

**INVESTIGATION AND CHARACTERIZATION
OF CAMPUS LOAD PATTERN**

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**A project report submitted in partial fulfilment of the
requirements for the award of Bachelor of Engineering
(Hons.) Electrical and Electronic Engineering**

**Faculty of Engineering and Science
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September 2016

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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I certify that this project report entitled **“INVESTIGATION AND CHARACTERIZATION OF CAMPUS LOAD PATTERN”** was prepared by **LIEW WEI JI** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical and Electronic Engineering at Universiti Tunku Abdul Rahman.

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Specially dedicated to
my beloved grandfather, grandmother, mother, father and brother.

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INVESTIGATION AND CHARACTERIZATION OF CAMPUS LOAD PATTERN

ABSTRACT

Energy auditing is an important method to study the pattern of the energy consumption of a building or facilities. Energy audit provides the detailed information on the load pattern to identify places where energy conservation measures can be implemented. The benefits of energy audit are to save energy, protect the environment by reducing emission of greenhouse gases and to reduce the energy cost. In this project, we are required to investigate the campus load pattern. Due to financial and time constraints, two floors are selected to study the pattern of energy consumption. Two types of energy audit are used for this project. First, walk-through audit involves field trip to targeted area in order to determine the number of electrical appliances and observe its operating time and operating condition. Next, general audit involves a more detailed analysis of the energy consumption by installing data acquisition device for measurement and data collection. In this event, power analyser and energy logger are the measuring devices used for data collection. In this project, the energy consumption data for 2nd and 6th floor are recorded for three to four weeks respectively. After that, Microsoft Excel is used to organise the data collected from both power analyser and energy logger. In order to analyse the load characteristics, the correlation co-efficient is calculated to find the linear relationship between data. Apart from these, a histogram is produced in order to present the frequency of occurrence of classes of power with a step size of 5kWh. After obtaining the frequency, load duration curve is produced and many information can be extracted out of it. The loads that are measured in this project is lighting and switch socket outlet, therefore the relationship between power consumed by both

units is found out. The measuring units are tapped to a single electrical riser which are connected to a limited amount of electrical appliances. Thus, the energy consumption by all the electrical appliances present in that floor is determined through simple calculation. Lastly, suitable energy conservation method is suggested according to the load profile analysed.

TABLE OF CONTENTS

DECLARATION	ii
APPROVAL FOR SUBMISSION	iii
ACKNOWLEDGEMENTS	vi
ABSTRACT	vii
TABLE OF CONTENTS	ix
LIST OF TABLES	xiii
LIST OF FIGURES	xv
LIST OF SYMBOLS / ABBREVIATIONS	xviii
LIST OF APPENDICES	xix

CHAPTER

1	INTRODUCTION	1
1.1	Background	1
1.2	Aims and Objectives	2
1.3	Milestones	2
2	LITERATURE REVIEW	4
2.1	Malaysian National Grid	4
2.2	Energy Auditing	5
2.2.1	Overview	5
2.2.2	Measurement Parameters	7
2.2.3	Current Prospects of Energy Auditing	8
2.2.4	Data Acquisition System	9

	2.2.4.1	Current Measurement	9
	2.2.4.2	Voltage Measurement	11
	2.2.4.3	Power Analyser and Energy Logger	11
	2.2.4.4	Benefits and Drawbacks of Different Data Acquisition System	12
2.3		Demand Side Management (DSM)	13
	2.3.1	Types of DSM	13
	2.3.1.1	Energy Efficiency	14
	2.3.1.2	Energy Conservation	14
	2.3.1.3	Demand Response	14
	2.3.2	DSM approaches	15
	2.3.2.1	Energy Reduction	15
	2.3.2.2	Load Management	15
	2.3.3	Challenges of DSM	15
3		METHODOLOGY	17
	3.1	Building Overview	17
	3.1.1	Brief Description of UTAR Electrical System	18
	3.2	Energy Auditing	20
	3.2.1	Preliminary Audit	20
	3.2.2	Load Characterisation	21
	3.3	Hardware Implementation: Data Acquisition System	22
	3.3.1	Power Analyser	22
	3.3.2	Energy Logger	23
	3.3.3	Software Implementation for Data Analysis	25
4		RESULTS AND DISCUSSION	28
	4.1	Introduction	28
	4.2	Power Consumption Based on Timetable	29
	4.3	Weekdays Correlation Analysis	30
	4.3.1	Second Floor of UTAR KB Block	31
	4.3.1.1	Correlation Analysis on Mondays and Tuesdays	31

4.3.1.2	Correlation Analysis on Wednesdays, Thursdays and Fridays	34
4.3.1.3	Correlation Analysis on Weekdays	37
4.3.2	Sixth Floor of UTAR KB Block	39
4.3.2.1	Correlation Analysis on Monday and Tuesdays	39
4.3.2.2	Correlation Analysis on Wednesdays and Thursdays	42
4.3.2.3	Correlation Analysis on Fridays	44
4.3.2.4	Correlation Analysis on Weekdays	46
4.4	Load Duration Curve	47
4.4.1	Second Floor of UTAR KB Block	48
4.4.1.1	Load Duration Curve for Mondays	48
4.4.1.2	Load Duration Curve for Tuesdays	49
4.4.1.3	Load Duration Curve for Wednesdays	50
4.4.1.4	Load Duration Curve for Thursdays	51
4.4.1.5	Load Duration Curve of Fridays	53
4.4.1.6	Load Duration Curve for Whole Second Floor	54
4.4.2	Sixth Floor of UTAR KB Block	55
4.4.2.1	Load Duration Curve for Mondays	55
4.4.2.2	Load Duration Curve for Tuesdays	56
4.4.2.3	Load Duration Curve for Wednesdays	57
4.4.2.4	Load Duration Curve for Thursdays	58
4.4.2.5	Load Duration Curve for Fridays	59
4.4.2.6	Load Duration Curve for Whole Sixth Floor	60
4.5	Relationship between Lighting and Switch Socket Outlet (S.S.O)	61
4.6	Estimation of Energy Consumption	63
4.6.1	Second Floor of UTAR KB Block	64
4.6.2	Sixth Floor of UTAR KB Block	65
4.7	Energy Conservation Method	66

5	CONCLUSION	69
5.1	Conclusion	69
5.2	Recommendations	70
	REFERENCES	71
	APPENDICES	74

LIST OF TABLES

TABLE	TITLE	PAGE
Table 1.1:	Gantt Chart for FYP I	2
Table 1.2:	Gantt Chart for FYP II	3
Table 4.1:	Power Consumption on Mondays and Tuesdays for Second Floor	32
Table 4.2:	Correlation Coefficient of Mondays for Second Floor	33
Table 4.3:	Correlation Coefficient of Tuesdays for Second Floor	33
Table 4.4:	Power Consumption on Wednesdays, Thursdays and Friday for Second Floor	35
Table 4.5:	Correlation Coefficient of Wednesdays for Second Floor	35
Table 4.6:	Correlation Coefficient of Thursdays for Second Floor	36
Table 4.7:	Correlation Coefficient of Fridays for Second Floor	36
Table 4.8:	Daily Average Power Consumption for Second Floor	38
Table 4.9:	Correlation Coefficient for Second Floor	38
Table 4.10:	Power Consumption on Mondays and Tuesdays for Sixth Floor	40
Table 4.11:	Correlation Coefficient on Mondays for Sixth Floor	40
Table 4.12:	Correlation Coefficient on Tuesdays for Sixth Floor	41
Table 4.13:	Power Consumption on Wednesdays and Thursdays for Sixth Floor	42
Table 4.14:	Correlation Coefficient on Wednesdays for Sixth Floor	43

Table 4.15: Correlation Coefficient on Thursdays for Sixth Floor	43
Table 4.16: Power Consumption on Fridays for Sixth Floor	44
Table 4.17: Correlation Coefficient on Fridays for Sixth Floor	45
Table 4.18: Daily Average Power Consumption for Sixth Floor	46
Table 4.19: Correlation Coefficient for Sixth Floor	47
Table 4.20: Calculation for Power Consumption of Lighting of DB-N-2/1A	64
Table 4.21: Estimation of Total Power Consumed by Lighting for Second Floor	64
Table 4.22: Calculation for Power Consumption of Socket of DB-N-2/2A	64
Table 4.23: Estimation of Total Power Consumed by Socket for Second Floor	65
Table 4.24: Calculation for Power Consumption of Lighting of DB-N-6/1B	65
Table 4.25: Estimation of Total Power Consumed by Lighting for Sixth Floor	65
Table 4.26: Estimation of Total Power Consumed by Socket of DB-N-6/2C	66
Table 4.27: Estimation of Total Power Consumed by Socket for Sixth Floor	66

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1:	Equivalent Circuit of Resistive Component	10
Figure 2.2:	Equivalent Circuit of Magnetic Components	11
Figure 3.1:	Single-line diagram for Incoming 11 kV electrical system for Universiti Tunku Abdul Rahman KB Building	19
Figure 3.2:	Sub Section MSB-01 400 V Single Line Diagram	19
Figure 3.3:	Single Line Diagram for Air-Conditioner System	20
Figure 3.4:	TES-3600 Power Analyser	22
Figure 3.5:	Fluke 1730 Energy Logger	24
Figure 3.6:	Power Analyser Software Interface	25
Figure 3.7:	Fluke Analyser Interface	26
Figure 3.8:	Sorting of Data Using Excel	27
Figure 4.1:	Power Consumption Based on Timetable	30
Figure 4.2:	Average Hourly Power Consumption on Mondays	33
Figure 4.3:	Average Hourly Power Consumption on Tuesdays	34
Figure 4.4:	Average Hourly Power Consumption on Wednesdays	36
Figure 4.5:	Average Hourly Power Consumption on Thursdays	37
Figure 4.6:	Average Hourly Power Consumption on Fridays	37
Figure 4.7:	Average Hourly Power Consumption on Weekdays	39
Figure 4.8:	Average Hourly Power Consumption on Mondays	41

Figure 4.9: Average Hourly Power Consumption on Tuesdays	41
Figure 4.10: Average Hourly Power Consumption on Wednesdays	43
Figure 4.11: Average Hourly Power Consumption on Thursdays	44
Figure 4.12: Average Hourly Power Consumption on Fridays	45
Figure 4.13: Average Hourly Power Consumption on Weekdays	47
Figure 4.14: Frequency Distribution for Monday at Second Floor	48
Figure 4.15: Load Duration Curve for Monday at Second Floor	49
Figure 4.16: Frequency Distribution for Tuesday at Second Floor	49
Figure 4.17: Load Duration Curve for Tuesday at Second Floor	50
Figure 4.18: Frequency Distribution for Wednesday at Second Floor	51
Figure 4.19: Load Duration Curve for Wednesday at Second Floor	51
Figure 4.20: Frequency Distribution for Thursday at Second Floor	52
Figure 4.21: Load Duration Curve for Thursday at Second Floor	52
Figure 4.22: Frequency Distribution for Friday at Second Floor	53
Figure 4.23: Load Duration Curve for Friday at Second Floor	53
Figure 4.24: Frequency Distribution for Second Floor	54
Figure 4.25: Load Duration Curve for Second Floor	54
Figure 4.26: Frequency Distribution for Monday at Sixth Floor	55
Figure 4.27: Load Duration Curve for Monday at Sixth Floor	56
Figure 4.28: Frequency Distribution for Tuesday at Sixth Floor	56
Figure 4.29: Load Duration Curve for Tuesday at Sixth Floor	57
Figure 4.30: Frequency Distribution for Wednesday at Sixth Floor	57
Figure 4.31: Load Duration Curve for Wednesday at Sixth Floor	58
Figure 4.32: Frequency Distribution for Thursday at Sixth Floor	58
Figure 4.33: Load Duration Curve for Thursday at Sixth Floor	59

Figure 4.34: Frequency Distribution for Friday of Sixth Floor	59
Figure 4.35: Load Duration Curve for Friday of Sixth Floor	60
Figure 4.36: Frequency Distribution for Sixth Floor	61
Figure 4.37: Load Duration Curve for Sixth Floor	61
Figure 4.38: Relationship of Lighting and S.S.O on Second Floor	62
Figure 4.39: Relationship of Lighting and S.S.O on Sixth Floor	63

LIST OF SYMBOLS / ABBREVIATIONS

kWh	kilo-Watt per hour
UTAR	Universiti Tunku Abdul Rahman
DSM	Demand Side Management
TNB	Tenaga Nasional Berhad
LCD	Liquid Crystal Display
DC	Direct Current
AC	Alternating Current
LED	Light-emitting Diode
GSM	Global System for Mobile networks
GPRS	General Packet Radio Service
SMS	Short Messaging Service
MSB	Main Switch Board
ESS	Energy Saving System

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A:	Walk Through Audit on Ground Floor	74
APPENDIX B:	Walk Through Audit of First Floor	76
APPENDIX C:	Walk Through Audit on Second Floor	77
APPENDIX D:	Walk Through Audit on Third Floor	78
APPENDIX E:	Walk Through Audit on Fourth Floor	79
APPENDIX F:	Walk Through Audit on Fifth Floor	80
APPENDIX G:	Walk Through Audit on Sixth Floor	82
APPENDIX H:	Walk Through Audit on Seventh Floor	84
APPENDIX I:	Walk Through Audit on Eighth Floor	86
APPENDIX J:	Walk Through Audit on Ninth Floor	87
APPENDIX K:	Walk Through Audit on Tenth Floor	89
APPENDIX L:	Timetable for Second Floor	90

CHAPTER 1

INTRODUCTION

1.1 Background

High rise commercial building consumes the most energy as compared to other buildings such as industrial or residential. This is because this type of building generally has the highest energy usage intensity (energy consumption per square foot) (Ian Shapiro, 2009). Hazran, Najmi and Suhairil (2012) found that the building used for educational purpose has higher energy consumption among the types of commercial buildings. By some estimates, the energy usage contributes to 65 percent of the total electrical demand of commercial buildings. Universiti Tunku Abdul Rahman (UTAR) is one of the private universities in Malaysia to have the highest number of students. Consequently, the energy usage of UTAR is very high to meet the needs of all students and staffs. This leads to a high annual electricity bill for UTAR. So, several ways or methods of minimizing the energy usage can be introduced to help reducing the electricity bill for UTAR.

Many methods of proper energy management had surfaced in the market and had already been used by corporations all over the globe. Before implementing the solution, a proper load pattern analysis on the building has to be conducted first. Energy auditing is the most used and best approach in analysing the load consumption of a site. It can give an accurate and up-to-date knowledge of the energy consumption pattern of the building. Several universities in Malaysia had already done energy auditing on their building to periodically analysed its energy utilization and systematically reviewed ways to conserve energy. An example of

university conducting energy auditing on their building is University Teknologi MARA (UiTM). The energy auditing done showed the potential of saving 0.15 million kWh of energy for the university (Singh, Seera and Adha, 2012).

1.2 Aims and Objectives

The main aims of this final year project is to investigate and characterize the load pattern of UTAR KB block. By conducting energy auditing, a detail observation can be made from the load consumption of UTAR. This can provide the opportunity to implements techniques with the sole purpose of reducing the energy costs.

The objectives of this project comprised of the following:

- i. To identify and categorized types of loads in the site
- ii. To analyse the energy flows in a building
- iii. To identify potential energy conservation methods

1.3 Milestones

Table 1.1: Gantt Chart for FYP I

[illegible]

CHAPTER 2

LITERATURE REVIEW

2.1 Malaysian National Grid

As of 2015, Malaysia is estimated to have 13 gigawatts (GW) of electric generation capacity. 84% of it is generated through thermal while the remaining 16% is produced by hydroelectric. According to U.S. Energy Information Administration (EIA, 2014), as of 2012, petroleum and natural gas occupies 70% of total energy consumption in Malaysia. Every electricity generation technologies will emit greenhouse gases to the atmosphere. These harmful gases will bring dangerous consequences to the world climate and living things inhabiting the Earth. Electricity generation, transportation, industrial and residential are the four sectors that contributes to the emission of these gases in Malaysia. Since the electricity generation in Malaysia is mainly using fossil fuels, therefore electricity sector emits the highest amount of greenhouse gases and contributes about 43.40% of the total emissions (Department of Chemical Engineering, Universiti Teknologi Malaysia, 2010). Malaysia Government are currently introducing several measures to reduce the emission of carbon dioxide by electrical sectors.

Currently, there are three main utility providers in Malaysia. Tenaga Nasional Berhad (TNB) is the main electrical provider that operates in Peninsular Malaysia while Sarawak Energy Berhad (SEB) and Sabah Electricity Sendirian Berhad (SESB) supply electricity to Sarawak and Sabah respectively. In Peninsular Malaysia, all the substations are linked together by 11,000km of transmission line operating at different levels of voltage. According to Tenaga Nasional Berhad (TNB, 2011), there

are 19,000 circuit-kilometers of overhead transmission lines and 780 km of underground transmission cables. In 2015, there are estimated 420 substations still actively operating with transmission capacity of 83,000 MVA in Peninsular Malaysia. The backbone of the transmission system in Malaysia is a 500 kV transmission lines covering length of 522 km. The 500 kV will then energised transmission line of 73 km at 275 kV. On the other hand, medium transmission system is operating at 132 kV which used for distribution to urban and rural areas whereas the low transmission system is operated at 33 kV and is connected to residential area. At distribution level, electrical voltage will be stepped down by transformers and distributed at 33 kV, 22 kV, 11 kV, 6.6 kV and 400/230 V based on the residential areas. The transmission system in Malaysia is also connected to transmission system in neighbouring countries. The cross-border interconnection includes 300 kV HVDC or 132 kV HVAC connection with Thailand and 275 kV HVAC link with Singapore.

2.2 Energy Auditing

2.2.1 Overview

According to the Environmental Protection Agency (EPA, 2003), energy audit is defined as the investigation of the energy usage and the cost of each form of energy of a building, process, manufacturing unit, equipment or an area within a given period. There is also another definition of energy auditing by Sachin, 2012 which states that energy auditing is a systematic procedure that obtains an adequate knowledge of existing energy consumption profile of the site. The purpose of energy auditing is to determine the energy usage among various equipment and to identify chances for energy conservation. In addition, an energy management program can be developed along the energy auditing program. Jayamaha (2007) found that energy auditing is proven to be a useful method to provide a better understanding in the energy usage pattern of a buildings and facility so that areas with potential of energy saving can be identified. Energy auditing gives many benefits in many areas from financial to environmental (EPA, 2003). Energy auditing provides opportunities to buildings to carry out energy conservation measure. Energy conservation promotes

reduction of energy consumption through using less resources. By having a proper load management, a lot of resources and energy can be conserved and put to greater use in the future. The technique for energy conservation can be as simple as switch off electrical appliances when not in use or increasing the temperature of air conditioner.

There are several methods to implement energy auditing as suggested by American Society of Heating, Refrigerating and Air-Conditioner Engineers (ASHRAE) as follows:

- a) Walk through audit
- b) Energy survey
- c) Investment Grade Audit

Walk through audit can be the simplest form of audit where site inspections are involves in understanding and analysing the equipment and devices available in the building. Additional bill assessment can be done as well as the preliminary analysis for energy auditing. During this stage of audit, activities including collection, classification, presentation and analysis of data is carried out. Walk-through audit only involves areas with major problem and during this audit, the auditor is only interested on the energy input and areas with high energy wastages (Nilesh & Rahul, n.d.). Besides that, during this stage, a brief meeting with the operators is done to know more about the energy consumed by respective department or area within the surveying site. The time span of this stage is very short and generally only lasts for three days to one week, therefore the cost involved is minimal. Furthermore, walk-through audit can bring benefits such as fast estimation on the cost of implementation, giving direction on potential operating cost savings and simple payback periods are provided. Despite these advantages, walk-through audit is not the best approach in energy auditing. This is because the time involved is too short which does not provide sufficient information for searching a final decision on implementing proposed measures (Malkait, 2012).

Energy survey and engineering analysis audits, also known as general energy audit is a no cost or low-cost measures to have a more detailed analysis on the load pattern of a building. It builds on the first audit by collecting more detailed

information about the operation of facility and by performing a more detailed evaluation of energy conservation measures. According to Shradha in 2013, in this stage, the auditor involved in energy survey will collect all the flow diagram, energy utility diagram and utility bill in order to observe the facility's demand rate and energy usage pattern. Subsequently, the auditor will conduct a survey around the facility and monitors the pattern of usage of the electrical appliances present in the building. In this event, various energy conservation methods can be proposed and followed by a financial analysis performed by each measures and lastly to identify the best project which can save the most energy with lowest cost possible. Since the time taken for this stage of audit is longer, therefore the cost for this auditing will be higher. In addition, the limitations of this method is that it only involves observing the usage pattern of electrical appliances and came out with an energy saving plan, ignoring the other factors such as temperature and weather that might causes variation in the energy.

Last level of auditing is known as detailed energy audit or investment grade audit. This audit will expands on the previous stage of audit and covers estimation of energy input for different processes, collection of past data on production levels and specific energy consumption (Malkait, 2012). The previous project that is chosen during the general audit stage will be reviewed constantly to observe whether the chosen plan is functioning. Unlike the previous two stages which only focus on observing the energy pattern of all the electric consuming units, detailed energy audit will take into account on scenario which can cause load profile variations on both annual and daily basis. In conclusion, it is used to create a detailed plan on the basis of quantitative and control evaluation and at the same time improving the detailed engineering for options to reduce the cost.

2.2.2 Measurement Parameters

Energy audit is a survey on the energy consumption by every equipment available in the facility. Various parameters needed to be measured so that identification and quantification of energy can be done. Electricity is the main energy source that are

used in a building since most of the loads present in the building consumes electrical energy. Therefore electrical parameters is the basic aspect for energy audit. The electrical parameters include voltage (V) and current (A) in DC and AC system, active power (kW), reactive power (kVA) and apparent power (kVA). With these parameters, energy consumption of various load can be determined and a load profile can be produced. The criteria for the measuring instruments includes portable, durable, easy to operate and inexpensive. These will make the taking of measurement to be simple.

2.2.3 Current Prospects of Energy Auditing

Currently, energy auditing is the most widely used method to study the energy usage pattern of a site or building. Many countries had adopted this program in order to find a way to conserve energy. For example, an energy survey was conducted at New Jersey State located in United States of America. According to survey conducted, many residents and business owners in New Jersey are seeking ways to save energy and reduce the cost. Therefore, New Jersey's Clean Energy Program had initiated a program called Local Government Energy Audit Program (LGEA) which encouraged the participation of local government, private agencies and residents to conduct an energy audit on a site and then implement a suitable energy conservation measures, in addition of subsidizing full cost of the audit.

