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Load Inventory Survey of Curtin University Malaysia

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Abstract

As an important part of economical society, higher educational institutions and universities have been shouldering the responsibilities towards quality education, scientific research and social services throughout the world. However, they are found to be one of the major consumers of energy and the universities in Malaysia also have been identified as foremost energy consumers in the country. In order to follow energy conservation measures, a comprehensive energy audit becomes essential to determine how and where the energy is being consumed in a facility. In this study, the load inventory technique is adapted comprehensively to determine the different load categories in the university campus in terms of their connected demand, actual demand and total consumption. Based on the load inventory, an analysis has been carried out to identify the diversity and load factors and suggestions are given to improve them.

Keywords: Educational Institutions, Energy Consumption, Load Inventory Survey

1. Introduction

Today, energy and environment are two areas that have sought the greatest attention at the international level. The global energy consumption will grow by 56% between 2010 and 2040, from 524 quadrillion Btu to 820 quadrillion Btu[1]. The industrial sector endures to account for the major share of energy consumption and is probable to devour more than 50% of global delivered energy in 2040. Based on current policies and regulations governing fossil fuel use, global energy-related carbon dioxide emissions are expected to rise to 45 billion metric tons in 2040, a 46% increase from 2010[2,3]. Economic growth in developing nations fueled by a continued reliance on fossil fuels, accounts for most of the emissions increases[4-7]. So as to tackle the issue of emission impact due to consumption of energy, one can either look at the supply side or the demand side. The supply side necessitates implementation on macroscopic level where entirely new energy systems such as the renewable energy sources are introduced into the grid[8,9]. However, this is not always a precise doable option due to the cost of implementation. On the demand or consumer side, the issue can be undertaken with comparative ease through microscopic perspective and inspection, which requires a comprehensive study of consumer facility[10,11]. Hence energy conservation in every sector worldwide is one of the most lucrative mechanisms for reducing energy imports, the trade deficit and energy related environmental impacts[12-15].

As an important part of economical society, higher educational institutions and universities have been shouldering the important mission of education, science research and social services throughout the world. However they are found to be one of the major consumers of energy[16-21] and the universities in Malaysia also have been identified as foremost energy consumers[21-25] in the developing country due to the following reasons:

- Higher extent of land area
- Larger campus buildings
- Cluster of old and new buildings limiting energy conservation opportunities
- Building orientation and shape factors
- Low building densities within the campus
- Energy intensive equipments and their scattered usage

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- Large number of students and staff in a campus
- Reduced operational periods during vacations
- Lack of financial incentives and resources
- Student and staff behavior to energy consumption
- Manual operation of lightings and air-conditioners
- Very limited renewable energy resources, and
- Less importance to non-academic affairs

Promoting energy conservation is one of the current methodologies to scheming and controlling universities' utilities expenses in Malaysia. The Ministry of Education Malaysia has urged all educational centers to conserve energy and eradicate the lack of awareness among building users.

2. Energy Audit

An energy audit is a process of obtaining data and understanding the patterns and flow of energy in a particular system. At the center of energy audit are data collection, site observation and analysis. There are many methods and tools available for performing/conducting energy audit. Based on the complexity and size of the facility and availability of equipment, the process of conducting energy audit differs. In other words, energy audit is a method of determining where the energy is being used and how it is being used[2, 6, 8, 10]. The analysis of the data collected from energy auditing forms the basis for finding potential energy management opportunities. The process of collecting data may include several methods such as load profiling, inventory surveys, tabulation of electricity bills, and comparative analysis. Each of these methods provides a different perspective at how the energy is being consumed and used in a facility.

Logging actual facility loads is an important part of energy auditing[26] as it provides real load data to compliment the estimates made through load inventories. These data provide more accurate information on peak and minimum load values, operational hours and consumption. Loads can be measured at the facility level, or for individual circuits. Data should be logged for a number of days and preferable for several weeks. Longer data logging sessions add confidence to the results of the load analysis in energy auditing. By tracking loads over multiple days or weeks, it is possible to distinguish between periods of facility operation and downtime, such as days, nights and weekends.

