DEMAND SIDE MANAGEMENT:
LOAD FORECASTING BASED ON TIMETABLE

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(Hons.) Electrical and Electronic Engineering

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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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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"DEMAND SIDE MANAGEMENT: LOAD FORECASTING BASED ON TIMETABLE"** was prepared by **TEO TECK CHEONG** 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.

Approved by,

Signature : _________________________

Supervisor : MR CHUA KEIN HUAT

Date : 18/4/2013

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DEMAND SIDE MANAGEMENT:
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ABSTRACT

In the past decades, industrial energy audits have being developed remarkably due to the increasingly expensive energy costs and the world trend is now moving towards a sustainable future. Generally, a high billing of electricity has a linear relationship with its power consumption. In other words, the bill of the electricity will increase when the power consumption is rising. This paper presents the energy auditing assessment toward the SE block of UTAR located in Kuala Lumpur (KL) Setapak campus. The main reason to conduct the energy auditing assessment is to identify the causes of the high billing of electricity by looking into the power consumption of SE block. Hence, in order to know the estimated power consumption, prediction of the power consumption of loads throughout the SE block based on timetable is done as the objective in this project. In this project, we will use the timetable obtained from the general office to forecast the power consumption of loads in each floor of the SE block. First of all, the real time power parameters are obtained from the main switchboard in SE block by using the TES-3600 power analyzers. After that, all the temporary data will be saved within its memory. Then, the data from power analyzers are transferred to laptop by using the RS232 to USB converter. Then, the average power consumption of real time loads are obtained through the method of taking the real time data for four consecutive day of week that counts a month. For example, the Monday of 11/3/2013, 18/3/2013, 25/3/2013 and 1/4/2013 that count a month will result in the average power consumption of real time loads on Monday. The same method also applicable to find the average estimated power consumption of loads based on timetable. Hence, the average estimated power consumption of loads is compared with the average power consumption of real time loads in the SE

block. In addition, the predictive ability of the average estimated power consumption of loads to the average power consumption of real time loads is verified by using the correlation function in the Microsoft Excel. Then, the power distribution of SE block is further divided into the ground floor, first floor and second floor in order to have a better understanding on which floors of the SE block consumed the most energy during the particular timeframe of 8:00 until 18:00. Moreover, the power utilisation of power equipments in use on each floor of SE block can then be identified. Thus, power equipment that consumed the most energy is recognised in order for the corrective steps to be taken.

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LIST OF SYMBOLS / ABBREVIATIONS

y_t	Peak Load Value
$\{y_t\}_{t=1}^{T}$	Peak Load Value denoted as Time Series
$\{\in_t\}_{t=1}^{T}$	Time Series of White Noise
S_t	Peal Load with Periodicity *s*
N_t	Peak Load without Periodicity
s	Period of S_t which is 24 Hours
x_t^1	Time of Day
x_t^2	Day of Week
x_t^3	Ambient Temperature
x_t^4	Variance
x_t^5	Last Peak Load
T	Total Duration of Measurement
γ	Regularization Parameters
t	Hour
σ^2	Variance
ANN	Artificial Neural Networks
AR	Auto-Regression
ARMA	Auto-Regression Moving Average
CFL	Compact Fluorescent Lamp
HVAC	Heat, Ventilating and Air Conditioning
ECO	Energy Conservation Opportunities
ECM	Energy Conservation Measures
EEM	Energy Efficiency Measures
DSM	Demand Side Management

LS-SVR	Least Squares Support Vector Regression
MA	Moving Average
RMSE	Root Mean Square Error
ROI	Return On Investment
SARMA	Seasonal Auto-Regression Moving Average
SVR	Support Vector Regression
TNB	Tenaga Nasional Berhad
UTAR	Universiti Tunku Abdul Rahman
KL	Kuala Lumpur

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CHAPTER 1

INTRODUCTION

1.1 Background

Energy audit is an inspection, investigation and analysis of energy flows for energy conservation in a building, process or system in order to cut down the amount of energy input into the system without affecting the current outputs. In the past decades, industrial energy audits have being developed vastly due to the increasingly expensive energy costs and the world trend is now moving towards a sustainable future. In the industrial energy audits, it is the Heat, Ventilating and Air Conditioning (HVAC), lighting, and production equipment that consumed the most energy. (Energy audit 2013)

Energy audit is normally used to describe some energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of investors. Several audit procedures have been developed for commercial buildings such as ASHRAE, IEA-ECBCS Annex 11 and Krarti (2000). Audit is required to identify the most efficient Energy Conservation Opportunities (ECOs) or Measures (ECMs). (Energy audit 2013)

Based on the existing audit methodologies developed by ASHRAE, IEA-ECBCS Annex 11 and Krarti (2000), the main concerns of audit process are:

- The detailed analysis of building and utility data, including the study of installed equipment and the analysis of energy bills
- The survey and inspection of the real time operating conditions
- The understanding of the building behaviour includes the consideration of weather, occupancy and operating schedules
- The choices and the evaluation of energy conservation measures
- The forecasting of potential energy saving
- The consideration of customer regarding about their needs and comfortabilities

(Energy audit 2013)

Generally, there are three levels of audits defined by ASHRAE:

- Level 1: Site Assessment or Preliminary Audits

This is a preliminary analysis made to identify the minimal cost and even no cost energy saving opportunities. Besides that, potential capital improvements are also sought in this stage. The activities carried out include an assessment of energy bills and a brief site survey and investigation throughout the building.