India are currently facing a major shortage of electricity generation capacity. The demand of electricity in India is increasing around 6-8% annually but the generation of electricity is unable to catch up with the increasing demand (Sachin & Santosh, 2015). Therefore many parties in India are focusing on conserving energy rather than increase the generation of electricity. One company uses energy auditing to find appropriate energy conservation measure to help their company reduce the cost and save energy. Industry "Kohler Power India" Aurangabad performs a walk-through and general audit for their company which at last results in several method to save energy. Such methods include changing conventional lights to LED lights, controlling load factor and many more which help them saves up to an estimation of

(USD 1877.8) for one month. Besides that, an energy audit was done by automobile company and the pharmaceutical industry at Hyderabad, India by conducting all three levels of energy audit including walk-through audit on the site, energy survey and investment grade audit. Along the energy audit, the energy efficiency improvement measures for industry can be divided into two groups: energy efficiency improvements of energy sources in industry and energy efficiency improvements of industrial production process. An energy conservation method has been proposed to use a lower rated power lighting, more energy savings electrical motors and install a capacitor bank to maintain the power factor above 0.95 in order to get incentives from government. In our homeland, there are many parties had already started this energy audit program. For example, Curtin University had done a walk-through audit on their campuses. By doing so, they are able to determine the factors that affects the energy consumption within the campuses. Therefore, they are able to come up with a suitable energy conservation measure to help save energy for the University. The university can save up to approximately RM 80k annually by following this energy conservation measures (Fu E.Tang, n.d.).

2.2.4 Data Acquisition System

A detailed energy audit requires real data collection so that an in-depth energy study can be computed. Thus, measuring instruments are required to measure all the important parameters. The instruments had to be light weight, durable and easy to operate to enable easy collection of data.

2.2.4.1 Current Measurement

Current is an essential electrical parameter for energy study. There are three types of current measurement method as stated by Bryan Yarborough. The direct measurement involves using resistive component which is current sense resistor or transistor. The indirect approach is by using magnetic components which includes

current transformer, rogowski coil and hall effect device. Current transformer is one of the widely used instrument since it gives a lossless current measurement and cut-off from the line voltage. Resistive component such as the current sense resistors provide a direct method for measuring current which also provides the benefits of simplicity and linearity. Direct current sensing method is based on Ohm's law. By placing the current sense resistor in series with the load, voltage will be generated. The generated voltage which is proportional to the load current is then measured. On the other hand, the indirect approach for measuring current is based on Ampere's and Faraday's laws. When a coil was coil-around a current carrying conductor, the changing AC current will induce a voltage across the coil which is proportional to the current. The advantage of this method is that it can provides a lossless current measurement. Figure 2.1 shows the measurement of current using current sensing resistor. A shunt resistor is connected in series with the connected load, so a voltage proportional to the load current will be generated across the shunt resistor. This voltage is then measured by differential amplifiers and the current produced across the load can be determined through Ohm's Law. Figure 2.2 shows the measurement of current using transformer which is an indirect approach for measuring current. When an AC current is flowing through the primary winding, a changing magnetic field is provided to the secondary windings. Therefore, a voltage is induced at the secondary winding and the load current can be known. This method provides a lossless measurement because current passing through the copper wire is considered lossless.

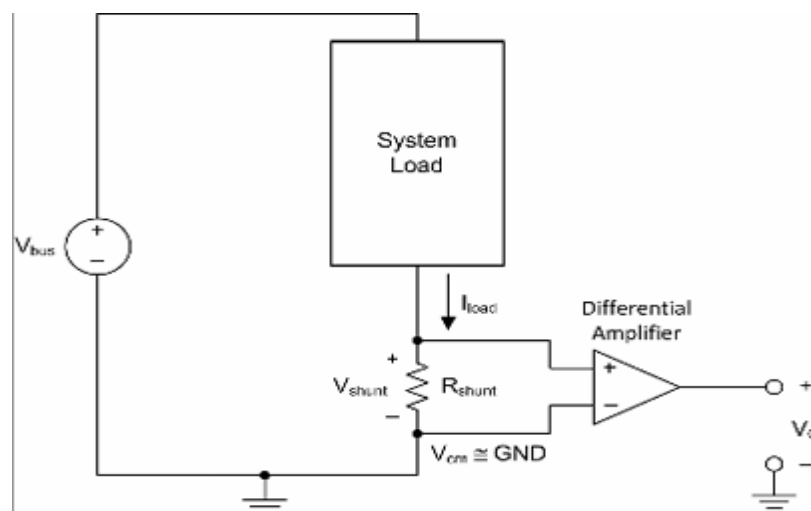


Figure 2.1: Equivalent Circuit of Resistive Component

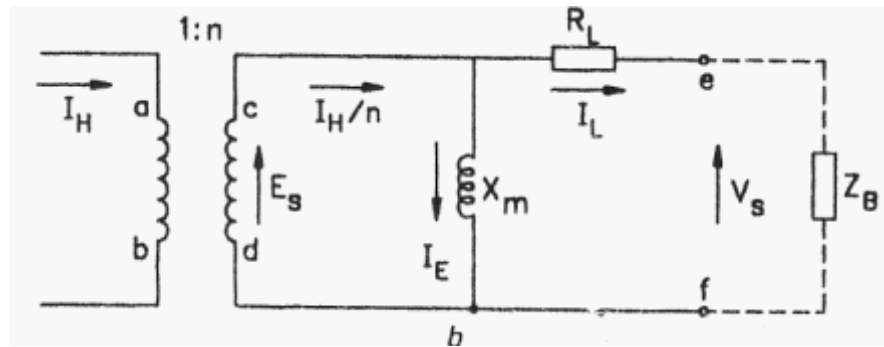


Figure 2.2: Equivalent Circuit of Magnetic Components

2.2.4.2 Voltage Measurement

Voltage is another essential parameter to determine the power consumption of equipment. National Instruments (NS, 2014) states that voltage measurement only have two methods. First is the ground referenced voltage measurement and the other is the differential voltage measurement which means electrical potential difference between two points is measured. Ground referenced voltage measurement is the method where voltage is measured with respect to a common point or “ground”. Normally, the ground point is kept 0 V by connecting the signal directly to the earth. This type of method is good for input signal with high-level. On the other hand, differential voltage is a method where the voltage is found by measuring the difference in voltage between two separate points in a circuit. This method is used mainly for circuit with low input signal. Voltmeter and voltage transformer are the good instruments for measuring voltage.

2.2.4.3 Power Analyser and Energy Logger

Power analyser is a very important measuring tools for energy study. It provides many features to measure different electrical parameters which are crucial

ingredients for studying energy. It can use to measure basic electrical parameters such as AC and DC voltage or current. Other than that, power analyser has the functions to measure power in W, kWh or to analyse and measure harmonics.

Energy logger is a powerful measuring instrument which can measure a wide range of parameters. It provides a new simplicity to discovering sources of electrical energy waste and it is extremely useful for load profiling. Energy logger can measure all the key parameters such as current, AC-DC voltage, power factor, power and other associated values that can enable energy saving strategies to be implemented. There is another unit in the market that can measure power which is the smart meter. Smart meter is a more advanced measuring instrument because it can performs many features that energy logger unable to do. Smart meter is using GSM/GPRS mobile phone network which means the user can collect the data via SMS. This is extremely useful for the user because he/she has the advantage of knowing first hand on the power consumption. With this, users can always take appropriate steps to save energy. Besides that, it can identify areas with leakage of energy by detecting unusual pattern on the energy consumed pattern. However, the data collected by the smart meter might not be as accurate as the energy logger. However, it can be connected together with the logger so that the data collected from the logger can be sent directly to the user via smart meter.

2.2.4.4 Benefits and Drawbacks of Different Data Acquisition System

Power analyser and energy logger had been widely used in energy study due to the benefits it brings. Both instruments can measure a wide variety of parameters ranging from current to power factor. This proves to be useful because single instrument can measure all the data needed by the auditor. Besides that, both of the instruments are designed to be portable enabling the user to carry everywhere. Furthermore, they are easy to use which the user can master all the functions in a short period.

Although power analyser and energy logger brings many benefits, there are some disadvantages too. Both equipment are very expensive with the price normally

over thousands. The memory of power analyser are quite low which limits the period to collect the data. This makes collection of large quantities of data over a long period not practical with single power analyser. Besides that, the data collected can only be view in certain software specially developed to work in collaboration with the power analyser or the logger. Thus, the user had to spend extra time to learn the software. In addition, most of the power analyser operates on battery, so the equipment has to be constantly charged. Energy logger is developed to solve this problem. The logger can be directly power from the measured circuit eliminating the need to find a power outlet or constantly charging the equipment.

2.3 Demand Side Management (DSM)

Demand side management (DSM) is a program which purpose is to influence the consumer demand for energy through various methods (James David Zahniser, 2010). The methods includes providing financial incentives or behavioural change through education with the sole goal of encouraging consumer to modifies their way of consuming energy. The most common attempt is to alter the quantities and period of the consumer's demand, either by increasing or decreasing the demand. The aim of DSM is also to reduce the cost, provides improvement on the social and environmental issues and also reliability issues.

2.3.1 Types of DSM

There are three types of DSM which are energy efficiency, demand response and energy conservation. The relevance between these three concepts is important to be found in order to improve the energy cycle (Boshell and Veloze, 2008).

2.3.1.1 Energy Efficiency

Energy efficiency refers to step taken to reduce the power used to perform same task. This usually involves technological measures to provide the solution. Technologies tend to be long-lasting, therefore the energy can be saved all times resulting in permanent reduction of demand. Several approaches can be taken such as using more energy-efficient appliances such as compact fluorescent bulbs and refrigerators or doing regular maintenance on the electrical equipment.

2.3.1.2 Energy Conservation

Energy conservation promotes behavioural changes to decrease the demand of energy. It is usually associated with sacrificing one's comfort or productivity. It will induce a change to the behaviour of consumer in order to have an energy-saving lifestyle. Some example of energy conservation measures are increasing the temperature of air conditioner, switching off light when not in use or using daylight as much as possible to reduce the period of using the light.

2.3.1.3 Demand Response

Demand response refers to preventative methods to reduce, flatten or shift demand. Actions will usually be taken at the consumer's side in response to particular conditions within the electricity system. For example, consumer will shift their activity period to a non-peak hour to avoid the extra penalty imposed by supplier of electricity.

2.3.2 DSM approaches

2.3.2.1 Energy Reduction

Energy reduction involves reducing the energy demand through more efficient processes. A series of 'energy saving tips' will be presented to the consumer as part of load reduction measures. The methods available here often involve no-cost or low-cost while a handful of steps require large amount of capital investment. One example of energy reduction measure is by using more efficient lighting. Furthermore, additional switches can be installed in large areas to enable the switching off of light in selected area where is not necessary to illuminate a long period.

2.3.2.2 Load Management

Load management is one of the method in energy conservation measures. It involves the changing of energy usage pattern to encourage less demand at peak period. By having a proper load management, consumer can shift the demand to non-peak period and thus reducing electricity cost. Several load management techniques involve the load levelling, load control and tariff incentives.

2.3.3 Challenges of DSM

Although DSM is a great approach to save energy and reduce the cost, however the implementation of DSM is very slow due to the challenges associated with it. DSM concept had exist since long time ago, however the programmes in DSM is not known to many people in developing countries. The lack of information on the DSM and its benefits leads to consumer have zero confidence on the programmes. Besides that, DSM based approach will increases the complexity of the system when compared with traditional approach. Furthermore, there had been some argument

made by people where DSM is ineffective because it resulted in higher utility costs for consumers and less profit for utilities (James David Zanihser, 2010). Last but not least, some consumer does not want to implement the concept of DSM due to privacy issue. Consumers have to provide information regarding their electricity usage pattern to the suppliers.

CHAPTER 3

METHODOLOGY

3.1 Building Overview

Universiti Tunku Abdul Rahman (UTAR) has a campus located in Sungai Long. The campus has two buildings namely KA and KB building but this project only targets the KB block building. The building has a total of 12 floors including two basement carpark. The building itself consists of offices, lecture rooms, lecture halls, library and various labs. The energy consumption of each floor is different since the amount of electrical appliances and the time of usage is different from each other. Normally, the floor which consists of labs has a higher energy usage due to the high power consumption of lab equipment. The energy consumption of KB building mostly comes from lighting and air-conditioner as both items is running for long period of time. The lights used in this building consist of two types: fluorescent lamp and downlight. Two chillers located at the basement of this building is used to lower the temperature for the whole building. On the other hand, there are two transformers which use to step down the voltage supply from TNB.

3.1.1 Brief Description of UTAR Electrical System

Universiti Tunku Abdul Rahman (UTAR), KB building consists of 10 storey building including one basement and sub-basement carpark. Figure 3.1 shows UTAR has taken in 11 kV electrical supply from Tenaga Nasional Berhad (TNB). The 11 kV incoming is step down via step-down transformer to 420 V for utilisation before being distributed to four main feeders namely MSB-01, MSB-02 and two chiller. The main switch board will distribute the electricity to the electrical load such as lighting, switch socket outlets, cassette type air-conditioner via distribution board at every floors. Figure 3.2 shows the main switch board-01 supply electricity to the lighting, switch socket outlets and ventilation system to second floor and sixth floor. Figure 3.3 shows the number of distribution boards that will supply electricity from main switch board to all the ventilation systems present in sixth floor. Due to financial and time constraints for this project, two data loggers are installed at two distribution board once at a time. For the lighting on second floor and sixth floor, we tapped to the unit DB-N-2/1A and DB-N-6/1B respectively. On the other hand, we installed an energy logger to the unit DB-N-2/2A on 2nd floor and unit SSB-N-ELS6/1 which is the only unit for 6th floor to measure the power consumption of switch socket outlet. However, for the air conditioner, we are unable to record any data from the unit CP-AC-L6-AHU-02. This is because the chiller will directly delivered the power to all the ventilation system and we had to tapped the energy logger to the chiller to measure the power consumed however measuring the chiller power consumption required installation of the energy logger on the chiller main switch board that is located in the main switch room. Entering the main switch room is not permissible as it required the companion of charginman and doing the installation is not permissible.

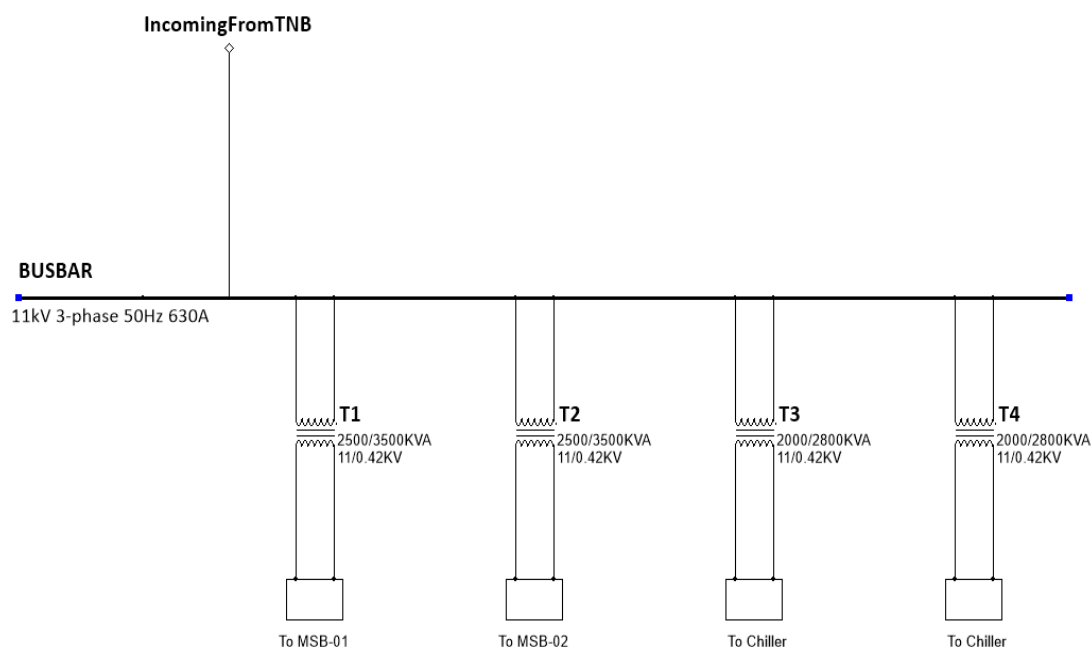


Figure 3.1: Single-line diagram for Incoming 11 kV electrical system for Universiti Tunku Abdul Rahman KB Building

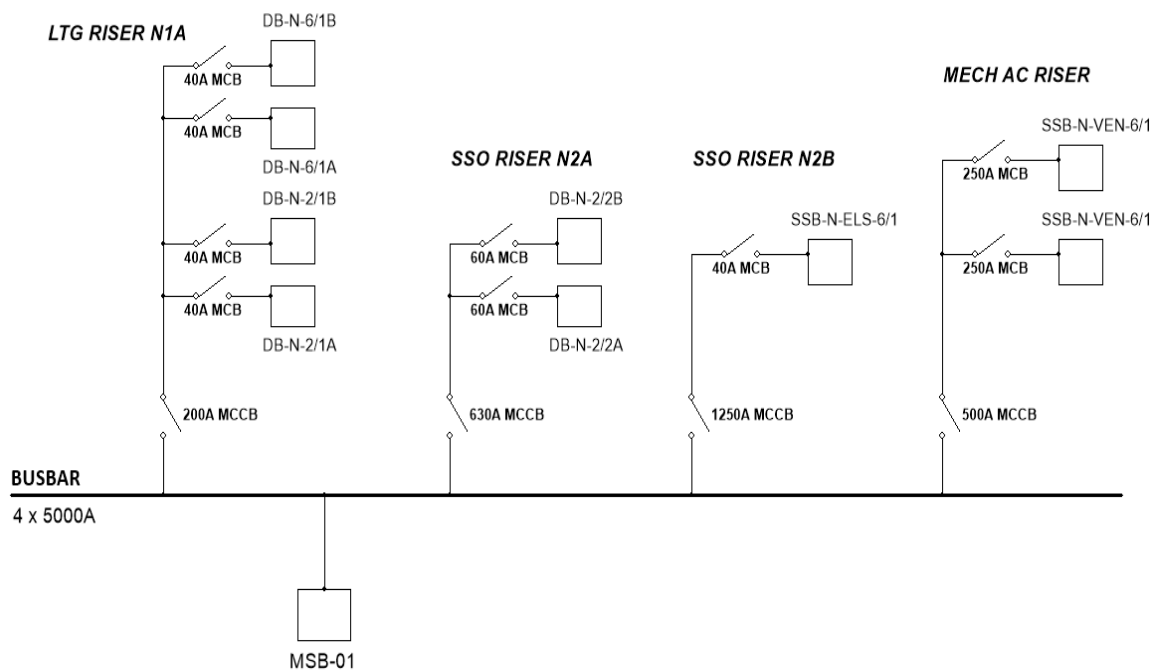


Figure 3.2: Sub Section MSB-01 400 V Single Line Diagram

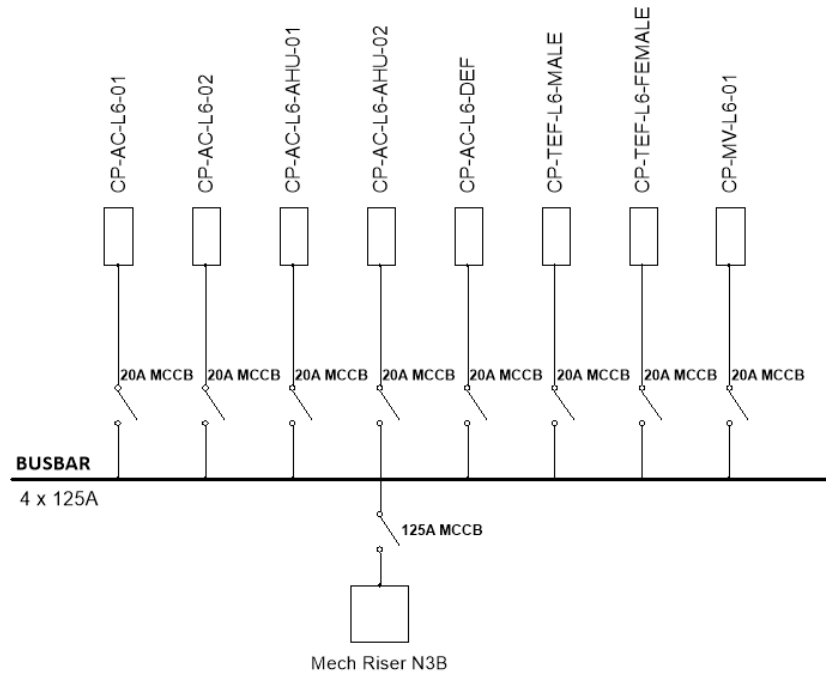


Figure 3.3: Single Line Diagram for Air-Conditioner System

3.2 Energy Auditing

The aim of this project is to investigate the load pattern of UTAR in order to implement an energy conservation measure to reduce the electricity cost. The challenges of this project is that each floor has a different energy consumption pattern and is different for each week in a month. Due to the time and financial constraints, only two floors in the building are selected to analyse its load pattern.

3.2.1 Preliminary Audit

Prior conducting the detailed audit, a walk through audit is conducted by calculating the number of electrical appliances located at each floor of the building. The purpose of this method is to estimate the energy usage of UTAR KB building. In order to investigate the load pattern of UTAR KB building, a walk through audit to all the areas in the building is done. The purpose of doing the walk-through audit is to

quantify the number of electrical appliances present in each floor. The floor plan of the building and the types of lab equipment is obtained from the management to aid in this project. The types of major electrical loads such as lighting, air-conditioner and computers is surveyed and counted thoroughly as these loads made up most of the total energy consumed by the building. All the operating time and operating condition of all the electrical appliances is observed to have a better understanding on the energy usage pattern. The specification of all the loads is taken to determine the power rating of the load which in turn can be used to estimate the power in kWh.

3.2.2 Load Characterisation

The loads in UTAR are separated into two types: regular load and burst load. Regular load refers to load where it is operating in a long period. The time of operation is almost constant each day, thus it produces a constant energy consumption pattern. This type of load includes lighting, air-conditioner and computers. On the other hand, burst load is the load where it only operates within the time desired by the user. Computers in computer lab and lab equipment are examples of this load. Since the period where the burst load is operating is not constant, the power consumption of each load is hard to predict. The only way to estimate the energy used is to conduct a survey or observation in order to approximate the operating time in a week. The operating hours of the regular load is tabulated as shown in Table 3.1.