3. Curtin University - Load Inventory Survey

A significant consideration for evaluating an entities energy consumption and demand is to conduct load inventory and to find out potential energy management opportunities through the different categories of load. The Load Inventory and survey provides an estimation of where, how much and how fast each category of loads is consuming energy. The load inventory provides a basis for fiddling with different systems in order to arrive at the best optimized way of consuming energy over time. The load inventory greatly complements the load profiles as it answers how much demand each load category is associated with and thus further contributing in realizing opportunities for energy management. The load inventory for Curtin has been done as a team consisting of a senior faculty member from the Faculty of Electrical and Computer Engineering, a Final year Project student and a technical staff from the Campus services section in 2013.

3.1 Main Switch Board/Main Campus

Figure 1 shows the locations of the Main Switch Board with meters at the main campus of Curtin University, Sarawak, Malaysia.

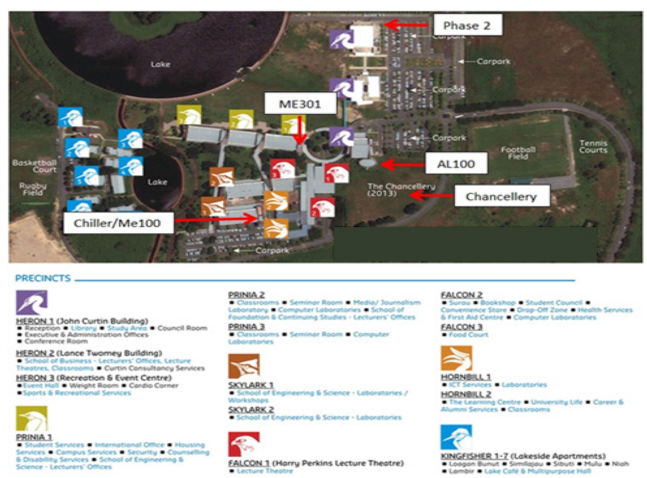

Figure 1. Main Switch Board.

The Phase 2 meter monitors Heron 3 and Heron 2. The AL100 meter monitors Heron 1 and Prinia 1-3. The Chancellery meter monitors only the chancellery building at the moment. The Chiller and ME100 meters are located in the same area. The chiller meter monitors the chiller units, whereas the ME301 meter monitors the consumption of Skylark 1-2, Hornbill 1-2 and Falcon 1-3. The meters are not smart meters; hence they do not have the ability to log on the data over time.

3.2 Connected Load

Curtin is comprised of four different load categories: HVAC (Heating, Ventilation and Air Condition), Lighting, Office Equipment/IT, Engineering Loads and miscellaneous loads[27].

3.2.1 HVAC

This is the largest load category at Curtin and warrants the most inspection for finding energy management opportunities. Curtin currently has three centrifugal chiller cooling units and each one demands 356.5 kW and the total maximum demand is 3 x 356.5 kW = 1069.5 kW. However, it is crucial to note that at any given time during standard operation; only one chiller cooling system is turned on. The second chiller cooling unit is very rarely turned on, while the third is never turned on. Therefore, at a given time, the maximum expected peak demand for chiller cooling system is about 365.5 kW.

There are a total of 27 Air Handling Units (AHUs) with different power ratings. The sum of their power demand is 245.5 kW. The Heron 2 and Heron 3 are cooled by a different system called water cooled package units. These units do not require separate AHU units for blowing cool air into the buildings. There are total of six water cooled package units, two large ones at Heron 3 and four relatively smaller ones at Heron 2. Their total power demand is calculated as 433.9 kW. The water cooled package units are rarely operated at full capacity. The large units located at Heron 3, are not operated during the standard operational hours of campus. Furthermore, only one out of two cooling water pumps each rated at 55 kW is operated during the standard operational time. Furthermore, the four smaller water cooled package units at Heron 2 are operated at 90% of full capacity. Therefore, the standard demand for water cooled package units located at Heron 2 is 215 kW.

