation and Management, December 1993, Hong Kong, pp. 977-981.
- [2] Meckler, Milton, "Retrofitting of Commercial, Institutional, and Industrial Buildings for Energy Conservation", VNR-Van Nostrand Reinhold Publisher, 1983.
- [3] IEEE Bronze Book on Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities, IEEE, New York, USA, 1993.
- [4] Petrecca, Giovanni, "Industrial Energy Management : Principles and Applications", Kluwer Academic Publishers (KAP), 1993.
- [5] V. Raudel, "Energy Conservation Lighting Retrofit", Industry Application Society Annual Meeting, 1992, Conf. Record of the 1992 IEEE, 1992, Vol. 2, pp. 1887-1889.
- [6] Atif Z. Khan, "Electrical Energy Conservation and its Application to a Sheet Glass Industry", IEEE Trans. On Energy Conversion, Vol. 11, No. 3, pp. 666-671, September 1996.
- [7] JKR, Panduan Teknik Cawangan Elektrik, 3rd Edtition, 1991.

APPENDICES

- (i) Appendix 1 – As-built Drawing developed for existing system.
- (ii) Appendix 2 – Proposed drawing for new design scheme