Table 3.1: Average Operating Hours of Electrical Appliances

AVERAGE OPERATING HOURS OF ELECTRICAL APPLIANCES		
APPLIANCE	OPERATING HOURS	AREA
Lights	24	Lift lobby, toilet, hallway
	15	Architecture Studios
	8.5	Labs, offices
A/C Unit	18	Lift lobby, hallway
	8.5	Labs, offices
Computer	7.5	Offices

3.3 Hardware Implementation: Data Acquisition System

A general audit requires real data collection in order to have a detailed information on the energy consumption of a site and perform a better evaluation of energy conservation measures. For this project, power analyser and energy logger are used to measure the load profile.

3.3.1 Power Analyser

The model of power analyser that are used for this project is TES-3600 3P4W power analyser as shown in Figure 3.4. It has an easy-to-view LCD screen and shows power quality parameters such as real power, reactive power, three phase voltages and currents at the same time. The power analyser come equipped with 4 current probe with one to measure neutral current and also 3 crocodile clips with the purpose of measuring voltage. The power analyser has a memory of 504 KB which can use to record a total of 10,000 sets of data.



Figure 3.4: TES-3600 Power Analyser

The power analyser does not have the feature of producing graphical data. In order to record graphical data, a software known as NI (National Instrument) LabVIEW has to be used in par with the power analyser. A laptop is required to connect with the power analyser when in use to enable collection of data. The data retrieved includes voltage, current, power and other important parameters. Since the memory of this power analyser is very small, therefore there is limitation on the amount of data collected. In order to solve this problem, another power analyser is used to collect the remaining sets of data if the first one has reached its maximum capacity.

There are four current probes, each of them has been labelled to show the phase and the fourth one is used to measure neutral current. The probe is clamped directly to the wire for current measurement. On the other hand, there are four crocodile clips with each having different colour to represent the different phase. The clips are directly attached to the busbars for voltage measurement. When connecting the power analyser to the busbars, a rubber gloves is worn to prevent electric shock.

Prior using the power analyser, the unit needs to be configured. These settings include date and time for the first set reading. Next, interval of time between each set of data is set to 1 minute which is the most ideal for this project. Then, the data logging can be started and the power analyser is left there to collect data for one week.

3.3.2 Energy Logger

The model of energy logger we are using for this project is Fluke 1730 as shown in Figure 3.5. This model offers a bright, colour touch screen which enables the user to use it easily. It contains an intelligent verification function to indicate a correct connection has been done. The Fluke 1730 comes with current clamps and test leads to enable measurement of parameters.



Figure 3.5: Fluke 1730 Energy Logger

Fluke 1730 energy logger is designed to have a feature which displays the data collected in graphical manners. Therefore, it does not require a special software to observe the data as all the data collected can be directly transferred to the computer from the energy logger using USB thumbdrives. The memory of this model is large enough to accommodate 20 logging sessions of 10 weeks with 10 minute interval. There are a range of averaging period and demand interval for the user to select. We decided to choose the averaging period of 30 seconds as this is the most suitable for our project.

Before connecting the energy logger to the busbars, a few settings had to be set up. A change configuration button is pressed to open up a menu for the settings. Energy study is selected for the type of study and the topology is chosen as 3 phase delta connection. After that, the energy logger is connected to the electrical box. Current clamp is clamped directly onto the wire. Since the energy logger does not come with crocodile clip, the clips are bought so that it can be connected to the live busbars. Then we choose verify connection button to let the energy logger check whether the connection is correct. If the connections are wrong, we can choose auto-correct button to correct the connections. Next, logger button is pressed to change

more settings. In here, we are required to choose the duration of logging and the averaging period. After all is done, data logging session can start. During the energy logging, we can still check the values of voltage and current. The energy logger is left there until the duration of logging ends before retrieving the data.

3.3.3 Software Implementation for Data Analysis

After collecting data from power analyser and energy logger, certain software needed to be installed in order to extract data out from both measuring instruments. This is then followed by using Microsoft Excel to sort the data, display the data in presentable form and lastly performing some analysis on the data obtained.

Power analyser is connected to the computer via a RS 232 to USB converter. After connecting the unit, a correct port has to be identified and selected before further progress. Next, the installed power analyser software is opened to collect the data. This software is a LabView based graphical user interface (GUI) that shows all the measured parameters and the mode it is in as shown in Figure 3.6. For our project, we choose the 3 phases and 4 wires mode since we are connecting the unit to a 3-phase system. After extracting the data from the analyser, we export the data collected and save it in .xls form which can be used later in Microsoft Excel for future analysis.

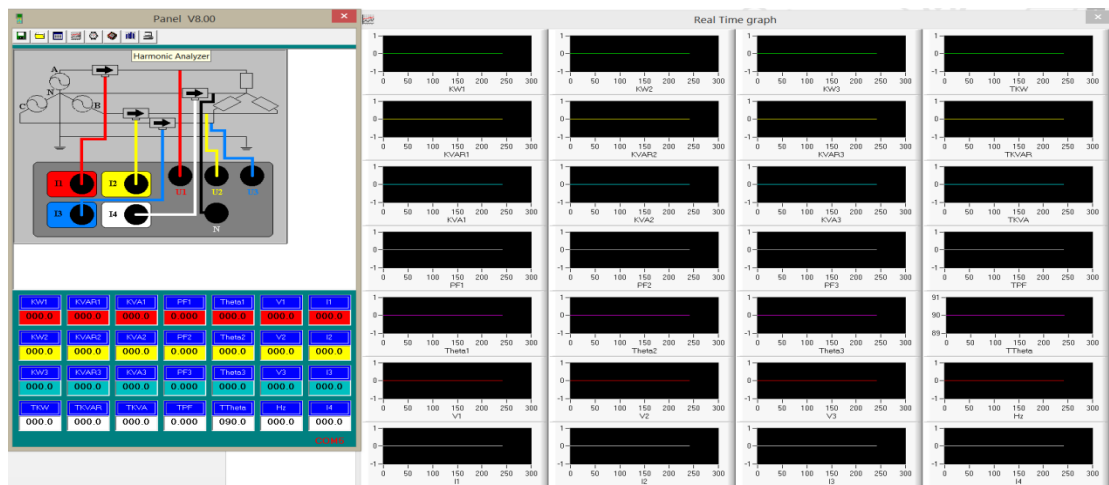


Figure 3.6: Power Analyser Software Interface

On the other hand, energy logger is an advanced measuring unit as compared to power analyser. It has a built-in USB port which enables the user to directly connect a thumbdrives into the unit to extract the data. Fluke company has their own software to collect and display the data collected. There are many parameters that are measured by the energy logger and since all the data are displayed in graphical form together, the graph looks messy. Therefore, the user has to choose the interested parameter to be display. The collected data also has to be export out which is used later in Microsoft Excel.



Figure 3.7: Fluke Analyser Interface

Microsoft Excel is the tool that we used for our data analysis in this project. This is because our analysis will produces many graph and Excel is the best tool to sort data and producing graph. For our project, the duration for measuring power is approximately 2 months which results in a large amount of data that makes the data analysis becomes difficult. Therefore, data sorting is required to organize the data into more presentable form and easier to access for analysis. The data are all arranged in rows and columns, filter function is also applied to organize the data more systematically as shown in Figure 3.8. The filter function also allows us to view the data on a particular date or enable the grouping of data into particular order. This enables us a faster finding on the data we required and also makes data analysis easier.

	A	B	C	D	E	F	G	H	I	J	K	L
1	No.s	Date	Time	KW1	KVAR1	KVA1	PF1	Theta1	V1	I1	KW2	KVAR2
2	1	8/8/2016	0:00:00	0.7	0.5	0.9	0.808	36.1	247.4		3.5	1.1
3	2	8/8/2016	0:02:00	0.5	0.7	0.9	0.577	54.8	247.6		3.5	1.1
4	3	8/8/2016	0:04:00	0.5	0.7	0.9	0.577	54.8	247.6		3.5	1.1
5	4	8/8/2016	0:06:00	0.5	0.7	0.9	0.577	54.7	247.4		3.5	1.1
6	5	8/8/2016	0:08:00	0.7	0.6	0.9	0.785	38.2	247.6		3.6	1.1
7	6	8/8/2016	0:10:00	0.5	0.7	0.9	0.577	54.8	247.8		3.5	1.1
8	7	8/8/2016	0:12:00	0.5	0.7	0.9	0.576	54.8	247.9		3.5	1.1
9	8	8/8/2016	0:14:00	0.5	0.7	0.9	0.576	54.8	248		3.5	1.1

Figure 3.8: Sorting of Data Using Excel

The interval chosen for the data collection by power analyser is 2 minutes whereas the interval for energy logger is 5 minutes. The difference in the interval leads to a difficult comparison between data of both units. Therefore, the data are averaged every hour to shrink down the amount of data required for analysis and enables an easier and more accurate comparison. Energy logger is programmed to average the data collected in several time which are 10 minutes, 15 minutes, 20 minutes, 30 minutes and 1 hour. Thus, we does not need to self average the data from the energy logger, we can just export the averaged data into Microsoft Excel. On the other hand, power analyser does not has this features, so we needs to use a formula to average the data in one hour.

$$= \text{AVERAGE}(\text{OFFSET}(\text{AA}\$, (\text{ROWS}(\text{AH}\$:\text{AH})-1)*30, 0, 30)) \quad (3.1)$$

Microsoft Excel has a built-in math functions and one of them is to calculate average of values and equation 3.1 is created based on the function available. The formula is modified to read the required data only and the calculated data is then inserted into the column of AH. The value at the back of the formula shows the number of data required to average. The interval for power analyser is 2 minutes, therefore a total of 30 data is required to take into consideration to find the average for 1 hour.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In doing load profiling, power consumption (kWh) is the essential component because the electricity charged by Tenaga Nasional Berhad is based on the power consumed during a month. By measuring power consumption, we can observe the trend of how energy is used and able to determine the maximum power. Therefore, energy logger and power analyser are installed to the electrical riser to collect the power consumed in UTAR KB block. However, due to time and budget constraint, both measuring instruments are tapped to second floor and sixth floor. Although air-conditioner consumes the most power as compared to lighting or switch socket outlet, however the measuring unit cannot be tapped to the electrical riser that supply electricity to the air conditioner. This is because the voltage and current are too high which poses a very dangerous risk to human and the department of facilities does not allow any unit to tap to the cables connected to air-conditioner. The interval for collecting data using power analyser is set as 2 minutes whereas for energy logger is 5 minutes. The duration for the collection of data is one week, however only weekday data are analysed because the power consumption on weekend is low as it is not a school day.

4.2 Power Consumption Based on Timetable

Figure 4.1 shows the estimated power consumption based on timetable for second floor. The timetable is obtained from the office to enable the estimation of power consumed. Since this project only involves second floor and sixth floor, therefore only the power consumption of both floors are estimated. However, only second floor is full of lecture halls and tutorial rooms whereas sixth floor is all occupied by labs and architecture room, thus only timetable of second floor is obtained. The power consumed by lighting is estimated on that floor because this floor is mainly lecture hall and tutorial room, so the switch socket outlet is seldom used. In addition to that, the load that connected to the switch socket outlet is difficult to predict because the range of the type of load is vast. In doing this estimation, an assumption is being made such that every light inside the lecture hall and tutorial is turned on for the whole period of the ongoing class. Besides that, since the corridor light of second floor is directly shone on the multipurpose area of the first floor, another assumption is made such that half of the corridor lights are turned on throughout the day since student of UTAR always stay back for extra-curricular activities that carried out at the multipurpose area. In order to estimate the power consumption used, the number of lightings present in the lecture hall or room and the power consumed by different types of lighting used are determined. From that the total power consumed in a period is calculated by using the formula below.

$$= \text{RATED POWER OF LIGHTING} * \text{NUMBER OF LIGHTINGS} \quad (4.1)$$

We observed from the figure 4.1 that the power consumed starts to increase starting from 8 a.m. until 7 p.m. This is the period where the all the classes in UTAR are carried out. All the power consumed for each weekdays share a similar trend. However, there is a fluctuation on the graph for Friday. This is because 12.30 p.m. till 2.30 p.m. is a praying time for Muslim, thus no classes are carried out during this period which results in a low power consumption. The highest estimated power consumed is 25.82 kW.

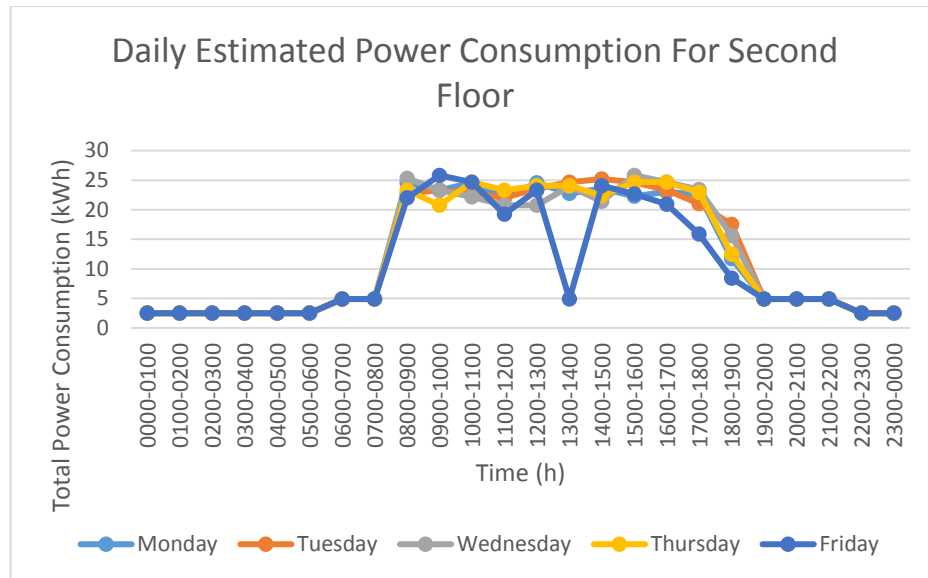


Figure 4.1: Power Consumption Based on Timetable

4.3 Weekdays Correlation Analysis

In doing load profiling, power consumption (kWh) is the essential component because the electricity charged by Tenaga Nasional Berhad is based on the power consumed during a month. By measuring power consumption, we can observe the trend of how energy is used and able to determine the maximum power. Therefore, energy logger and a power analyser are installed to the electrical riser to collect the power consumed in UTAR KB block. However, due to time and budget constraint, both measuring instruments are tapped to second floor and sixth floor only. Second floor mainly consists of lecture whereas sixth floor is occupied by laboratory and architecture studio, therefore these two floors were chosen to observe the difference in their energy consumption pattern.

The data are collected within the range of 3-4 weeks for second and sixth floor respectively, therefore a method is required to compare the data that are collected on the same weekday but in different week. This can enables us to observe how similar the load pattern are for every weekday over the period of one month. Correlation coefficient is determined because it can shows how strongly two

variables are related to each other. The correlation coefficient has a range of -1 to +1. The correlation coefficient is calculated using the formula below.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

(4.2)

where

r = correlation coefficient

n = number of pairs of scores

$\sum xy$ = sum of the products of paired scores

$\sum x$ = sum of x scores

$\sum y$ = sum of y scores

$\sum x^2$ = sum of squared x scores

$\sum y^2$ = sum of squared y scores

A positive value means the data are having positive linear relationship and a negative value means they are having negative linear relationship. For the analysis of data, correlation coefficient between each weekday is calculated using EXCEL. The floor we are measuring is 2nd floor and all the activities conducted there are lectures and tutorials. Since the timetable is fixed for the whole semester, therefore I theorises that all the power consumption of the same day over a period of one month is almost similar. By determine the value of correlation, we can use it to prove the assumption made.

4.3.1 Second Floor of UTAR KB Block

4.3.1.1 Correlation Analysis on Mondays and Tuesdays

Table 4.2 shows the correlation of all four Mondays fall under the range of 0.9 till 1. Since the correlation has a value bigger than 0.7, this shows that all Mondays have

strong positive relationship. This proves that my assumption that the power consumption for all Mondays are almost similar to be correct. An observation is made from the graph that the power consumption is high from 9am till 6pm. This is the standard working hour, so the power consumption should be high. However, the power consumption is quite high from the period 7pm till 11pm. This is most likely due to extracurricular activities going on during this period. The highest power consumption recorded falls on the 13th and the value is 7.908 kWh.

Table 4.3 shows the correlation of all three Tuesdays fall under the range of 0.9 till 1. Since the correlation has a value bigger than 0.7, this shows that all Tuesdays have strong linear relationship. An observation is made that the power consumption of Tuesdays are not very high compared to Monday. Since Tuesdays have lesser classes, therefore it will leads to the reduction of power consumed. The highest power consumption recorded is 9.201 kWh at the day 28th June 2016.

Table 4.1: Power Consumption on Mondays and Tuesdays for Second Floor

	POWER CONSUMPTION (kWh)					
	MONDAY			TUESDAY		
DATE TIME	13/6/2016	20/6/2016	27/6/2016	14/6/2016	21/6/2016	28/6/2016
12 a.m.	2.775	2.344	2.475	3.884	4.101	4.112
1 a.m.	2.237	2.327	1.627	2.985	3.766	3.559
2 a.m.	1.37	2.139	0.967	3.157	3.33	2.901
3 a.m.	1.124	2.18	2.422	4.249	4.429	4.571
4 a.m.	4.462	4.294	4.332	5.195	5.198	5.272
5 a.m.	5.237	5.019	5.640	5.783	5.424	5.822
6 a.m.	5.898	5.927	6.004	6.103	6.181	6.415
7 a.m.	5.412	5.383	5.532	6.435	6.329	6.392
8 a.m.	5.479	5.699	5.348	6.355	6.795	6.658
9 a.m.	7.068	7.418	6.911	7.478	7.15	7.579
10 a.m.	7.908	7.456	7.038	8.735	8.402	8.655
11 a.m.	7.612	7.575	7.516	8.988	9.091	9.035
12 p.m.	7.06	7.289	7.295	8.874	8.316	9.201
1 p.m.	6.674	6.404	6.185	8.005	7.493	7.659
2 p.m.	5.995	6.508	5.476	7.33	7.103	7.074
3 p.m.	5.85	5.935	5.694	6.629	5.952	6.649
4 p.m.	6.307	6.412	6.056	5.756	5.421	6.152
5 p.m.	6.847	6.458	6.433	5.176	5.573	6.183
6 p.m.	6.137	6.531	6.253	4.7	4.682	4.830
7 p.m.	5.995	5.187	5.950	4.005	3.924	4.070

8 p.m.	5.191	4.656	4.793	4.356	4.313	4.152
9 p.m.	4.934	4.461	4.843	3.507	3.558	2.881
10 p.m.	4.211	4.101	4.213	1.735	2.071	1.294
11 p.m.	3.959	4.094	4.092	0.769	0.597	0.482

Table 4.2: Correlation Coefficient of Mondays for Second Floor

CORRELATION	13/6/2016	20/6/2016	27/6/2016
13/6/2016	1		
20/6/2016	0.973	1	
27/6/2016	0.974	0.966	1

Table 4.3: Correlation Coefficient of Tuesdays for Second Floor

CORRELATION	14/6/2016	21/6/2016	28/6/2016
14/6/2016	1		
21/6/2016	0.989	1	
28/6/2016	0.988	0.988	1

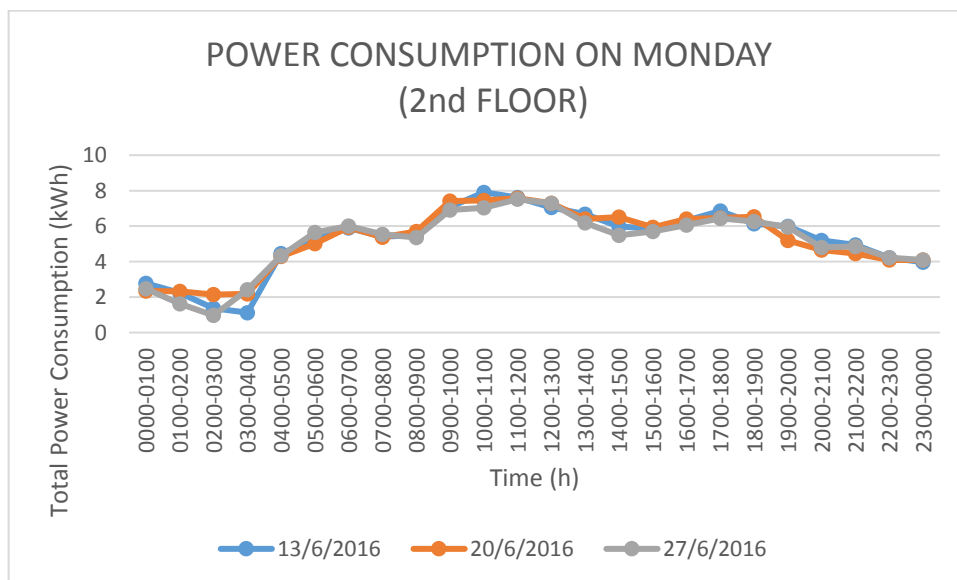


Figure 4.2: Average Hourly Power Consumption on Mondays

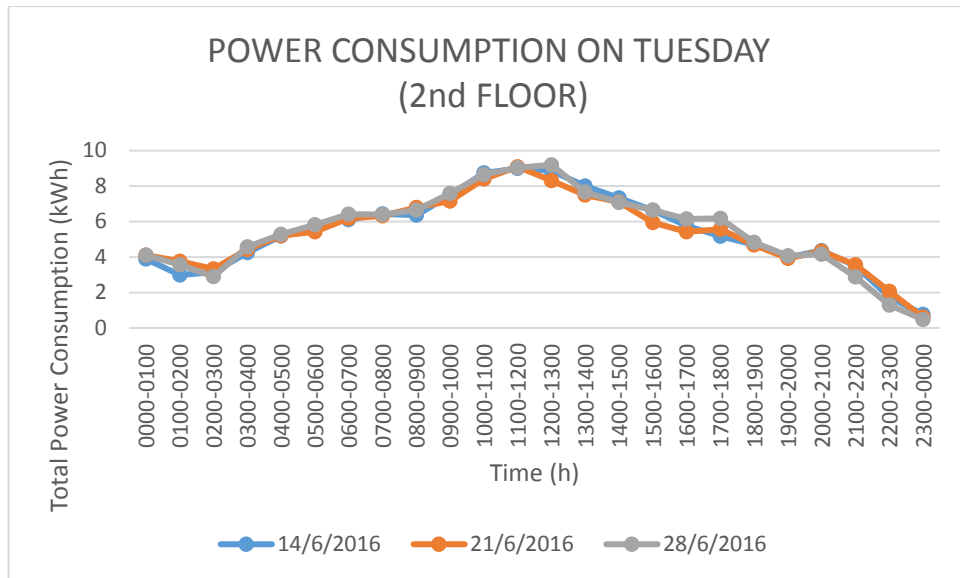


Figure 4.3: Average Hourly Power Consumption on Tuesdays

4.3.1.2 Correlation Analysis on Wednesdays, Thursdays and Fridays

For Wednesdays, there is one particular day which has a very low power consumption over the whole day. This is because 22th of June is a public holiday, therefore the university is closed and there is no activity going on inside the campus. Thus, the correlation coefficient between this Wednesday and other two Wednesday is negative value which indicates they do not have linear relationship. For the other two Wednesdays, the calculated correlation shows that they have a strong linear relationship. The highest power consumption recorded is 6.664 kWh on the day 29th June 2016 at 6 p.m.