Furthermore, most of the rooms at Curtin also have dedicated air condition systems ranging from 930 W to 5,600 W of power demand. There are three types of dedicated air condition systems: Wall mounted split, Ceiling Expose Split and Cassette Split air-condition. They are rarely operational, since most of the rooms are already supplied either through Centrifugal Chiller Units or Water Cooled Package Units. The total rated demand for the split air conditions in the campus is 364 kW. However, the split air condition units are rarely operated in the campus except for in Hornbill 1 and Hornbill 2, where cooling is neither provided by chiller, nor by water cooled package units. This brings the maximum standard operational demand for split air conditions to 79.5 kW.

The exhaust fans as well as the ventilation fans installed in the toilets all across the campus have a total demand of 26.46 kW. During night operations, the chillers and most of the air condition systems are turned off except for in the ICT labs, where the split air conditions are kept on over the night. All in all, the maximum connected load for all the HVAC, including the two (non-operating) chiller systems is 2,018 kW. However, during standard operation, the peak demand is 930 kW. This is assuming that the AHU, ventilation fans, and split air conditioners located at Hornbill 1 and Hornbill 2 are operating at 100% capacity, which is rarely the case.

3.2.2 Lighting

The lighting on campus consists of three different categories: fluorescent tube, Compact Fluorescent Lamp (CFL), and Metal Halide Lamp (MHL). Each 4 feet fluorescent tube is rated at 36 W and 3 feet variant is rated at 18 W. Fluorescent tubes are the prime installation among the interior of the building. They are also installed outdoors along the walkways. The total maximum demand for the fluorescent tube lights adds up to 166.12 kW. This includes both lights that are only turned on during night as well as that are operating during office hours. Therefore, in order to estimate the peak demand for fluorescent tube lights, the demand for the night operating tube lights must be subtracted. Thus the total peak demand under standard operating circumstances for fluorescent tube lights is 166.12 kW – 11 kW = 155 kW; where 11 kW entails the power demand for fluorescent tubes operating at night.

The CFL fixtures are mostly down lights, but can also be found in lamp posts across the lake side as well as behind Prinia 1-3. The CFL energy demand ranges from a 20 W to 65 W. The 20 W CFL bulbs are mostly found as the down lights of buildings' exterior. The 65 W

CFLs are located at LT foyer as well as on the lamp posts. Other than the down lights at Chancellery building and SOB, the CFL lamps are operated during night time. The maximum demand for the down lights adds up to 38.958 kW. This includes the sum of both CFL operating at night as well as day. Down lights and CFL bulbs are mostly operated at night; therefore, their operation during day can be neglected.

The MHL (Metal Halide Lamps) are the prime fixtures for street lights, parking lights as well as for the large down lights for the rec hall (Heron 3). They range from 100W to 200W and thus giving a total demand of 27.4 kW. They are only operated at night time; therefore, they are not taken into consideration for the peak demand during operating hours.

3.2.3 Office Equipment

The office equipment comprises of IT related appliances such as computers, printers, scanners, servers and photocopiers. The computers are operated continuously during the operating hours whereas the printers, scanners and photocopiers are mostly under ideal conditions. During peak hours; however, they are mostly operated. The total office equipment demand in our campus is calculated as 386 kW, with the peak demand estimated at 80% of the maximum connected demand = 300 kW. 80% is estimation based on the fact that 80% of the IT related appliances are located at Labs accessible by students. During peak hours, most of the labs are occupied by the students. It can be estimated that around 15-20 % of the office equipment at Curtin is kept on during night operations. This includes ICT labs and the servers.

3.2.4 Engineering Load

The engineering loads mostly comprise of mechanical and chemical engineering lab equipment such as furnaces, ovens, machines and motors. Their total demand is 120 kW, but they are rarely all operating at the same time especially during the peak hours. It is estimated that 30-35 % of the maximum demand of engineering loads is operated at a time. This gives an estimated peak demand of 42 kW.

3.2.5 Miscellaneous Load

Miscellaneous loads comprise of elevators and pantry appliances such as microwave, refrigerators and water heaters. The total demand for miscellaneous loads is 95 kW; however, other than the refrigerator, the rest of the appliances are rarely operated at the same time. Thus it is estimated that 25% of the miscellaneous loads' maximum demand is reserved as peak demand. This totals to 23.75 kW. During night, the refrigerators and freezers across the campus stalls and shops are kept on.

All the connected load and category-wise maximum demand are consolidated and presented in Table 1.