Table 4.6 shows the correlation of all three Thursdays fall under the range of 0.9 till 1. Since the correlation has a value bigger than 0.7, this shows that all Thursdays have strong linear relationship. There is a steep rising on the graph. This shows that all the activities and class only starts carry out at 10am, therefore the power will rise steeply when the time is approached. An observation is made that the power consumption slowly decreases over the day. This further shows that all the activities are packed into the period of 10am till 11am. The highest power consumption recorded are 7.193 kWh on 16th June 2016.

Table 4.7 shows the correlation of all three Fridays fall under the range of 0.9 till 1. All the Fridays have strong positive relationship since the correlation coefficient is more than +0.7. As observed from the figure 4.6, the power consumption is high from 9 am till 6 pm. This is the standard working hour, so the power consumption should be high. The highest recorded power consumption on Fridays is 9.285 kWh.

Table 4.4: Power Consumption on Wednesdays, Thursdays and Friday for Second Floor

	POWER CONSUMPTION (kWh)								
	WEDNESDAY			THURSDAY			FRIDAY		
DATE TIME	15/6/ 2016	22/6/ 2016	29/6/ 2016	16/6/ 2016	23/6/ 2016	30/6/ 2016	17/6/ 2016	24/6/ 2016	1/7/ 2016
12 a.m.	3.412	1.351	0.171	3.287	3.279	3.488	3.836	3.114	3.510
1 a.m.	2.532	0.789	0.210	3.587	3.275	3.486	2.907	2.953	2.851
2 a.m.	2.457	0.883	0.218	3.238	2.796	2.906	2.73	2.838	2.401
3 a.m.	3.065	1.03	0.223	2.352	2.327	2.178	2.97	2.591	2.964
4 a.m.	1.608	1.246	0.221	2.813	2.031	1.750	5.362	5.27	5.297
5 a.m.	1.463	1.122	0.216	1.447	2.027	2.172	6.174	5.635	6.091
6 a.m.	1.236	1.337	0.275	3.26	3.423	3.419	7.206	6.106	6.754
7 a.m.	1.852	1.058	0.750	3.404	3.48	3.501	6.794	7.016	6.972
8 a.m.	1.318	0.906	1.179	3.325	3.578	3.650	7.165	7.038	6.817
9 a.m.	2.962	0.81	2.676	6.444	6.85	6.508	8.058	7.959	8.177
10 a.m.	3.724	0.841	3.704	7.019	6.905	7.129	9.285	8.926	9.024
11 a.m.	4.718	0.501	4.215	7.193	6.725	6.685	8.491	8.615	8.666
12 p.m.	4.168	0.837	4.428	6.704	6.479	7.140	8.032	8.701	9.003
1 p.m.	4.641	0.786	4.735	6.538	6.504	6.659	7.864	6.751	7.811
2 p.m.	5.069	1.311	4.912	6.743	6.634	6.579	6.237	5.967	6.211
3 p.m.	5.467	1.36	5.747	6.504	5.951	6.478	6.259	6.407	6.361
4 p.m.	5.762	0.643	5.528	6.127	6.126	6.502	6.686	6.45	6.009
5 p.m.	5.701	0.916	6.180	6.092	6.347	5.819	6.518	6.362	6.037
6 p.m.	5.918	0.883	6.664	5.411	6.071	5.698	5.833	5.961	5.525
7 p.m.	5.103	0.714	5.477	5.415	5.16	5.580	4.819	5.308	5.035
8 p.m.	5.362	0.84	5.365	5.138	4.975	5.452	4.306	4.107	4.213
9 p.m.	5.048	0.876	4.935	4.94	4.482	5.111	2.816	2.639	2.736
10 p.m.	4.738	0.577	4.871	4.834	3.884	4.581	2.902	2.645	2.657
11 p.m.	4.421	0.585	4.296	4.365	4.217	4.142	3.111	2.851	2.881

Table 4.5: Correlation Coefficient of Wednesdays for Second Floor

CORRELATION	15/6/2016	22/6/2016	29/6/2016
15/6/2016	1		

22/6/2016	-0.364	1	
29/6/2016	0.929	-0.404	1

Table 4.6: Correlation Coefficient of Thursdays for Second Floor

CORRELATION	16/6/2016	23/6/2016	30/6/2016
16/6/2016	1		
23/6/2016	0.973	1	
30/6/2016	0.977	0.981	1

Table 4.7: Correlation Coefficient of Fridays for Second Floor

CORRELATION	17/6/2016	24/6/2016	1/7/2016
17/6/2016	1		
24/6/2016	0.980	1	
1/7/2016	0.989	0.986	1

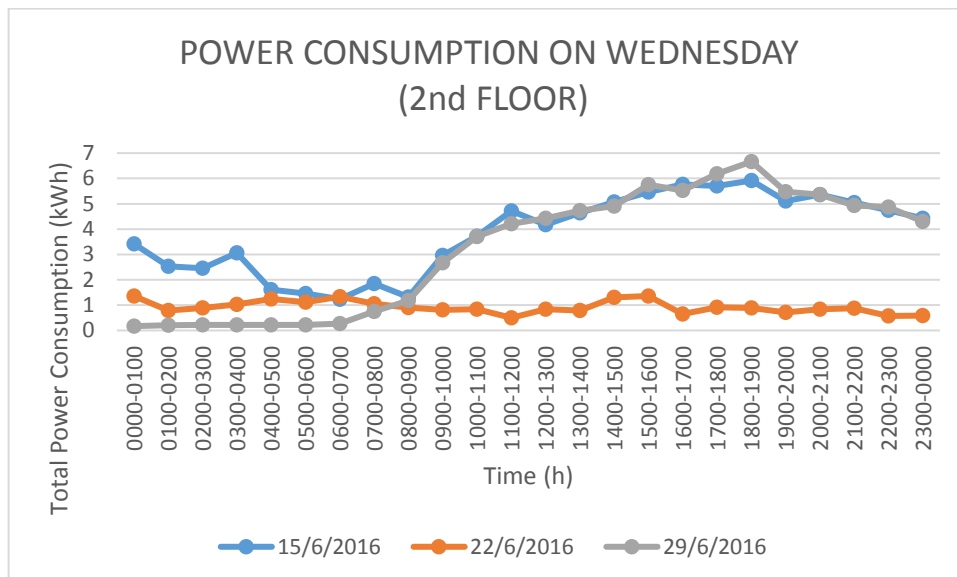


Figure 4.4: Average Hourly Power Consumption on Wednesdays

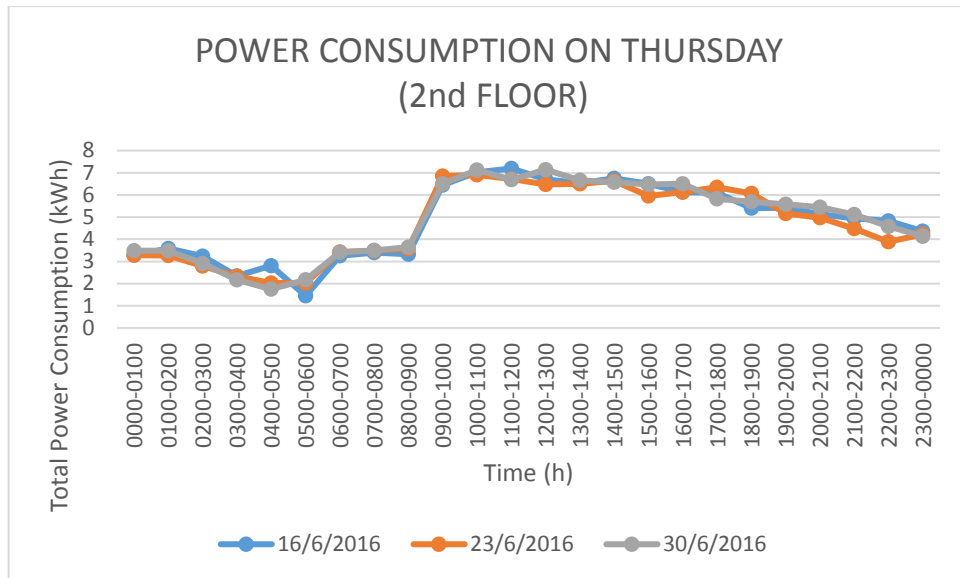


Figure 4.5: Average Hourly Power Consumption on Thursdays

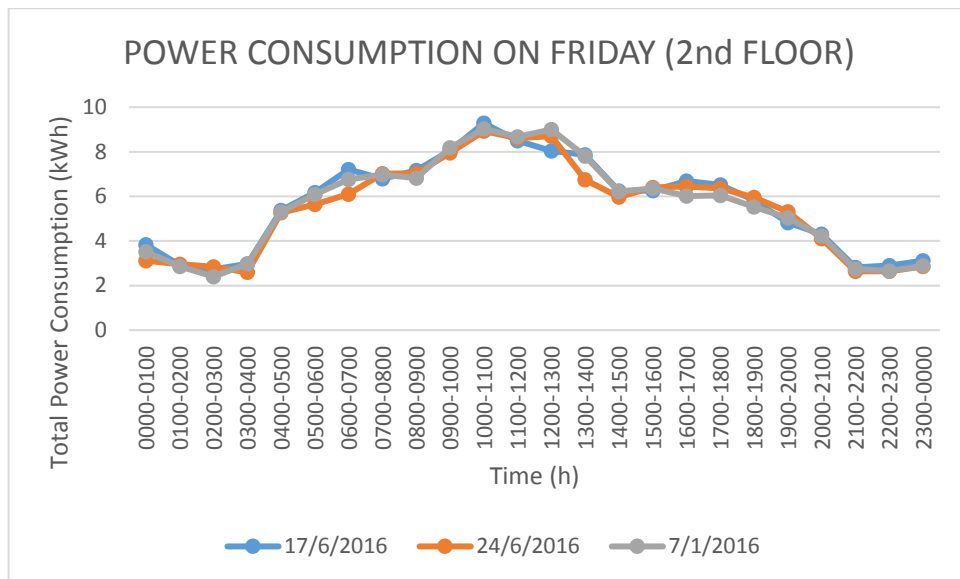


Figure 4.6: Average Hourly Power Consumption on Fridays

4.3.1.3 Correlation Analysis on Weekdays

All the correlation coefficient calculated has a vast range of values which means that every day have a different linear relationship between one another. Figure 4.7 shows only Monday, Tuesday and Wednesday have a similar trend on the power consumed.

On the other hand, Wednesday has the lowest power consumed throughout the day as compared to other weekdays. This might cause by the fact that Wednesday has the least activities such as lab going on. Despite their difference, a similar point between them is observed which is the peak power consumed is around noon time except for Wednesday which has its peak in the evening. Friday has the overall highest average power consumed and the highest peak power consumption recorded for all weekdays is 9.08 kWh which falls on Friday.

Table 4.8: Daily Average Power Consumption for Second Floor

DAYS TIME	DAILY AVERAGE POWER CONSUMPTION (kWh) FOR 2ND FLOOR				
	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
12 a.m.	2.53	4.03	1.79	3.35	3.49
1 a.m.	2.06	3.44	1.37	3.45	2.90
2 a.m.	1.49	3.13	1.34	2.98	2.66
3 a.m.	1.91	4.42	1.64	2.29	2.84
4 a.m.	4.36	5.22	0.91	2.20	5.31
5 a.m.	5.30	5.68	0.84	1.88	5.97
6 a.m.	5.94	6.23	0.76	3.37	6.69
7 a.m.	5.44	6.39	1.30	3.46	6.93
8 a.m.	5.51	6.60	1.25	3.52	7.01
9 a.m.	7.13	7.40	2.82	6.60	8.06
10 a.m.	7.47	8.60	3.71	7.02	9.08
11 a.m.	7.57	9.04	4.47	6.87	8.59
12 p.m.	7.21	8.80	4.30	6.77	8.58
1 p.m.	6.42	7.72	4.69	6.57	7.48
2 p.m.	5.99	7.17	4.99	6.65	6.14
3 p.m.	5.83	6.41	5.61	6.31	6.34
4 p.m.	6.26	5.78	5.65	6.25	6.38
5 p.m.	6.58	5.64	5.94	6.09	6.31
6 p.m.	6.31	4.74	6.29	5.73	5.77
7 p.m.	5.71	4.00	5.29	5.39	5.05
8 p.m.	4.88	4.27	5.36	5.19	4.21
9 p.m.	4.75	3.32	4.99	4.84	2.73
10 p.m.	4.18	1.70	4.80	4.43	2.73
11 p.m.	4.05	0.62	4.36	4.24	2.95

Table 4.9: Correlation Coefficient for Second Floor

CORRELATION	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
MONDAY	1				
TUESDAY	0.731	1			

WEDNESDAY	0.472	0.018	1		
THURSDAY	0.745	0.519	0.783	1	
FRIDAY	0.879	0.927	0.112	0.581	1

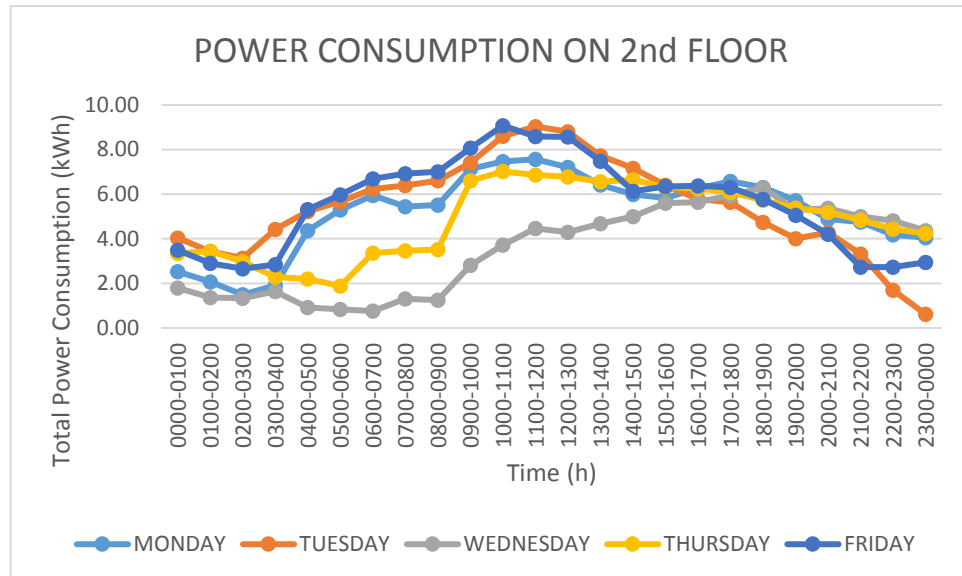


Figure 4.7: Average Hourly Power Consumption on Weekdays

4.3.2 Sixth Floor of UTAR KB Block

4.3.2.1 Correlation Analysis on Monday and Tuesdays

Table 4.11 shows the correlation coefficient between all Mondays for sixth floor. All the correlation coefficient falls between the ranges of 0.7 to 1 which indicates all the Mondays have a strong positive linear relationship. Both Mondays of 1st August 2016 and 8th August 2016 has a similar graph trend whereas the other Mondays have a higher power consumption. 25th July 2016 has the highest power consumption and the power consumed is higher than other three Mondays throughout the day. This is caused by the extra activities going on that week. The highest power consumption recorded is 13.67 kWh on 25th July.

Table 4.12 shows the correlation coefficient between all Tuesdays for sixth floor. From the result, it's shown that 26th July has a very weak linear relationship

with other Tuesdays. However, the other three Tuesdays have strong linear relationship between them as the correlation coefficient falls between the ranges of 0.7 to 1. All the graph has a similar trend, however the 26th July has a high power consumption even in the time from 12 a.m. to 8 a.m. The highest recorded power consumption is 14.36 kWh on the day 2nd August 2016.

Table 4.10: Power Consumption on Mondays and Tuesdays for Sixth Floor

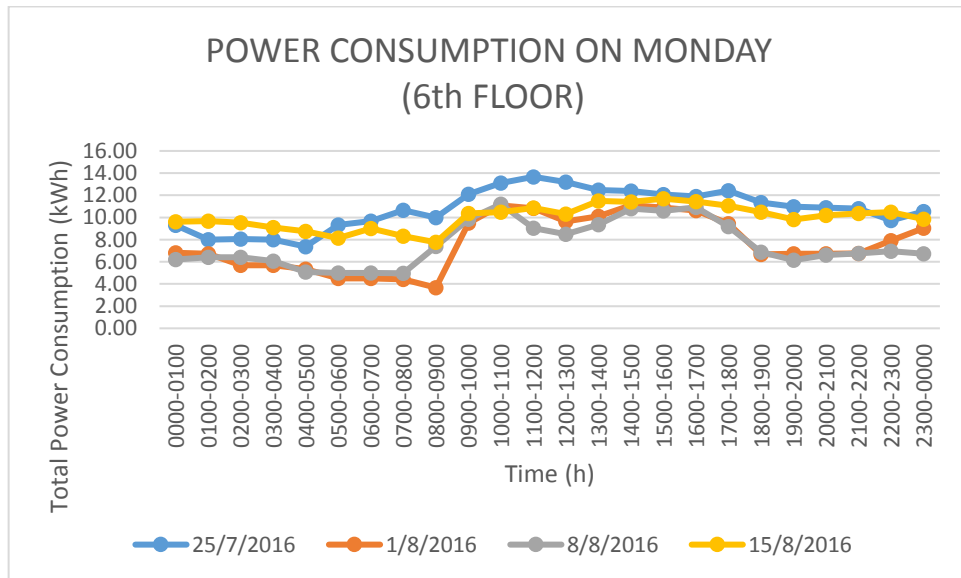
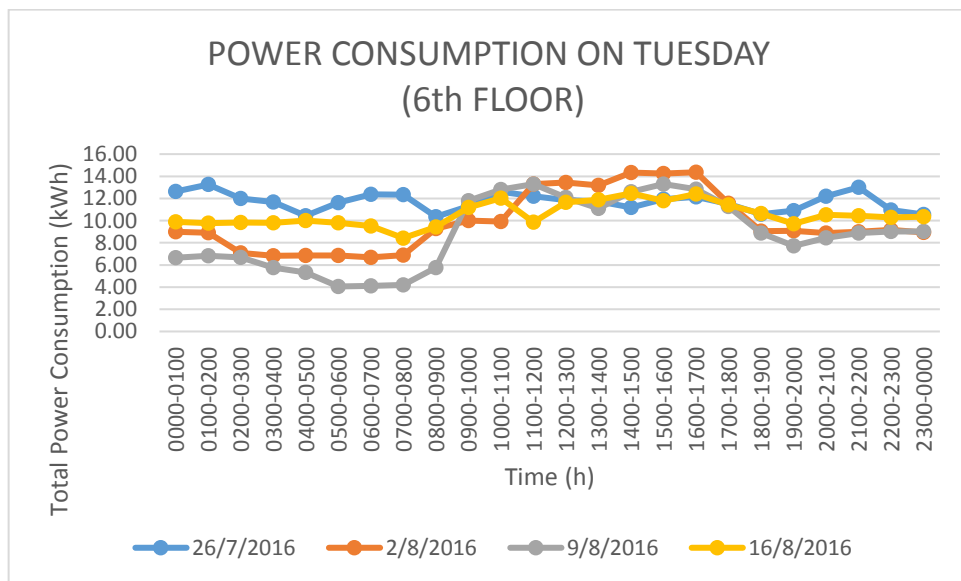
	POWER CONSUMPTION (kWh)							
	MONDAY				TUESDAY			
DATE TIME	25/7/ 2016	1/8/ 2016	8/8/ 2016	15/8/ 2016	26/7/ 2016	2/8/ 2016	9/8/ 2016	16/8/ 2016
12 a.m.	9.30	6.81	6.21	9.61	12.64	8.99	6.64	9.87
1 a.m.	8.00	6.73	6.40	9.67	13.25	8.91	6.84	9.77
2 a.m.	8.07	5.70	6.42	9.51	11.99	7.08	6.69	9.82
3 a.m.	7.99	5.69	6.05	9.09	11.66	6.84	5.75	9.81
4 a.m.	7.37	5.33	5.08	8.75	10.43	6.86	5.33	10.01
5 a.m.	9.34	4.51	4.99	8.13	11.62	6.87	4.06	9.81
6 a.m.	9.68	4.50	4.99	9.01	12.38	6.69	4.10	9.51
7 a.m.	10.66	4.42	4.97	8.32	12.34	6.88	4.20	8.43
8 a.m.	9.99	3.67	7.39	7.76	10.35	9.29	5.77	9.43
9 a.m.	12.10	9.49	9.84	10.36	11.30	10.01	11.81	11.19
10 a.m.	13.11	11.09	11.19	10.47	12.60	9.91	12.81	12.02
11 a.m.	13.67	10.83	9.05	10.86	12.21	13.29	13.29	9.85
12 p.m.	13.20	9.65	8.49	10.32	11.86	13.43	12.08	11.65
1 p.m.	12.46	10.12	9.35	11.49	11.74	13.17	11.09	11.87
2 p.m.	12.38	11.11	10.79	11.40	11.18	14.34	12.60	12.46
3 p.m.	12.08	10.89	10.60	11.70	11.93	14.25	13.30	11.79
4 p.m.	11.89	10.63	10.93	11.42	12.15	14.36	12.85	12.41
5 p.m.	12.40	9.45	9.18	11.07	11.51	11.56	11.29	11.42
6 p.m.	11.35	6.68	6.87	10.48	10.57	9.04	8.87	10.63
7 p.m.	10.97	6.71	6.15	9.81	10.90	9.08	7.73	9.72
8 p.m.	10.87	6.73	6.61	10.20	12.21	8.87	8.44	10.51
9 p.m.	10.80	6.75	6.75	10.38	13.00	9.00	8.87	10.43
10 p.m.	9.73	7.91	6.96	10.47	10.95	9.18	9.03	10.30
11 p.m.	10.54	9.04	6.71	9.84	10.56	8.95	9.02	10.35

Table 4.11: Correlation Coefficient on Mondays for Sixth Floor

CORRELATION	25/7/2016	1/8/2016	8/8/2016	15/8/2016
25/7/2016	1			
1/8/2016	0.767	1		
8/8/2016	0.763	0.894	1	
15/8/2016	0.671	0.894	1	1

Table 4.12: Correlation Coefficient on Tuesdays for Sixth Floor

CORRELATION	26/7/2016	2/8/2016	9/8/2016	16/8/2016
26/7/2016	1			
2/8/2016	0.041	1		
9/8/2016	0.052	0.889	1	
16/8/2016	-0.006	0.790	1	1

**Figure 4.8: Average Hourly Power Consumption on Mondays****Figure 4.9: Average Hourly Power Consumption on Tuesdays**

4.3.2.2 Correlation Analysis on Wednesdays and Thursdays

Table 4.14 shows the correlation coefficient between all Wednesdays for sixth floor. All the Wednesdays have a weak relationship between one another because the correlation coefficient is around 0.3 to 0.5. As shown in Table 4.13, 17th August has a very low power consumption starting from 12 a.m. to 10 a.m. The power consumption only started to increase after 11 a.m. On the other hand, the other Wednesdays have a similar trend but the correlation does not indicate they have strong linear relationship. The highest recorded power consumption is 13.05 kWh on 27th July 2016.

Table 4.15 shows the correlation coefficient between all Thursdays for sixth floor. All the Thursdays have strong positive linear relationship proven by the value of correlation coefficient which falls between 0.8 and 1. However, 28th July has a weak relationship with both Thursdays of 11th August and 18th August. All the graphs have similar trend but the power consumed on 28th July is particularly high in the midnight. The highest recorded power consumption is 14.39 kWh on the day 11th August 2016.

Table 4.13: Power Consumption on Wednesdays and Thursdays for Sixth Floor

	POWER CONSUMPTION (kWh)							
	WEDNESDAY				THURSDAY			
DATE TIME	27/7/ 2016	3/8/ 2016	10/8/ 2016	17/8/ 2016	28/7/ 2016	4/8/ 2016	11/8/ 2016	18/8/ 2016
12 a.m.	10.16	8.23	8.84	10.03	10.57	8.15	7.57	9.68
1 a.m.	11.59	6.52	8.39	10.13	10.14	5.68	7.45	9.45
2 a.m.	11.27	5.70	7.70	10.40	10.03	5.51	7.62	9.30
3 a.m.	10.54	4.03	7.59	9.77	10.28	5.61	7.61	9.55
4 a.m.	7.94	3.01	7.41	8.52	9.80	5.59	7.40	9.16
5 a.m.	7.78	3.04	7.41	8.45	9.73	5.57	6.41	8.91
6 a.m.	8.44	3.02	6.31	8.45	9.01	5.41	6.39	8.26
7 a.m.	12.95	1.14	7.08	9.54	9.73	4.93	4.06	8.68
8 a.m.	9.83	3.17	9.20	9.86	11.29	6.37	5.29	7.69
9 a.m.	12.26	3.99	10.42	10.33	11.86	7.02	6.60	8.58
10 a.m.	11.04	7.23	12.10	11.47	12.85	10.87	9.11	9.81
11 a.m.	10.91	8.06	13.13	11.92	13.07	10.98	12.12	10.44
12 p.m.	12.08	7.11	11.77	10.98	12.60	9.65	11.46	9.90
1 p.m.	13.05	8.03	11.93	12.00	10.94	8.53	11.92	9.99
2 p.m.	12.74	10.02	12.69	11.48	11.07	11.11	13.67	11.65

3 p.m.	12.48	10.01	12.35	11.48	12.36	12.72	14.39	11.98
4 p.m.	11.44	9.85	10.02	9.85	12.65	12.83	13.64	11.76
5 p.m.	11.61	8.43	8.96	10.78	11.68	11.17	11.37	10.52
6 p.m.	10.63	7.30	7.55	9.24	9.84	8.45	10.08	10.78
7 p.m.	10.61	7.69	7.72	9.50	9.68	7.65	9.75	9.48
8 p.m.	10.64	8.41	7.75	9.92	9.76	7.61	8.89	9.54
9 p.m.	10.73	8.99	7.77	10.18	9.82	7.69	9.01	9.35
10 p.m.	10.58	9.02	7.71	10.10	8.99	7.85	8.97	9.22
11 p.m.	10.49	8.87	7.69	10.32	9.60	7.81	8.85	9.86

Table 4.14: Correlation Coefficient on Wednesdays for Sixth Floor

CORRELATION	27/7/2016	3/8/2016	10/8/2016	17/8/2016
27/7/2016	1			
3/8/2016	0.397	1		
10/8/2016	0.567	0.461	1	
17/8/2016	0.739	0.598	1	1

Table 4.15: Correlation Coefficient on Thursdays for Sixth Floor

CORRELATION	28/7/2016	4/8/2016	11/8/2016	18/8/2016
28/7/2016	1			
4/8/2016	0.909	1		
11/8/2016	0.554	0.892	1	
18/8/2016	0.478	0.840	1	1

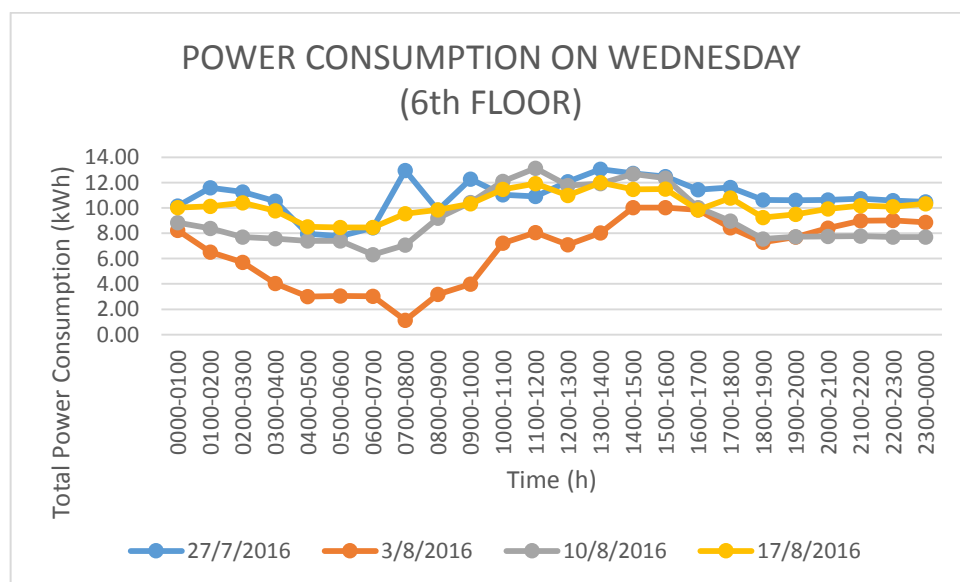


Figure 4.10: Average Hourly Power Consumption on Wednesdays

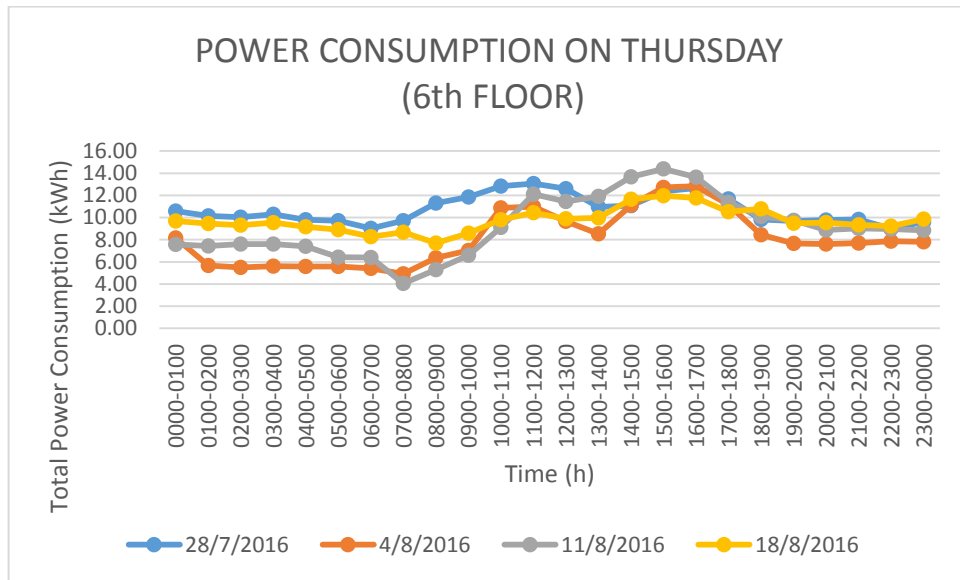


Figure 4.11: Average Hourly Power Consumption on Thursdays

4.3.2.3 Correlation Analysis on Fridays

Table 4.17 shows the correlation coefficient between all Fridays for sixth floor. All the Fridays have correlation coefficient between 0.6 and 0.8 which indicates that they have positive linear relationship but not strong. From the result, it is shown that 5th August has a very low power consumption throughout the whole day as compared to other Fridays. The highest recorded power consumption is 13.70 kWh on the day 29th July 2016.

Table 4.16: Power Consumption on Fridays for Sixth Floor

DATE TIME	POWER CONSUMPTION (kWh)			
	29/7/2016	5/8/2016	12/8/2016	19/8/2016
12 a.m.	9.65	7.78	8.83	9.65
1 a.m.	8.21	7.70	8.80	9.89
2 a.m.	7.51	6.63	8.92	9.70
3 a.m.	7.19	6.71	8.99	10.00
4 a.m.	5.90	6.71	8.93	9.09
5 a.m.	6.12	6.05	8.87	9.09

6 a.m.	6.19	5.42	8.69	8.49
7 a.m.	5.72	5.70	7.94	8.67
8 a.m.	6.07	6.52	9.94	8.55
9 a.m.	12.29	6.65	10.67	8.42
10 a.m.	11.67	6.53	12.85	10.05
11 a.m.	12.47	6.51	11.99	10.79
12 p.m.	13.70	6.39	12.72	10.84
1 p.m.	13.07	6.74	12.55	10.98
2 p.m.	13.25	7.76	13.09	11.94
3 p.m.	13.24	7.75	13.15	12.00
4 p.m.	13.37	8.18	12.79	11.14
5 p.m.	12.15	8.21	11.85	11.16
6 p.m.	9.63	8.20	9.57	10.34
7 p.m.	8.95	8.57	9.09	9.74
8 p.m.	10.25	9.02	6.91	9.97
9 p.m.	10.53	9.03	7.71	10.10
10 p.m.	10.22	9.03	7.62	9.67
11 p.m.	10.79	7.31	7.53	9.52

Table 4.17: Correlation Coefficient on Fridays for Sixth Floor

CORRELATION	29/7/2016	5/8/2016	12/8/2016	19/8/2016
29/7/2016	1			
5/8/2016	0.371	1		
12/8/2016	0.691	0.676	1	
19/8/2016	0.7592138	0.6763092	0.6763092	1

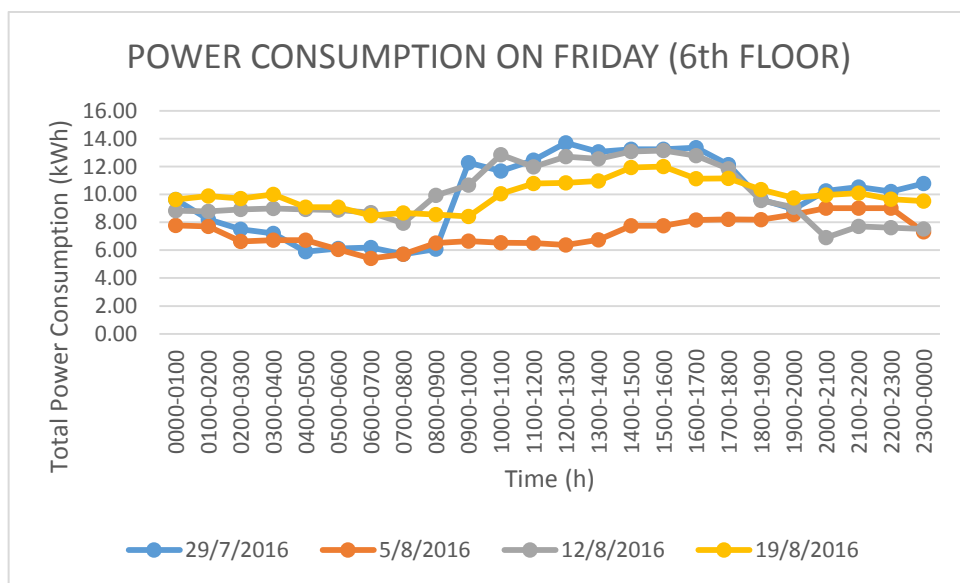


Figure 4.12: Average Hourly Power Consumption on Fridays

4.3.2.4 Correlation Analysis on Weekdays

The correlation coefficient of all weekdays for sixth floor falls under the range of 0.9 to 1. This shows that all the weekdays have a strong positive linear relationship between one another. All the weekdays also have a very similar trend for the energy consumed. The power starts to rise around 9 a.m. and remains high until 7 p.m. which is normal because the standard working hour is 9 a.m. to 6 p.m. We can make an observation from the graph which is the power consumed is surprisingly high at the dawn and late night. This is because all the architecture studio are situated in this floor. Architecture student will normally stays in the school whole day long as their assignment requires large amount of time to complete. Therefore, the lighting in the architecture studio contributes to the high power consumption at dawn and late night. Tuesday is observed to have the overall highest average power consumption and the highest peak power consumption recorded is 12.94 kWh at 4 p.m.

Table 4.18: Daily Average Power Consumption for Sixth Floor

	DAILY AVERAGE POWER CONSUMPTION (kWh) FOR 6 TH FLOOR				
DAYS TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
12 a.m.	7.98	9.53	9.32	8.99	8.98
1 a.m.	7.70	9.69	9.16	8.18	8.65
2 a.m.	7.43	8.89	8.77	8.11	8.19
3 a.m.	7.21	8.52	7.98	8.26	8.22
4 a.m.	6.63	8.16	6.72	7.99	7.66
5 a.m.	6.74	8.09	6.67	7.66	7.53
6 a.m.	7.05	8.17	6.56	7.27	7.20
7 a.m.	7.09	7.96	7.68	6.85	7.01
8 a.m.	7.20	8.71	8.02	7.66	7.77
9 a.m.	10.45	11.08	9.25	8.52	9.51
10 a.m.	11.46	11.84	10.46	10.66	10.27
11 a.m.	11.10	12.16	11.00	11.65	10.44
12 p.m.	10.42	12.25	10.48	10.90	10.91
1 p.m.	10.86	11.97	11.25	10.34	10.84
2 p.m.	11.42	12.65	11.73	11.88	11.51
3 p.m.	11.32	12.82	11.58	12.86	11.54
4 p.m.	11.22	12.94	10.29	12.72	11.37
5 p.m.	10.53	11.44	9.95	11.18	10.85
6 p.m.	8.84	9.78	8.68	9.79	9.44

7 p.m.	8.41	9.36	8.88	9.14	9.09
8 p.m.	8.60	10.01	9.18	8.95	9.04
9 p.m.	8.67	10.33	9.42	8.97	9.34
10 p.m.	8.77	9.86	9.35	8.76	9.13
11 p.m.	9.03	9.72	9.34	9.03	8.79

Table 4.19: Correlation Coefficient for Sixth Floor

CORRELATION	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
MONDAY	1				
TUESDAY	0.972	1			
WEDNESDAY	0.909	0.930	1		
THURSDAY	0.899	0.934	0.860	1	
FRIDAY	0.945	0.976	0.927	0.956	1

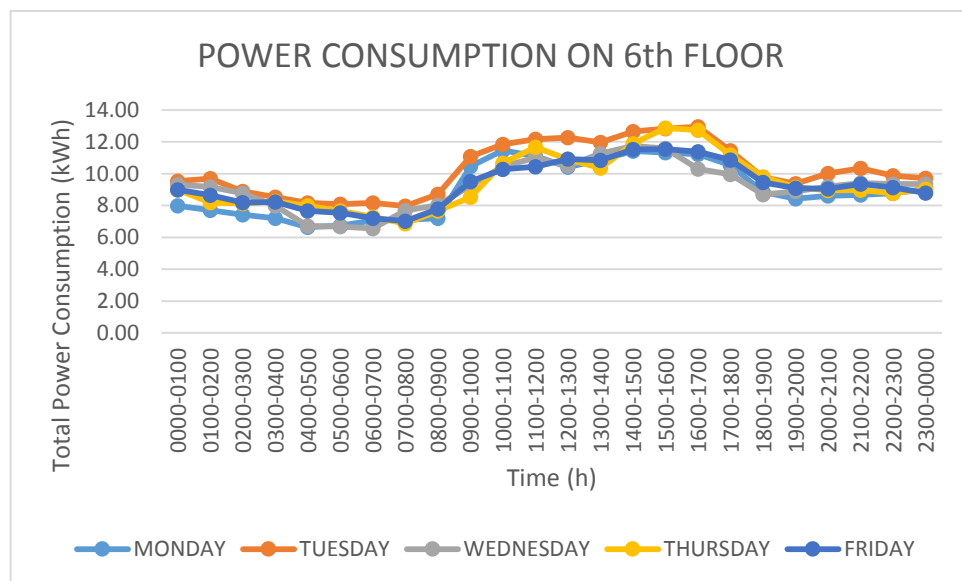


Figure 4.13: Average Hourly Power Consumption on Weekdays

4.4 Load Duration Curve

Another frequent method that people used to analyse a load demand is to produce a load duration curves. This curve are able to show the magnitude distribution of all load levels. Load duration curve will illustrates the magnitude of the power used in a downward form with the highest power recorded plotted in the

left and the lowest in the right. On the other hand, the time duration which certain load continues during the day is plotted on the x axis. Load duration curve provides several benefits than the standard load curve because it is more convenient to analyse. Besides that, from this curve, we are able to know the number of hours when the load demand exceeds a certain level. This facts alone is the reason why it is frequently used in economic dispatching and system planning. Since the measured power has a wide range of value, therefore I decided to group them into class with width of 5 kWh. After doing this, we can determine the frequency of occurrence for each classes and can easily enables us to observe the peak power consumed of each weekday. Load duration curve is created next and since the period of measuring data for each floor is different, therefore the x-axis is the percentage of time where the total time is the number of week required to measure the data.

4.4.1 Second Floor of UTAR KB Block

4.4.1.1 Load Duration Curve for Mondays

For Monday, the range of power consumed is within 4.5 kWh to 8 kWh as shown in Figure 4.14. This shows that there are activities carried out for almost whole day for Monday. The class with highest peak occurrence is the power of 6.0 kWh to 6.5 kWh. Figure 4.15 shows that the power is above 5 kWh for almost 70 percent of the time.

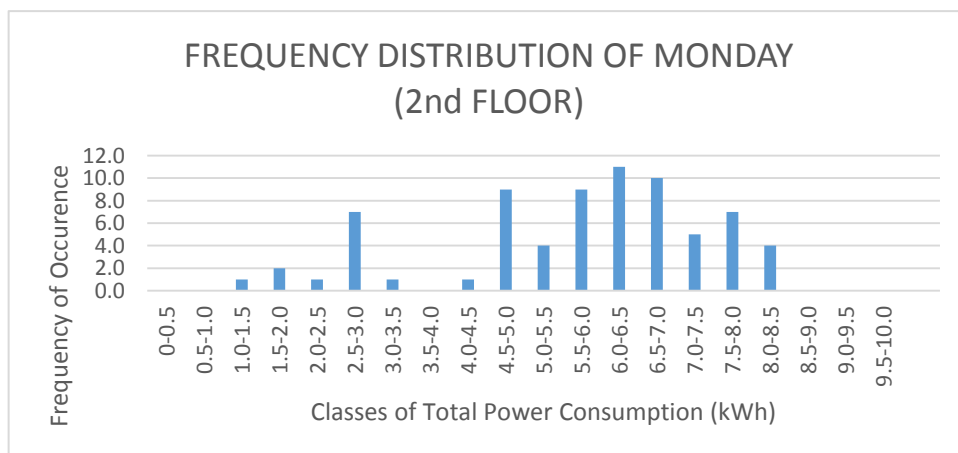


Figure 4.14: Frequency Distribution for Monday at Second Floor

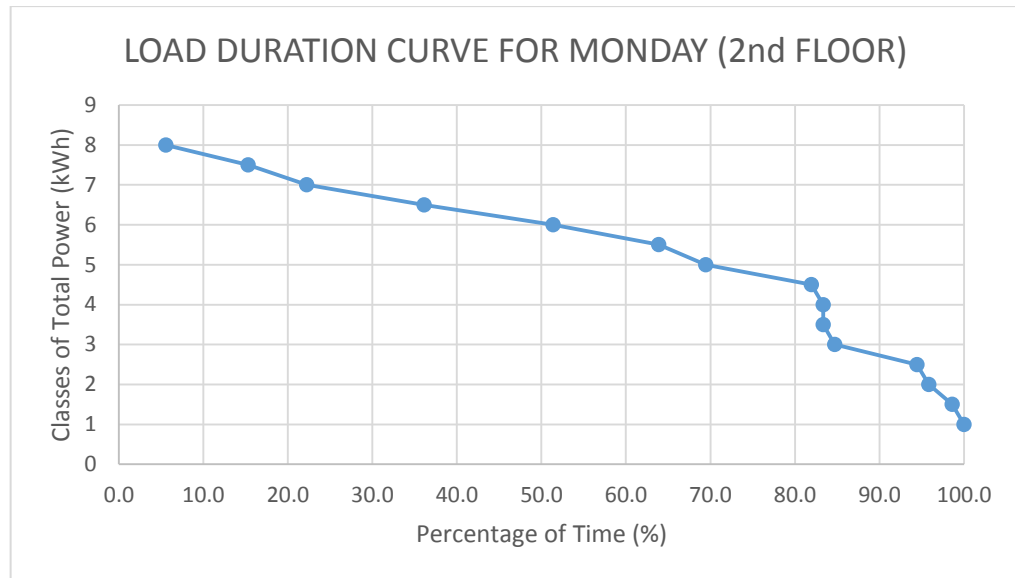


Figure 4.15: Load Duration Curve for Monday at Second Floor

4.4.1.2 Load Duration Curve for Tuesdays

According to the frequency distribution as shown in Figure 4.16, Tuesday has a wide range of value for the power consumed. This indicates that there is no specific group of power which occurs frequently. The class that occurs the most is the power step size of 4.5 kWh-5 kWh and 6.5 kWh-7 kWh. From the load duration curve, we can observe from Figure 4.17 that the power above 5 kWh takes out around 64% of the time over the period of three weeks.