Table 1. Connected load and maximum demand

Load Category	Connected Load, kW	Maximum Demand, kW
HVAC	2018	930
Lighting	232.478	155
Office equipment	386	300
Engineering	120	42
Miscellaneous	95	23.75
Total	**2,851.478**	**1450.75**

4. Load Inventory Analysis

It can be clearly seen from section 3 that the largest load category in Curtin Sarawak is the HVAC. There are three ways that the data from load inventory can be charted. Figure 2 highlights the connected load of all the connected electrical appliances. In other words, if all the devices on Curtin campus were to be on at a particular instance, then their demand profile would resemble as the one suggested in the figure. This means that the peak demand would be the total connected load of the Curtin campus that is 2,851.478 kW (sum of all the load categories, kW).

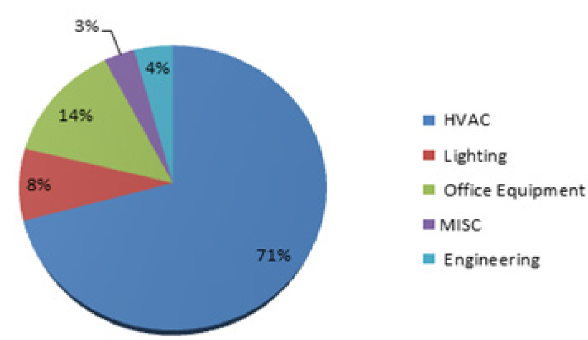

Figure 2. Connected Load, kW.

Figure 3 shows the actual load breakdown depending on the percentage of use per category at a given time. In this chart, the standard operation conditions have been taken into consideration. Meaning, the two standby chillers, the normally nonoperational split air-conditions, and other appliances have been disregarded. Both connected load and actual demand charts suggest that HVAC is the largest load category and warrants for greater inspection for finding energy management opportunity. The lighting and office equipment are also significantly form energy consuming categories. The total peak demand estimated through load inventory is 1450.75 kW.

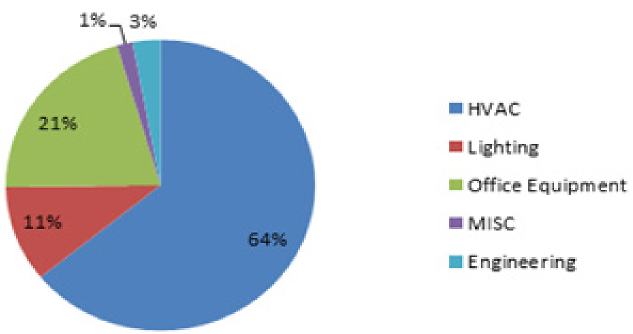

Figure 3. Actual Demand, kW.

4.1 Diversity Factor

An important calculation known as diversity factor can be made through the connected load (maximum demand) and the individual load categories maximum demand. Diversity factor is defined as the ratio between the peak demands of different components of the system and the total peak demand of the system.

$$Diversity\ Factor = \frac{Sum\ of\ Indivdual\ Component\ Maximum\ Demand}{Maximum\ Demand}$$

The diversity factor for different load categories at Curtin Sarawak is shown in Table 2. The diversity factor helps in prioritizing areas where potential energy management opportunities can be found.

Table 2. Diversity factor

Load Category	Diversity factor (%)
HVAC	64.10
Lighting	10.68
Office equipment	20.68
Engineering	2.90
Miscellaneous	1.64

4.2 Energy Consumption

Figure 4 shows the breakdown of how much energy each load category consumes on a normal weekday. For this, assumptions have been made such that office equipment are used at 60% of their maximum demand from 8:00 a.m. to 10:00 a.m., 80% of their maximum from 10:00 a.m. to 5:00 p.m. and then finally 20% of their maximum demand for the rest of the day. This gives office equipment's estimated energy consumption as 3500 kWh per day. It has also been assumed that most AHUs turned off by the end of office hours. However, there are 5-6 AHUs still on until 8:00 p.m. to accommodate the scheduled lectures. Therefore, the estimated energy consumption is 2,209.5 kWh from 8:00 a.m. to 5:00 p.m. and 163 kWh from 5:00 p.m. to 8:00 p.m. for the AHU and chillers. The total HVAC energy consumption is estimated to be around 6440 kWh per day.