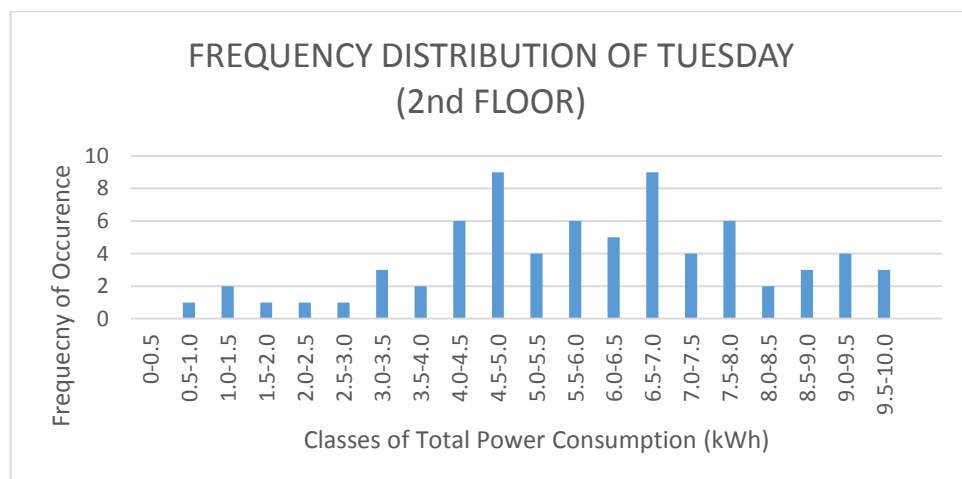


Figure 4.16: Frequency Distribution for Tuesday at Second Floor

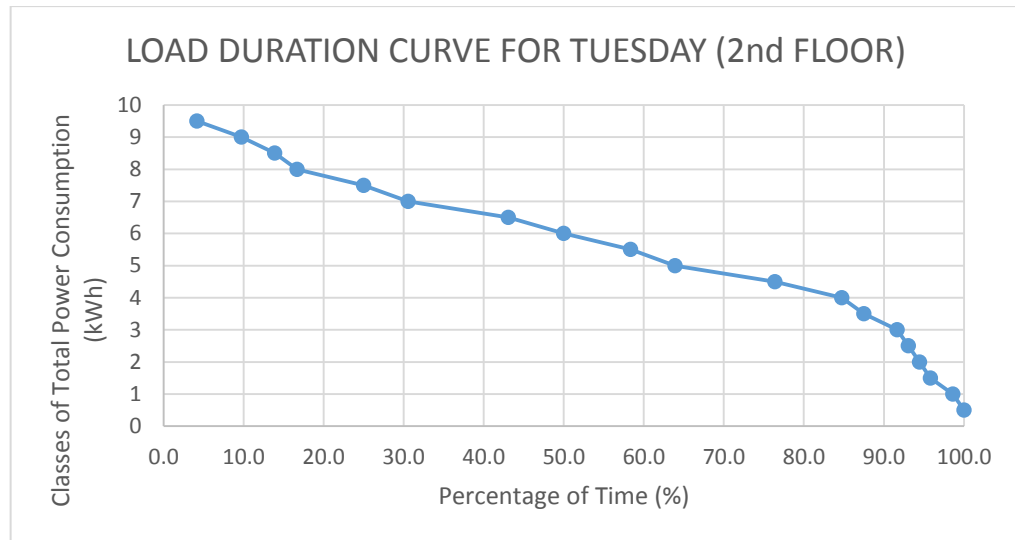


Figure 4.17: Load Duration Curve for Tuesday at Second Floor

4.4.1.3 Load Duration Curve for Wednesdays

Wednesdays has the lowest power consumption as we can observed from the Figure 4.18. The power with value above 3kWh has a very low frequency of occurrence. The highest frequency of occurrence is the class of power 1.0kWh-1.5kWh. This might causes by the fact that one of the Wednesday during taking of reading is a public holiday. This constitutes to the scenario where power with range of 1.0kWh-1.5kWh occurs the most. The load duration curve shows that the power with 5kWh and above only takes up a small amount of time while the class of power between 1kWh to 2kWh takes up around 40% of the period of three weeks as shown in Figure 4.19.

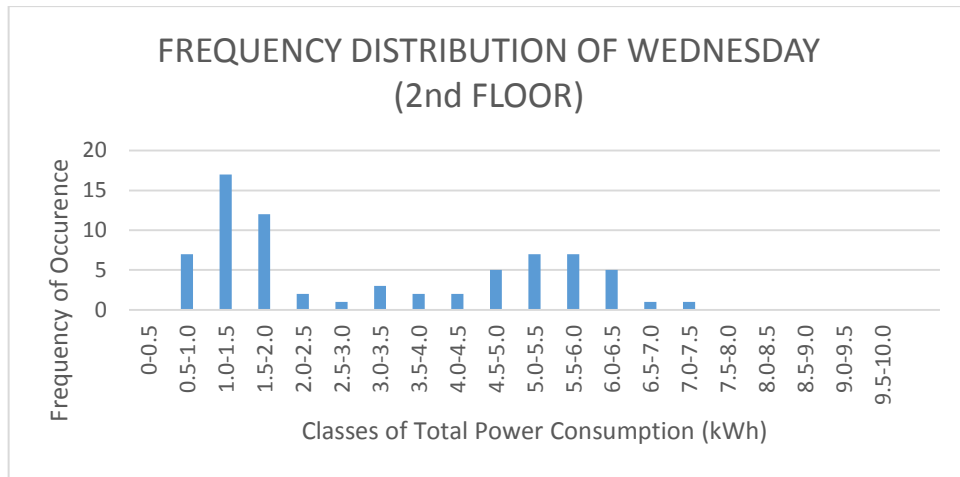


Figure 4.18: Frequency Distribution for Wednesday at Second Floor

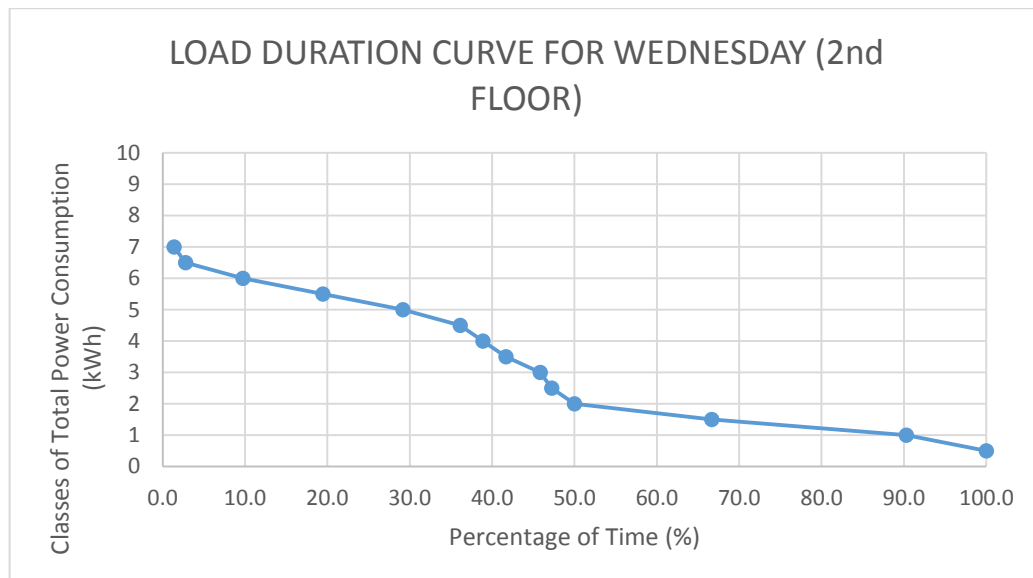


Figure 4.19: Load Duration Curve for Wednesday at Second Floor

4.4.1.4 Load Duration Curve for Thursdays

For Thursday, the power consumed generally falls within the range of 2.5-4.5 kWh and 5-8 kWh as shown in Figure 4.20. The power with values between 7-7.5 kWh has the highest frequency of occurrence. Most of the time, the power consumed is above 5 kWh whereas for Thursday there are less power consumed because the

amount of time for power consumption below the value of 3 kWh is only around 4% of the total three weeks as shown in Figure 4.21.

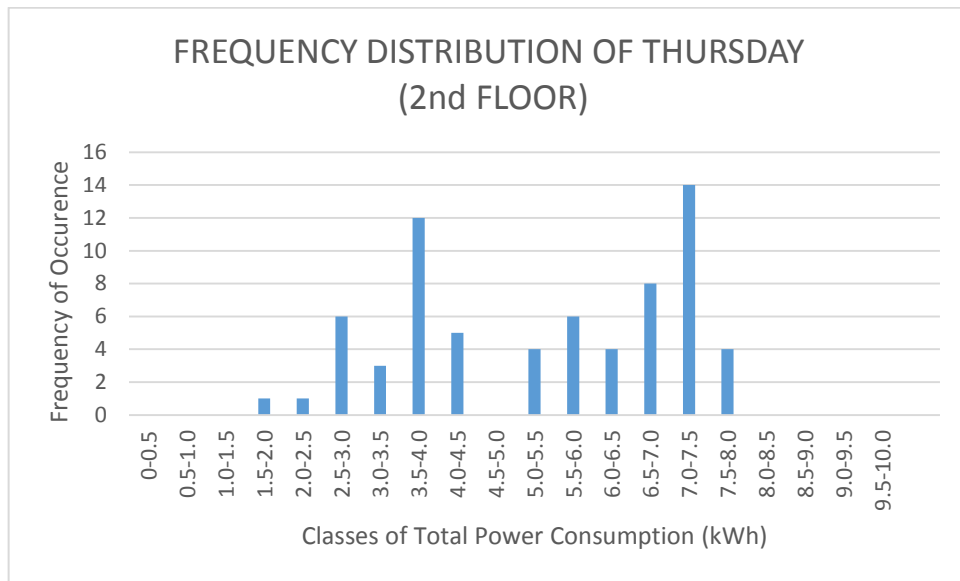


Figure 4.20: Frequency Distribution for Thursday at Second Floor

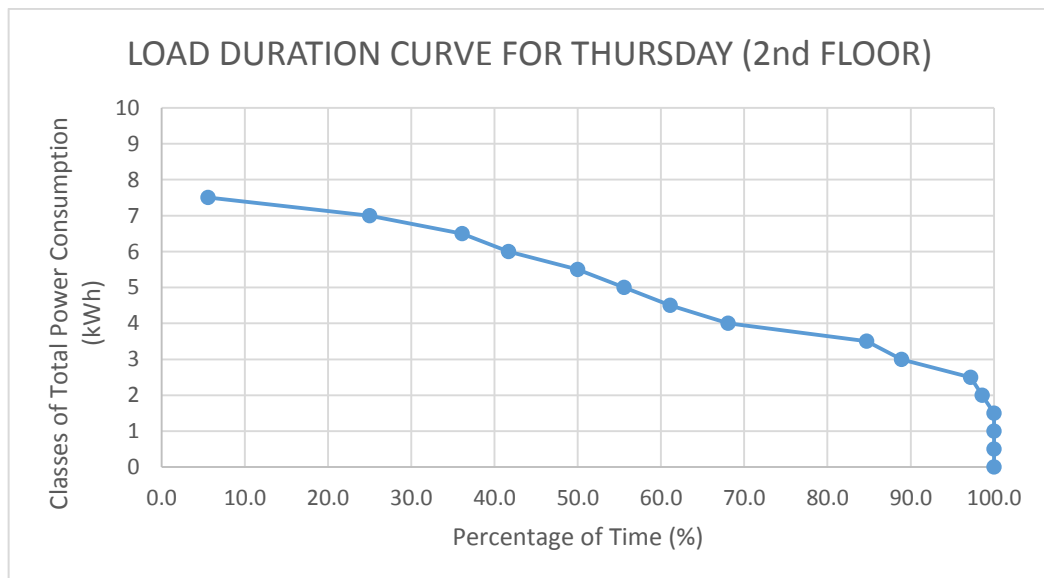


Figure 4.21: Load Duration Curve for Thursday at Second Floor

4.4.1.5 Load Duration Curve of Fridays

Friday is one of the weekdays which has the highest power consumption recorded because all power consume is above 3 kWh and there are power as high as 9.5 kWh. However, the power within the range of 3-3.5 kWh has the highest frequency of occurrence. The power above 5 kWh occurs for almost 67% of the time while the power below 3 kWh only occurs for around 3% as shown in Figure 4.23.

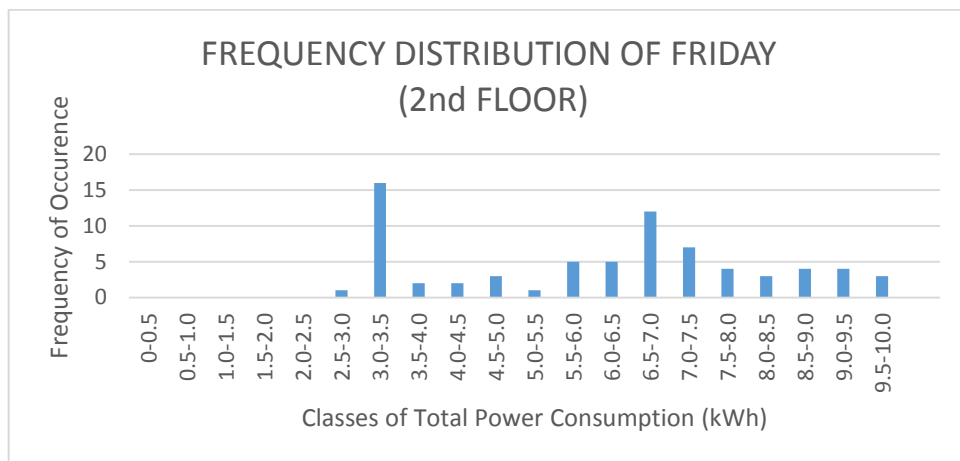


Figure 4.22: Frequency Distribution for Friday at Second Floor

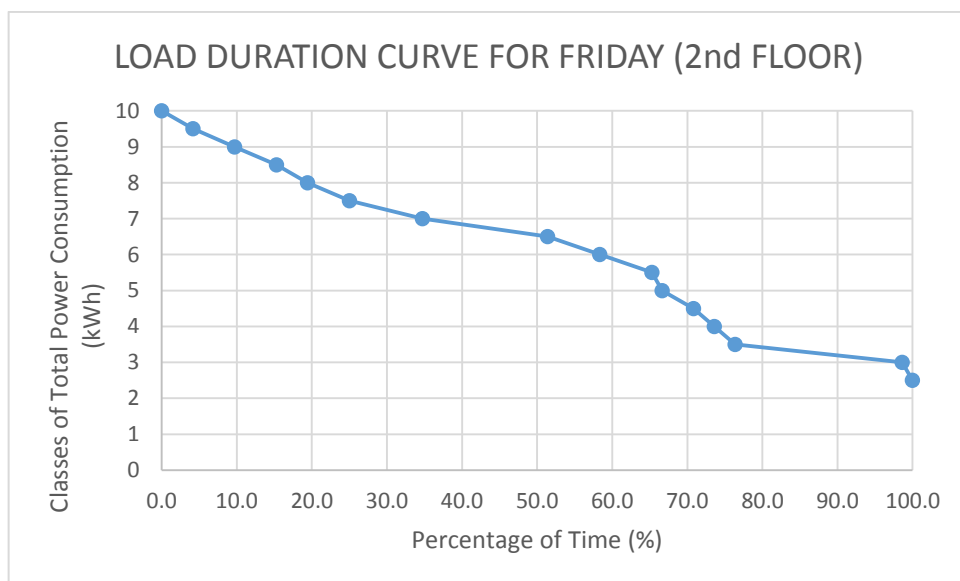


Figure 4.23: Load Duration Curve for Friday at Second Floor

4.4.1.6 Load Duration Curve for Whole Second Floor

Figure 4.24 shows that the frequency of occurrence of each of class of power consumed. 2nd floor generally has high power consumption with the power that frequently consumed falls within the range of 4.5-8 kWh. The highest frequency of occurrence is the class of power with range of 6.5-7 kWh. Figure 4.25 shows that for more than half of the time, the power consumed is above 5 kWh. However, low power consumption also occurs for quite a big percentage of time and this is due to the fact that Wednesday is a day with low power consumption.

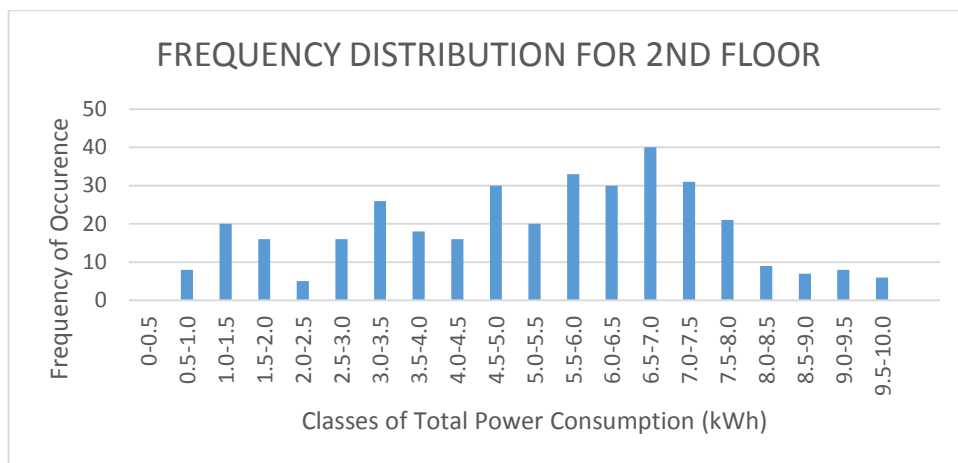


Figure 4.24: Frequency Distribution for Second Floor

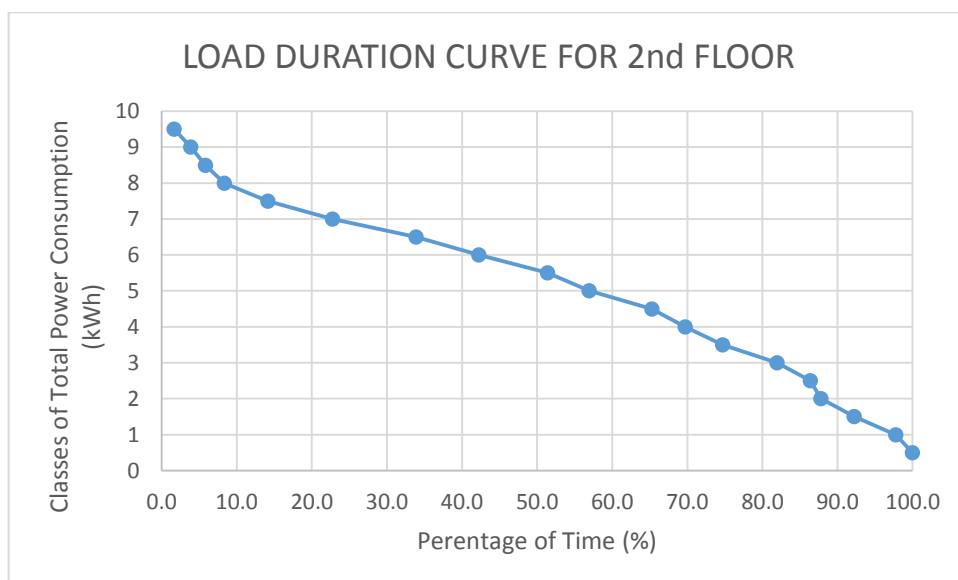


Figure 4.25: Load Duration Curve for Second Floor

4.4.2 Sixth Floor of UTAR KB Block

4.4.2.1 Load Duration Curve for Mondays

For Monday, the range of power consumed is within 4 kWh to 14.5 kWh as shown in Figure 4.26. This shows that there are activities carried out for almost whole day for Monday. The class with highest peak occurrence is the power of 11.0-11.5 kWh. From the load duration curve, we can observed that the power is above 10kWh for half of the time. However, Monday has a very high power consumed because 90% of the time, the power consumed is above 6kWh.