For lighting, the total energy consumption during day and night has been arrived at 2921.5 kWh for a 24-hour period. The engineering load is operational during the standard operating time of the campus and miscellaneous loads are operated during day as well as night. Their consumptions are found to be 378 kWh and 224.5 kWh respectively. Hence, the total energy consumption estimated through the Load Inventory analysis is 13,465 kWh per day with a peak demand of 1450 kW.

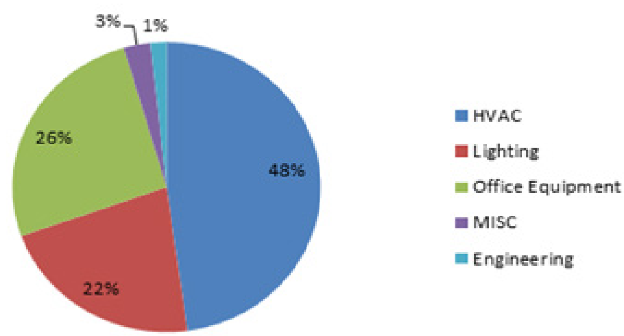

Figure 4. Energy Consumption.

4.3 Load Factor

Electrical Load Factor (LF) is the energy consumed by an electrical system relative to the energy that could have been consumed in kWh, if the maximum kW demand was maintained throughout a particular period[10].

$$\text{Load Factor (\%)} = \frac{\text{kWh Used in a given period}}{\text{Peak kW demand x 24 hrs x No. of days in time Period}} \text{x } 100$$

A short peak demand in a given time period compared to the rest of the demand in that period will result in a lower LF. A consistent consumption pattern, where the peak demand is maintained at fairly close rate in relation to the rest of the demand in the given period would raise the LF. Load Factor has a great concern in Demand Based Tariffs. An entity with low LF will have a higher billing cost per kWh in comparison to the entity with higher

LF. A lower LF also suggests a lower cost/kWh. Table 3 provides the load factors of Curtin at various periods in 2012 and 2013.

Table 3. Load factors

Date	Load Factor (%)
1/10/12	41
2/11/12	33
3/04/13	39
2/05/13	36
31/05/13	39
1/07/13	35
3/09/13	36.7

4.4 Recommendations to Improve Load Factor

In a plant or a factory, the load factor can be improved in two ways either by reducing the peak demand or by increasing the production of goods. In case of an educational institution like Curtin Sarawak, the same principal can also be applied.

Curtin Sarawak can improve its load factor, either by cutting down the peak demand or by spreading its load over a longer period of time. This could be best achieved by scheduling the classes so that classes are being conducted at a given time other than the peak demand periods. Since the peak demands are recorded from 10 a.m. to 12:00 noon, cutting down of some of the load at this time would greatly improve the load factor of the campus. Putting regulation on the amount of classes conducted from 10 a.m. to 12:00 noon is one of the best solutions to this problem so that lighting load and IT equipment load can be reduced. Scheduling and limiting the amount of classes conducted during the peak times would not only lower the peak demand, but would also distribute the load over a longer period of time, thus greatly improving the load factor.

5. Conclusion

The load inventory of the Curtin Malaysia campus has been studied with the help of the University Faculty, Final year project student and technical people associated with the Campus Services Department during the year 2013. Following the load inventory, analysis based on the connected load, maximum demand and energy consumptions were performed. The analysis reveals that the HVAC loads form the major share of the connected load, and it amounts to 70.77% and the office equipment shares 13.54%. For a tropical country like Malaysia, that too for the green campus of Curtin, these quantities are much higher compared to Universities in Middle East Countries. Next, the diversity factor of Curtin varies widely and it needs immediate attention. Also the load factor is on the average of 40% which is not an attractive value for energy saving. As Curtin opted for Demand Based Tariff, the load factor has to be improved in order to reduce the energy consumption and save the energy bills. To improve the load factor, load shifting has been proposed. As a whole, Curtin has tremendous potential for energy conservation and the future work will be on energy conservation opportunities for Curtin Malaysia.

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