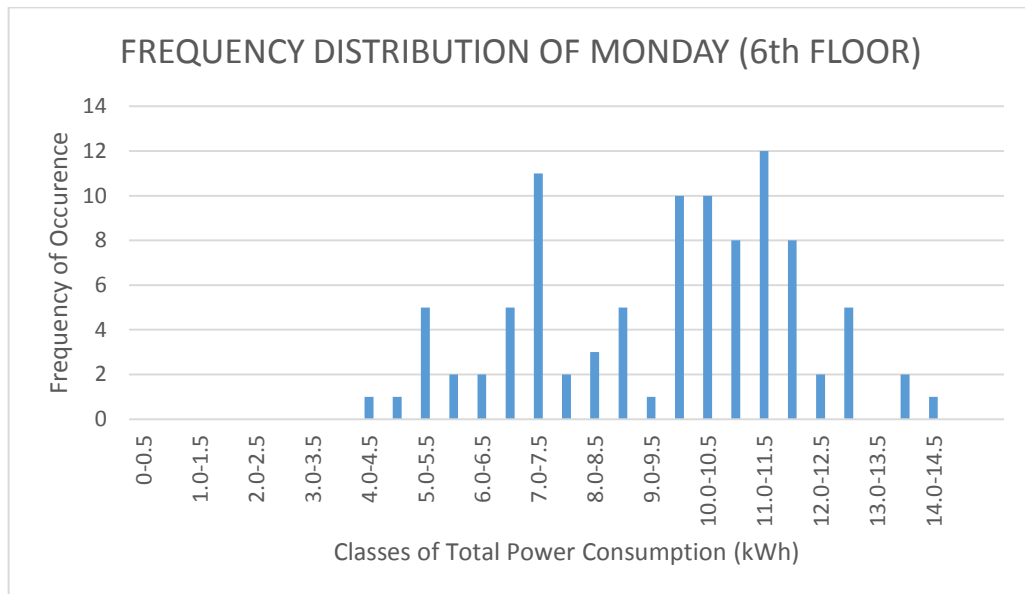


Figure 4.26: Frequency Distribution for Monday at Sixth Floor

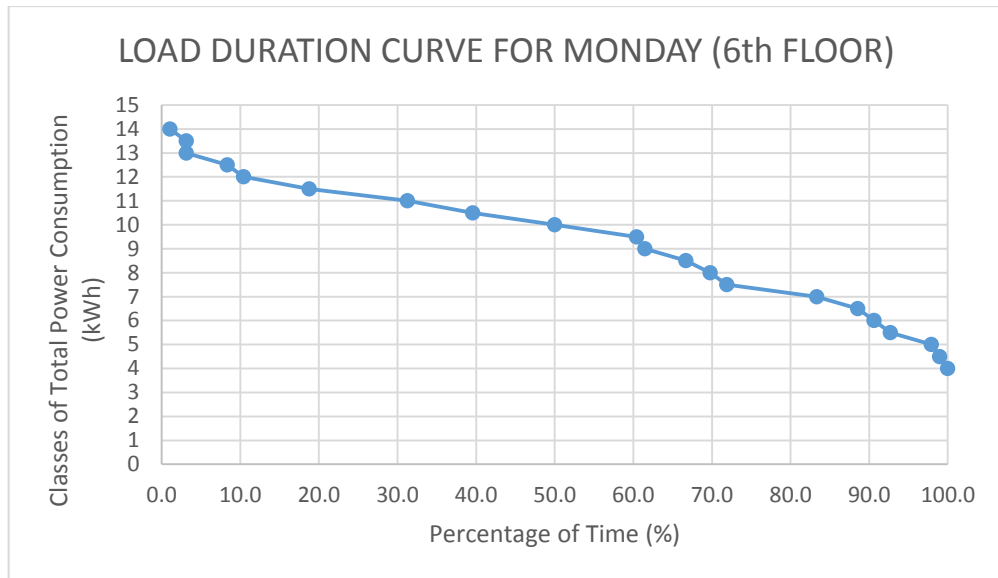


Figure 4.27: Load Duration Curve for Monday at Sixth Floor

4.4.2.2 Load Duration Curve for Tuesdays

Tuesday has a frequent of power consumed within the range of 7-14 kWh as shown in Figure 4.28. This shows that there are many activities carried out during Tuesdays. The class that occurs the most is the power consumption step size between 12-12.5 kWh. From the load duration curve, an observation is made that the power above 10 kWh takes out around 66% of the time over the period of three weeks.

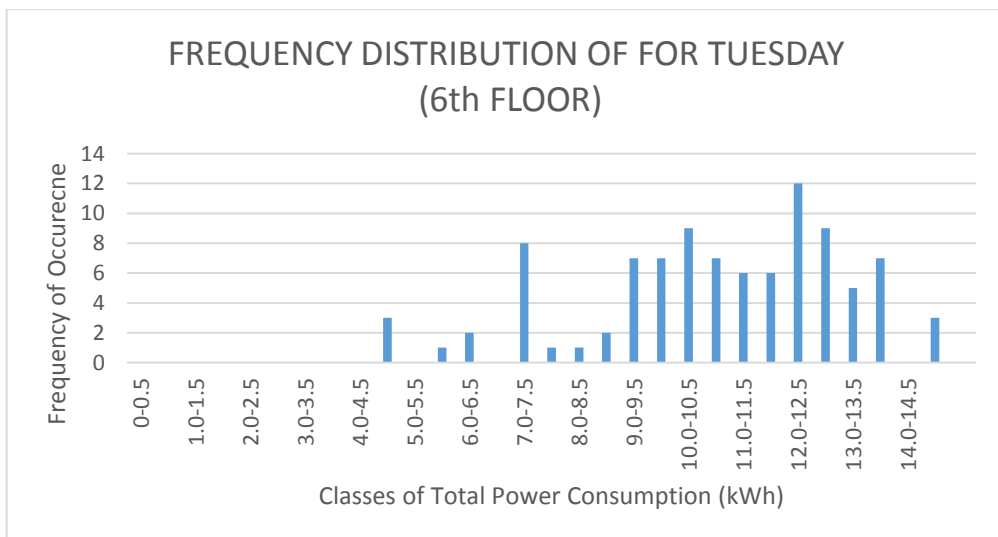


Figure 4.28: Frequency Distribution for Tuesday at Sixth Floor

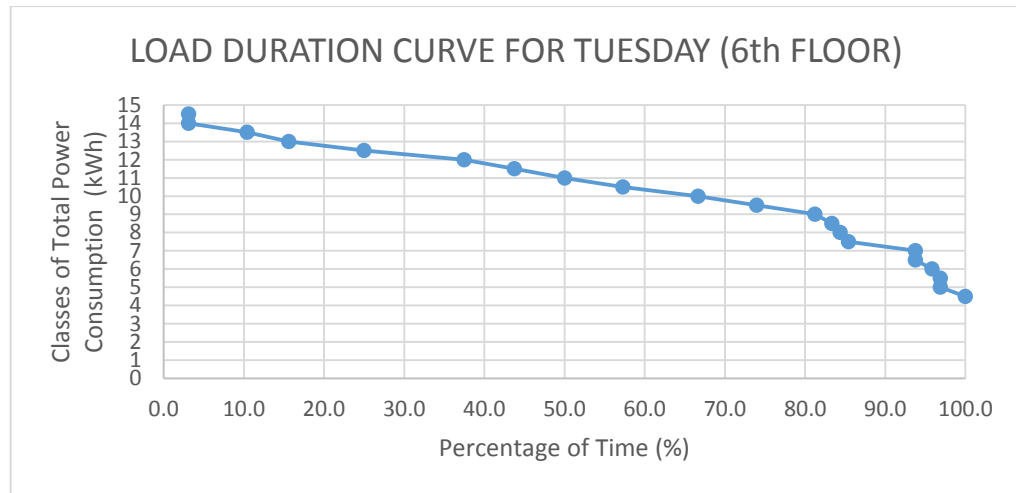


Figure 4.29: Load Duration Curve for Tuesday at Sixth Floor

4.4.2.3 Load Duration Curve for Wednesdays

Wednesdays also has a high power consumption. Figure 4.30 shows that the power within the range of 8-13 kWh are recorded frequently. The power with class of 10.5-11 kWh has the highest frequency of occurrence. Load duration curve shows that most of the time the power consumed are above 9 kWh.

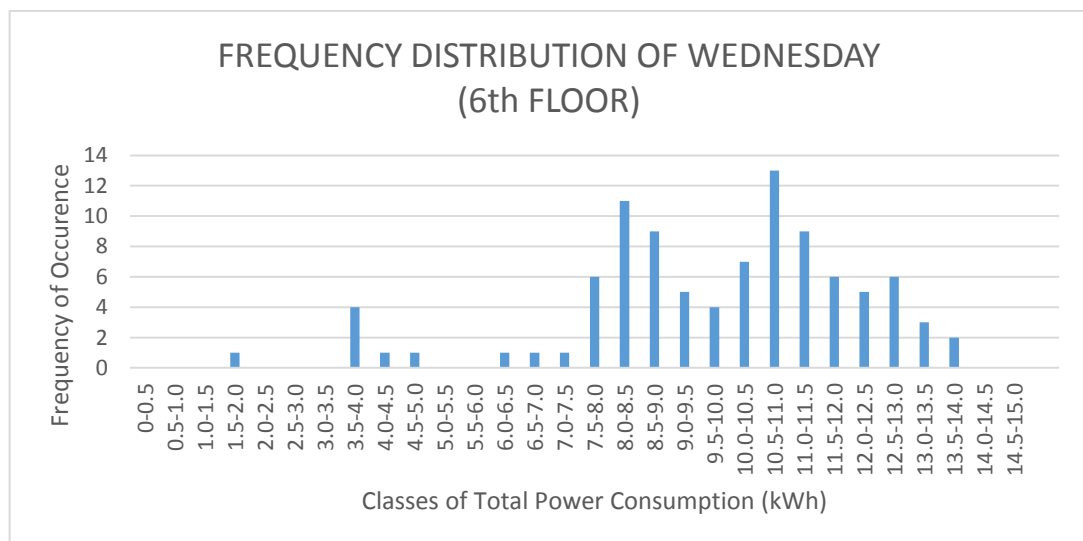


Figure 4.30: Frequency Distribution for Wednesday at Sixth Floor

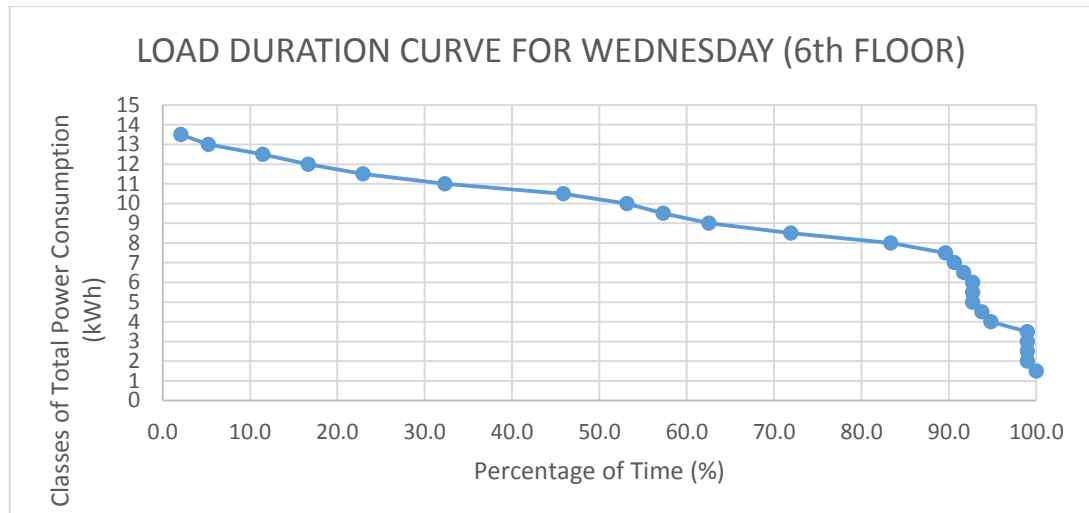


Figure 4.31: Load Duration Curve for Wednesday at Sixth Floor

4.4.2.4 Load Duration Curve for Thursdays

For Thursday, the power consumed generally falls within the range of 6-13.5 kWh as shown in Figure 4.32. The power consumption step size between 10-10.5 kWh has the highest frequency of occurrence. Most of the time, the power consumed is above 10 kWh as shown in Figure 4.33 whereas for Thursday low power consumption only occurs for short amount of time.

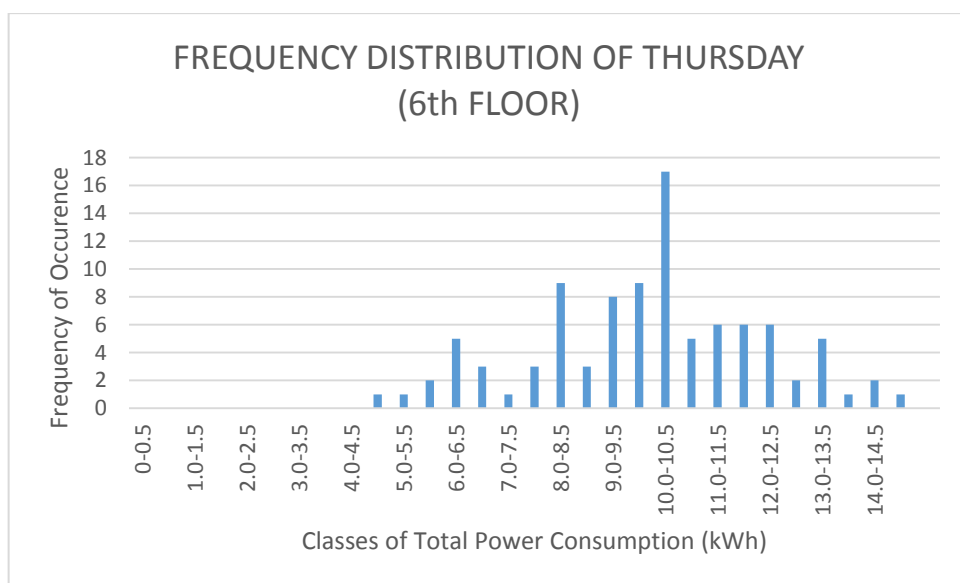


Figure 4.32: Frequency Distribution for Thursday at Sixth Floor

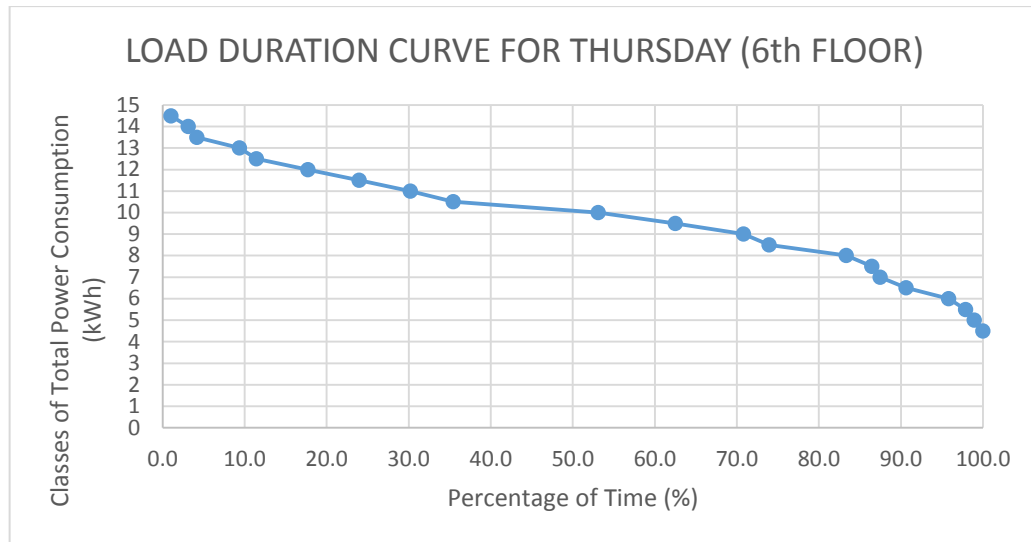


Figure 4.33: Load Duration Curve for Thursday at Sixth Floor

4.4.2.5 Load Duration Curve for Fridays

Friday has a high power consumption throughout the day. Most of the power recorded is high as shown in Figure 4.34 and the power between 7 kWh and 10.5 kWh occurs frequently. The power within range of 9-9.5 kWh and 10-10.5 kWh has the highest power consumption. Load duration curve above shows that the power above 9 kWh occurs around half of the time.

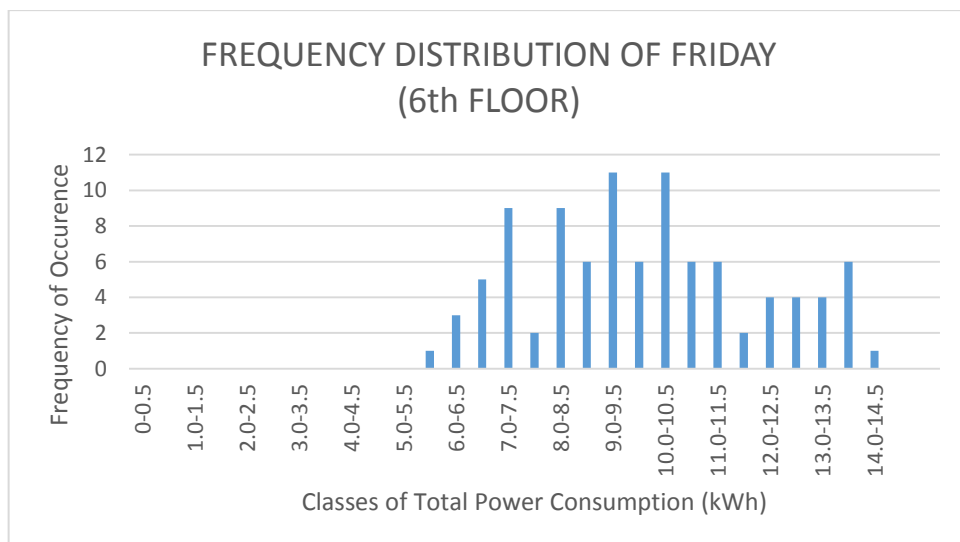


Figure 4.34: Frequency Distribution for Friday of Sixth Floor

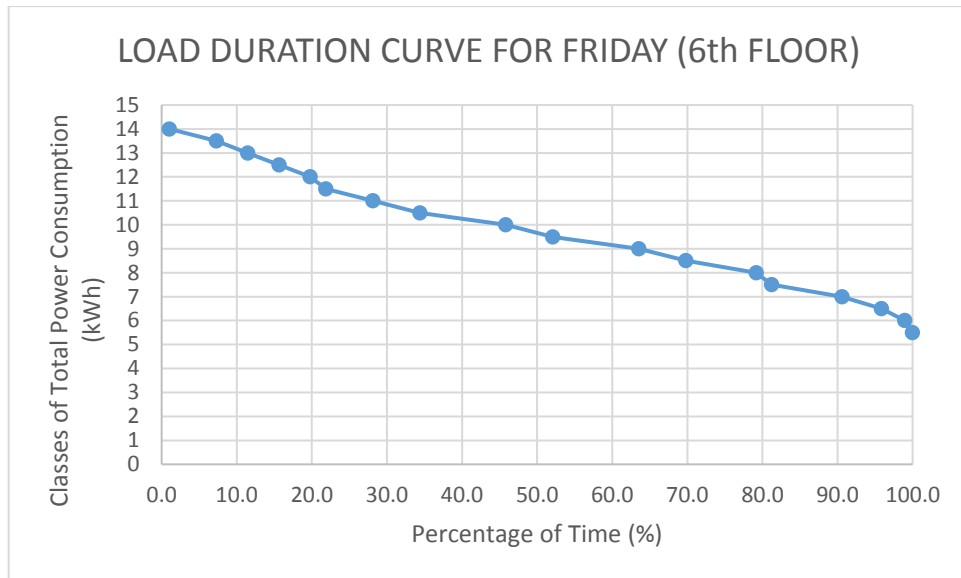


Figure 4.35: Load Duration Curve for Friday of Sixth Floor

4.4.2.6 Load Duration Curve for Whole Sixth Floor

Figure 4.36 shows that the frequency of occurrence of each of class of power consumed. 2nd floor has a very high power consumption throughout the week because no power of value below 3.5 kWh is recorded. The power consumed most of the time is within the range of 8-14 kWh. The power of 10-10.5 kWh has the highest frequency of occurrence. For around 80% of one month, the power consumed is above the range of 8 kWh. Low power consumption only occurs for a short while during the time of the project.

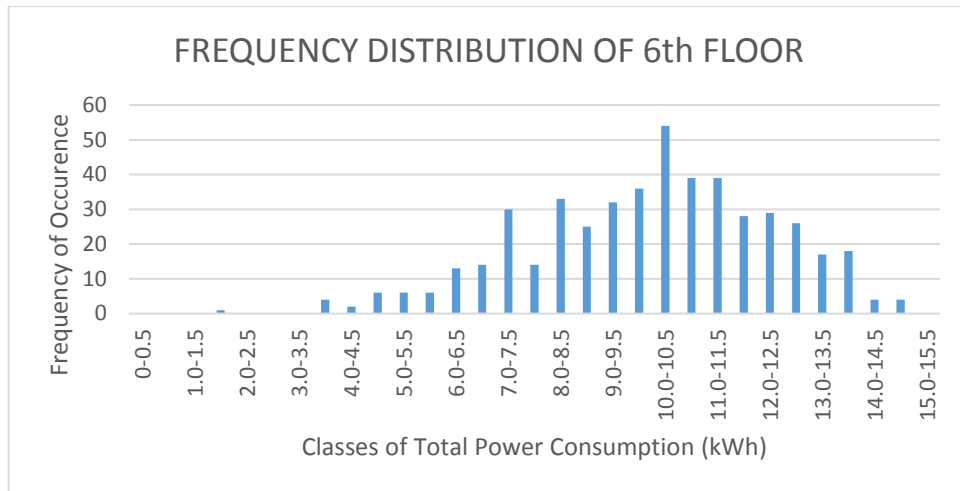


Figure 4.36: Frequency Distribution for Sixth Floor

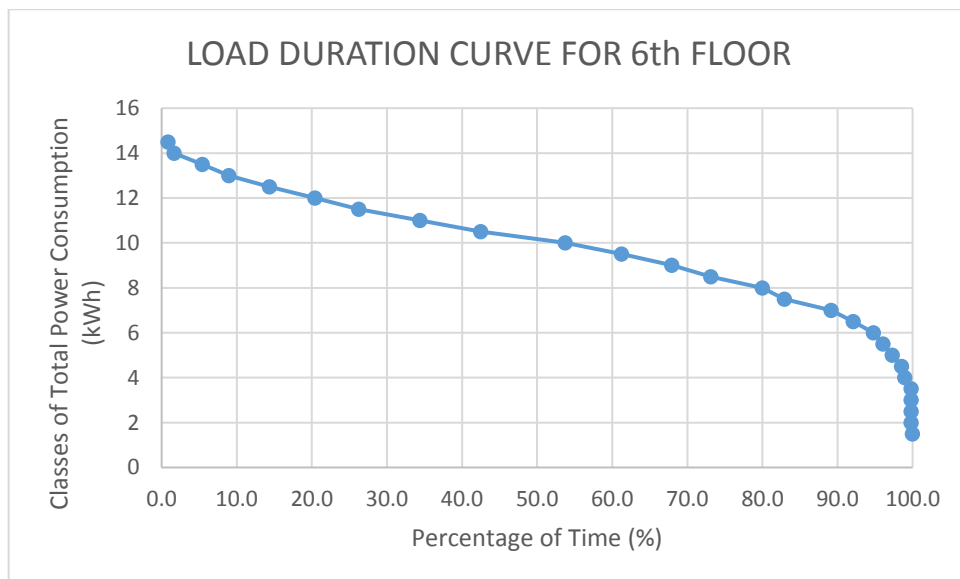


Figure 4.37: Load Duration Curve for Sixth Floor

4.5 Relationship between Lighting and Switch Socket Outlet (S.S.O)

Figure 4.38 shows that the power consumed from switch socket outlet has linear relationship with lighting. This is true because in real life, when someone is using switch socket outlet, light will be turned on as well. Therefore, when power for switch socket increases, the power consumed by the lighting also increases. However, for some period, when there is low power consumption, the power consumed by

lighting is high. This is because when lighting is used by someone does not mean that the person will use the switch socket outlet as well.

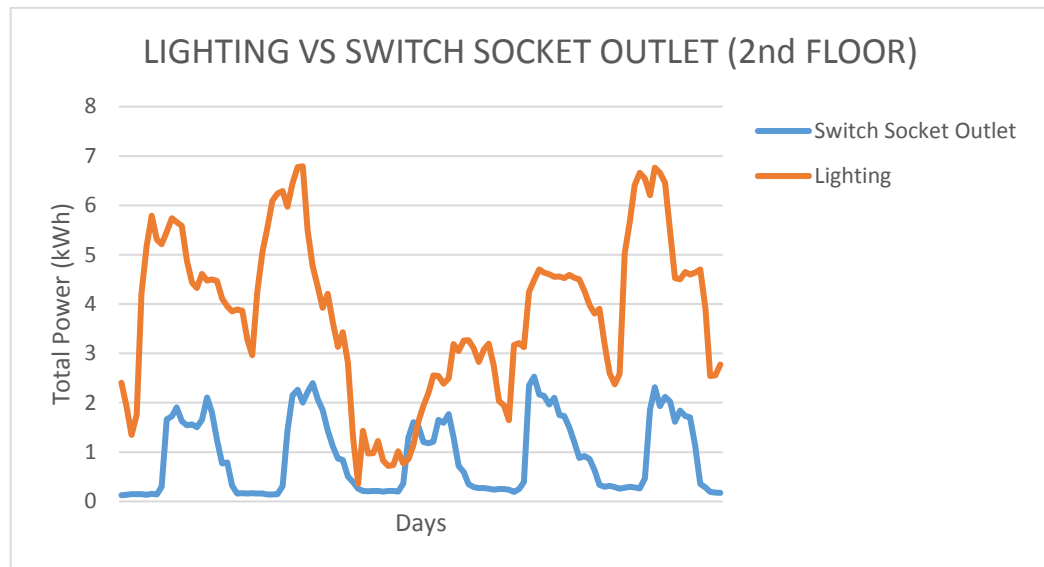


Figure 4.38: Relationship of Lighting and S.S.O on Second Floor

For sixth floor, we can observe from the graph that when power consumed by switch socket outlet increase, the power consumed by lighting also increases. However, the trend in sixth floor is differ from second floor. There are power consumed by the switch socket outlet even when the lighting only consumes a low amount of power. This might cause by the fact that sixth floor is mainly occupied by lab. Certain machines such as computers used for long simulation or manufacturing machines which requires to function whole day long, so even though the lab is closed, the machine is still running and thus consuming power. Besides that, for the architecture studio, everyone full occupies the switch socket outlet. So the power consumed by the switch socket outlet will be higher than the lighting. Nonetheless, the power consumed by lighting and switch socket outlet will drop and fall at around the same time.

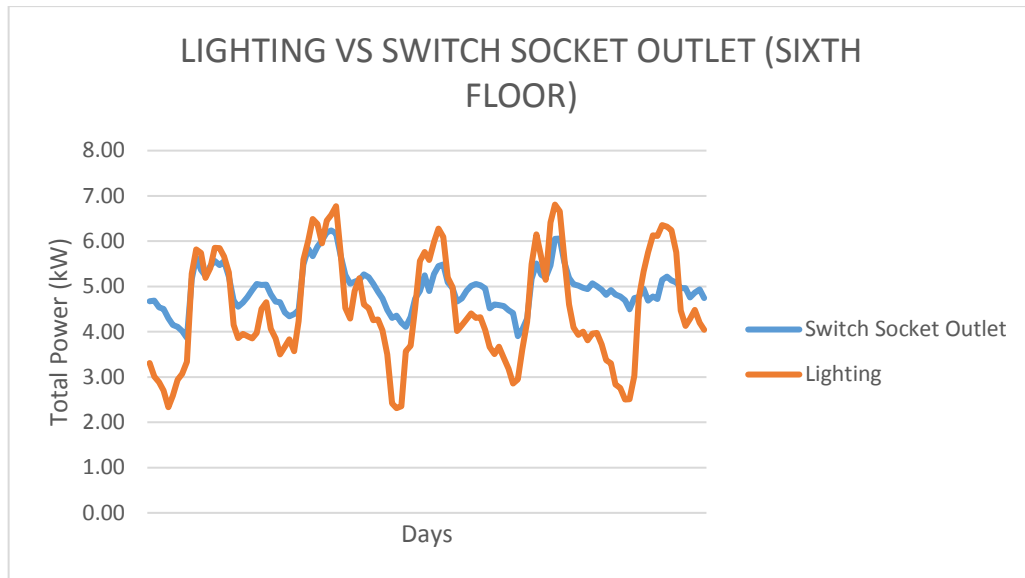


Figure 4.39: Relationship of Lighting and S.S.O on Sixth Floor

4.6 Estimation of Energy Consumption

Due to the limitation of time and budget, there are difficulty measuring the power consumed of whole floor during the project. There are only two unit sof measuring instrument available, therefore only two electrical riser can be tapped at a time. Each electrical riser only connected to a certain number of electrical appliances, so the power consumed of a limited amount of appliances is measured instead of the whole electrical appliances present in the floor. Therefore, an estimation method is used to find out the power consumed by the all the lighting and switch socket outlet for both second floor and sixth floor. Several assumptions are being made for this estimation. All the lighting is assumed to being use for the same amount of time and all the connected load to the switch socket outlet is consuming the same amount of power. However, for lighting, the electrical riser is connected to different types of lighting. Since the different type of lighting has different rated power, thus the power consumed by each type of light is not the same. Percentage of how much each type of lighting contributes to the total power is calculated and by then the power consumption of the lighting of that particular floor can be estimated.

4.6.1 Second Floor of UTAR KB Block

Data for tapped unit DB-N-2/1A:

Table 4.20: Calculation for Power Consumption of Lighting of DB-N-2/1A

NUMBER OF LIGHTINGS (NOS)	RATED POWER (Wh)	TOTAL RATED POWER (Wh)	PERCENTAGE OF POWER USED (%)	TOTAL POWER USED IN A WEEK (kWh)	POWER CONSUMPTION PER UNIT IN A WEEK (kWh)
63	28	1764.00	44.00	87.85	1.39
15	18	270.00	6.70	13.45	0.90
40	26	1040.00	25.93	51.79	1.29
13	42	546.00	13.62	27.19	2.09
30	13	390.00	9.73	19.42	0.65

Estimation for whole of second floor for lighting:

Table 4.21: Estimation of Total Power Consumed by Lighting for Second Floor

LIGHTING (NOS)	RATED POWER (Wh)	ESTIMATION OF TOTAL POWER CONSUMED PER WEEK (kWh)
237	28	330.49
28	18	31.38
174	26	102.29
40	42	41.83
70	13	38.85

Data for tapped unit DB-N-2/2A:

Table 4.22: Calculation for Power Consumption of Socket of DB-N-2/2A

NUMBER OF SOCKET (NOS)	POWER CONSUMPTION PER UNIT IN A WEEK (kWh)
82	1.36

Estimation for whole of second floor for socket:

Table 4.23: Estimation of Total Power Consumed by Socket for Second Floor

NUMBER OF SOCKET (NOS)	ESTIMATION OF TOTAL POWER CONSUMED PER WEEK (kWh)
168	228.16

Total estimated power consumption of 2nd floor for a week = 773 kWh

4.6.2 Sixth Floor of UTAR KB Block

Data for tapped unit DB-N-6/1B:

Table 4.24: Calculation for Power Consumption of Lighting of DB-N-6/1B

NUMBER OF LIGHTING (NOS)	RATED POWER (Wh)	TOTAL RATED POWER (Wh)	PERCENTAGE OF POWER USED (%)	TOTAL POWER USED IN A WEEK (kWh)	POWER CONSUMPTION PER UNIT IN A WEEK (kWh)
26	13	338	4.50	24.29	0.93
7	18	126	1.68	9.05	1.29
10	26	260	3.46	1868	1.87
238	28	6664	88.76	478.85	2.01
3	40	120	1.60	8.62	2.87

Estimation for sixth floor lighting:

Table 4.25: Estimation of Total Power Consumed by Lighting for Sixth Floor

LIGHTING (NOS)	RATED POWER (Wh)	ESTIMATION OF TOTAL POWER CONSUMED PER WEEK (kWh)
87	13	81.27
51	18	65.96
218	26	407.28
685	28	1378.21
4	40	11.50

Data for tapped unit DB-N-6/2C:

Table 4.26: Estimation of Total Power Consumed by Socket of DB-N-6/2C

NUMBER OF SOCKET (NOS)	POWER CONSUMPTION PER UNIT IN A WEEK (kWh)
489	1.21

Estimation for 6th floor socket:

Table 4.27: Estimation of Total Power Consumed by Socket for Sixth Floor

NUMBER OF SOCKET (NOS)	ESTIMATION OF TOTAL POWER CONSUMED PER WEEK (kWh)
168	204.02

Total estimated power consumption of 6th floor for a week = 2148.24 kWh

4.7 Energy Conservation Method

Energy conservation measures is important because it can helps save energy and reduce the energy cost for a building. To implement a proper energy conversation method, we must first classified the vast types of loads into essential load and non-essential loads. Essential loads are equipment that consumes active power to maintain their operation and is not interruptible. On the other hand, non-essential loads are equipment that only functions when there is demand. Since essential loads require constant supply of electricity to keep their operation running, non-essential loads such as lighting or air-conditioner are targeted.

The energy consumption pattern can be observed from the data collected. As shown in the graph of the energy consumption of weekdays, the peak power always happen around afternoon time. So, lectures or tutorials during this period can be shifted to a non-peak time to reduce the power consumed during peak period. This

can also results in a decrease in the peak power which then reduces the maximum demand surcharge by TNB. Besides that, changing the usage of the electrical appliances based on situation is another alternative method to save energy. For example, all the lighting and air-conditioners must be turned off when there is no classes going on. Another example is to arrange the essential loads so that not all loads are operating at their maximum capacity at the same time. If the loads are operating at the same time, it can leads to very high power consumption. Furthermore, sensor lighting can be implemented to reduce the usage of energy. For UTAR KB building, there are sensor lightings installed at the corridor for every floor. These lighting will sense the presence of human and will turned off when there is no one around. So by installing this lighting into lecture hall and office, the energy usage can be reduced.

Air-conditioner is the unit that consumes the most power. Current situation in UTAR is that the air-conditioner are constantly running even when there is no classes. Staff and student has to be advised to switch off the air-conditioner when the classes ended. The temperature setting on the air-conditioner can affect the power consumed by that unit. A lower temperature setting means the unit has to run for a longer time to achieve the desired temperature which increases its power consumption. Therefore, lecturer should be advised to increase the temperature setting on the air-conditioner unit for classes with less student. Besides that, there is potential energy saving in the centralized air-conditioning system which is the chiller. Energy saving equipment that are obtainable in the market can be installed to the chiller system to improve its efficiency. These energy saving equipment will optimize the chiller system in a way that it will not operate with excess capacity and preventing the consumption of unwanted energy.

Load shifting is an effective energy conservation method and it is widely implemented by industrial and large-scale commercial facilities. Energy storage system (ESS) can be installed in UTAR building. ESS can helps in performing peak load shifting. Peak load shifting is the process of lessen the impacts of large loads during the period of time by either advancing or delaying their effects until the power supply can meets the additional demand. When there is low power consumption which happens in period that is not working hours, the ESS will be charged. So when

there is an increase in the loading, ESS can discharged to supply electricity meeting the extra demand. In this way, the peak demand can be reduced resulting in a decrease in utility bill.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The main idea for this project is to analyse the power consumption of UTAR building in order to implement an appropriate energy conservation method. The power consumed in each floor is measured through the uses of two measuring units which are the power analyser and energy logger. After extracting the data collected from both units, the data are analysed through various method to observe the energy consumption pattern.

The data are first analysed through finding the correlation coefficient between any two sets of data to observe the linear relationship between them. Many observation can be made through the comparison of the two data. The peak demand can be observed through the graphs produced. In addition to that, the period where there is high power consumption can also be determined. The peak period is mostly caused by the packed timetable or many activities carried out during that time.

Histogram is produced to determine the frequency of occurrence of peak demand. After that, load duration curve can be formed and the time of high peak period and the period of peak demand can be observed in the curve. These information are crucial for finding suitable energy conservation method. The linear relationship between lighting and switch socket outlet is also found out through the help of graphic display. This proven the hypothesis that people will tend to use lights when they are using switch socket outlet. Due to limited budget and time, the

measuring units are tapped to one electrical riser only. Since certain amount of electrical appliances are connected to one electrical riser, the estimation of power consumed by all the appliances present in the particular floor is done through simple calculation. Many information are obtained through the analysis and these aids in the implementing of appropriate energy conservation method.

5.2 Recommendations

Although one of the measuring unit, the energy logger is an advanced unit, however, the other one, the power analyser is an outdated measuring unit. The memory of the power analyser is small, therefore the collection of data have to be done every week. Besides that, it does not have the advanced programming presents inside the energy logger such as auto-average of data and many more. Therefore, an improvement to the power analyser is favourable. The other recommendation here is to install a smart meter to the electrical system in UTAR. Smart meter is a more advanced measuring unit as compared to the energy logger. It can use to measure many parameters and it can provides the user with a daily update. Besides that, the user do not need to personally go to the unit and collects data because the data can be sent to the user via short messaging service (SMS). Furthermore, it can even allow the user to automatically control electrical appliances. Multi tariff functions can also be added to the smart meter to allow demand response techniques.

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APPENDICES

APPENDIX A: Walk Through Audit on Ground Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	3	-	-		
Back Staircase	1	3	-	-		
Toilet	2	26	-	-		
Entrance & Corridor	1	46	9	16		
Department of Admissions & Credit Evaluation	1	84	8	5		
Department of Program Promotion	1	42	30	8		
Store Room	4	16	-	-		
Meeting Room 1	1	60	4	2		
Meeting Room 2	1	36	4	2		
Multipurpose Hall	1	192	14	88		
					Stage Light	11
					PA System	8
Division of Finance	1	93	23	5		
Centre of Extension Education	1	93	30	5		
Division of Examinations, Awards & Scholarships	1	72	30	5		

Department of Student Affairs	1	72	23	7		
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APPENDIX B: Walk Through Audit of First Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	3	-	-		
Back Staircase	1	3	-	-		
Toilet	2	26	-	-		
Surau	1	4	-	-		
Multipurpose Area	1	60	22	16		
Lecture Theatre	5	450	10	6	PA System	2
					Projector	1
Lecture Room	2	90	7	2	PA System	1
					Projector	1
Tutorial Room	4	72	5	1	PA System	1
					Projector	1
Student Activity Centre	1	24	8	2		
Sport Facilities & Gym Centre	1	36	10	2		

APPENDIX C: Walk Through Audit on Second Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	3	-	-		
Back Staircase	1	3	-	-		
Toilet	2	26	-	-		
Surau	1	4	-	-		
Corridor	1	59	22	13		
Lecture Theatre	5	158	10	6	PA System	2
					Projector	1
Lecture Room	7	79	7	2	PA System	1
					Projector	1
Tutorial Room	4	44	5	1	PA System	1
					Projector	1
CEE Training Room	1	11	7	2	PA System	1
					Projector	1

APPENDIX D: Walk Through Audit on Third Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	26	-	-		
Corridor	1	99	22	12		
Lecture Room	7	315	7	2	PA System	1
					Projector	1
Tutorial Room	18	324	5	1	PA System	1
					Projector	1
Academic Staff Room	50	129	100	57		
Department of Alumi Relations & Placement	1	21	18	2		
Store	3	4	-	-		

APPENDIX E: Walk Through Audit on Fourth Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	26	-	-		
Corridor	1	27	-	7		
Store	1	4	-	-		
LKC FES Tutor & Postgraduate Room	1	54	-	2		
Internet/Comp uting Lab	3	54	144	2		
Library's Staff Room	1	60	23	3		
Mary Kuok Pick Hoo Library	1	230	57	250	Printer	2

APPENDIX F: Walk Through Audit on Fifth Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	26	-	-		
Corridor	1	95	22	15		
Store Room	4	16	-	-		
Chemistry Lab	2	72	40	2	Fan	8
Biology Lab	1	36	40	2	Fan	8
Physics Lab	1	36	40	2	Fan	8
CFS Preparation Lab & Staff Room	1	18	23	2		
CFS Multipurpose Lab	1	24	40	2	Fan	2
Lecture Room	3	270	7	2	PA System	1
					Projector	1
Tutorial Room	6	108	5	1	PA System	1
					Projector	1
Postgraduate Room	2	60	40	2		
LKC FES Unit Operation Lab	1	30	40	4		
LKC FES Process Control & Reaction Lab	1	30	40	4		
LKC FES	1	30	40	4		

Bioprocess & Environmental Lab						
LKC FES Instrumentation Lab	1	30	40	4		
Department of General Services	1	33	23	4		
Department of Security & Safety	1	21	23	4		
LKC FES Waste Room	1	9	-	1		

APPENDIX G: Walk Through Audit on Sixth Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	13	-	-		
Corridor	1	67	-	23		
LKC FES Digital Lab	1	30	96	60		
LKC FES Computer Technology Lab	6	96	184	60	Computer	184
Officer Room	1	6	-	23	Computer	6
LKC FES Electronics & Physical Lab	1	40	-	60		
LKC FES Electromagnet ics Lab	1	30	96	60		
LKC FES Telecommuni cation Lab	1	30	96	60		
LKC FES Physics Lab	1	36	-	60		
LKC FES Architecture Studio	1	225	-	45		
Utility Room	1	9	-	1		
LKC FES PCB Workshop	1	18	-	2		
LKC FES Foundry Lab	1	15	-	2		
LKC FES Etching Workshop	1	6	-	1		

LKC FES Power & Machine Lab	1	30	15	60		
Department of Estates & Facilities	1	45	-	23		
LKC FES Molecular & Tissue Engineering Lab	1	24	-	60		
LKC FES Biomedical Lab	1	36	-	60		
LKC FES Robotics & Automation Lab	1	32	-	60		
LKC FES Analog Lab	1	30	96	60		

APPENDIX H: Walk Through Audit on Seventh Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	26	-	-		
Corridor	1	91	22	10		
Tutorial Room	2	24	4	2	PA System	1
					Projector	1
FCI Design Room	1	24	10	1		
FCI Art Room	1	30	10	2		
FCI Game Room	1	9	10	1		
FCI PC Lab	3	36	80	1		
FCI iMac Lab	3	36	80	1		
FCI Photo Studio	4	32	18	1		
FCI Audio Lab	4	16	30	1		
FCI Early Child Education Lab	1	12	-	2		
LKC FES Advaced Mechanics Lab	1	24	60	2		
LKC FES Microscopy Lab	1	30	60	2		
LKC FES Thermofluids Lab	1	30	60	2		
LKC FES Applied Mechanics Lab 1	1	30	60	2		
LKC FES Applied	1	30	60	2		

Mechanics Lab 2						
LKC FES Chemical Engineering Lab	1	28	60	2		
Department Of International Student Services	1	30	40	2		
Department Of Soft Skills Competency	1	33	40	4		
LKC FES Heat Treatment & Furnace Lab	1	16	60	2		
LKC FES Materials & Manufacturing Engineering Lab	1	26	60	2		
LKC FES Hydraulics Lab	1	20	60	2		
LKC FES Traffic Engineering Lab	1	20	60	2		
FCI Counter	1	8	18	1		
FCI Equipment Room	1	12	18	2		

APPENDIX I: Walk Through Audit on Eighth Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	13	-	-		
Concourse Area	1	44	22	7		
Office Concourse	1	53	23	10		
LKC FES FGO	1	72	40	7	Printer	3
Mimos Lab	1	32	12	5		
Meeting Room	1	32	10	2		
Academic Staff Room	1	400	400	200	Printer	2

APPENDIX J: Walk Through Audit on Ninth Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT	EXTRA ITEM	NUMBER OF UNIT
Lift Lobby 1	1	4	-	1		
Lift Lobby 2	1	4	-	1		
Main Staircase	1	2	-	-		
Back Staircase	1	2	-	-		
Toilet	2	13	-	-		
Concourse Area	1	53	22	9		
Office Concourse	1	33	2	10		
ICS FGO	1	18	8	1		
Academic Staff Room	1	200	200	100		
LKC FES Mechatronics Lab	1	8	60	1		
LKC FES Acturial Modelling & Simulation Lab	1	16	29	1		
LKC FES Numerical & High Performance Computing Lab	1	18	24	2		
LKC FES Investment & Trading Strategies Lab	1	16	-	1		
CFS FGO	1	33	60	2		
FCI FGO	1	33	60	2		
Department Of Consultancy &	1	21	23	2		

Commercialisation						
ICS Academic Staff Office Councourse	1	13	2	3	Printer	2
ICS Academic Staff Room	11	22	22	11		

APPENDIX K: Walk Through Audit on Tenth Floor

LOCATION	NUMBER OF LOCATION	NUMBER OF LIGHTING	NUMBER OF SOCKET	NUMBER OF A/C POINT
Lift Lobby 1	1	4	-	1
Lift Lobby 2	1	4	-	1
Main Staircase	1	1	-	-
Back Staircase	1	1	-	-
Toilet	2	13	-	-
Concourse Area	1	43	22	9
Conference Room	2	10	20	2
President Office	1	25	6	4
Office Of Chairman	1	3	6	1
Office Of Chancellery	1	14	6	2
IAD Vice President Office	1	15	6	3
SDAR Vice President Office	1	15	6	3
RDC Vice President Office	1	15	6	3
Institute Of Postgraduate Studies & Research	1	78	-	3
Division Of Quality Assurance	1	12	23	2
IT Infrastructure & Support Centre	1	45	-	3
Software Development & Multimedia Services Centre	1	39	-	3
DCInternet	1	24	-	2
Division Of Human Resources	1	81	-	5
DCCPR	1	30	-	2

APPENDIX L: Timetable for Second Floor

DAY/TIME	NUMBER OF CLASSES											
	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800
	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
MONDAY	-	13	13	13	12	13	11	12	11	11	10	4
TUESDAY	-	11	13	13	12	12	14	14	14	13	11	7
WEDNESDAY	-	13	13	13	12	13	13	12	14	13	11	6
THURSDAY	-	13	12	14	12	13	14	10	14	13	12	6
FRIDAY	-	13	13	14	10	-	-	13	12	9	5	-