- Level II: Energy Survey and Engineering Analysis Audits

This type of energy audit is also tends to identify the no cost and the minimal cost opportunities. Moreover, it also provided Energy Efficiency Measures (EEM) recommendations together with financial plans and potential energy saving opportunities. EEM is an alteration being made to building and controls or the installation of equipments that will result in a lower energy usage. In addition, Level II audits will include a detailed and depth analysis of energy cost, energy usage and the characteristics of building and a more precise survey and investigation of how the energy is distributed and consumed within a building.

- Level III: Detailed Analysis of Capital-Intensive Modification Audits (Investment Grade Audit)

This type of energy audit generally provides solid recommendations and financial analysis for the major capital investments. It also emphasized the expected Return on Investment (ROI) after upgrading a facility's energy infrastructure. Compared to Level I and Level II activities, Level III audits provide monitoring of data, data collection and even detailed engineering analysis.
(Pacific Northwest National Laboratory, 2011)

1.2 Aims and Objectives

The objectives of this project are:

- To forecast the load in SE block of UTAR KL Setapak campus based on timetable in response to avoid the peak demand penalty imposed by the TNB.

- To determine the relationship between the forecasting loads to the actual loads obtained by using the correlation coefficient.

- To identify the major power consumption equipment on SE block of UTAR KL Setapak campus.

CHAPTER 2

LITERATURE REVIEW

2.1 Demand Side Management

Demand Side Management (DSM) has the capability of reducing peak electricity demands so that utilities can save on the cost of expanding their current power capacity. DSM has several beneficial effects which including mitigating electrical system emergencies, reducing the number of blackouts and increasing system reliability when the overall load on an electricity network is reducing. The DSM concepts that deal with energy efficiency measures and reduce the energy demand of end users. It introduces peak demand management which does not necessarily to reduce the total energy consumption but to shed loads in order to achieve optimum energy demands. The main benefit of DSM is to reduce energy costs for a given output. (United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

In addition, various reasons are established for promoting DSM with the aims of providing the cost reduction, environmental & social improvement and reliability & network issues. From the point of view of an energy customer, DSM activity is strongly recommended because the DSM activity can provide the following advantages:

- Reduced the cost of customer’s energy bills
- Reduced the extra peak power prices for electricity
- Reduced the air pollution to the environment

- Reduced the need for extra new power plant, transmission and distribution networks
- Reduced the dependency on unsustainable energy sources such as coal for generating the power plant

(United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

2.2 Types of DSM Approaches

2.2.1 Energy Reduction Programmes

It main aim is to reduce the demand through a more efficient processes, buildings and equipment. It involved a typical energy reduction measures such as energy saving tips for the existing housekeeping items. Most of these housekeeping items can be implemented at minimal cost or even no investment is needed, but others especially the group of people who have particular relevance to industrial and commercial enterprises may require significant capital investment.

In the industrial and commercial sectors, production of steam and hot water is a main activity for most enterprises and uses latest technology. But poor boiler operation and steam systems result in a significant loss of energy. Performance improvement steps which are practical and at minimal cost option are often considered. Combustion conditions of the systems are monitored routinely in order to keep the efficiently as high as possible while ensuring there are adequate controls to adjust the quality of combustion air.

Moreover, lighting fixtures is another equipment that often consumes 10% or more of industrial plant electricity or 50% or more in commercial buildings. Hence, lighting offers a great opportunity for saving. The common method to improve lighting efficiency is to replace the existing type with energy efficient fluorescent tubes, CFL, and other low energy light sources. Energy efficient electronic ballasts are also in consideration. Besides that, different parts of the work area can use different lighting levels in order to maintain the required luminosity and avoid any energy wastage. (United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

2.2.2 Load Management Programmes

Utilities suppliers can alter the distribution of the demand and time of electricity usage by performing the load management for their customers. Load management will generally be conducted so that the customer will be able to continue their production while the utility achieves a modified load curve. Types of load management techniques involved are (www.cogeneration.net, 2206):

- Load levelling
- Load control
- Tariff incentives and penalties

2.2.2.1 Load Levelling

The objective of the load levelling is to assist in optimizing the current generation base-load without the need of operating the reserve capacity in order to meet the periods of peak demand. Figure 2.1 shows the classic forms of load levelling.

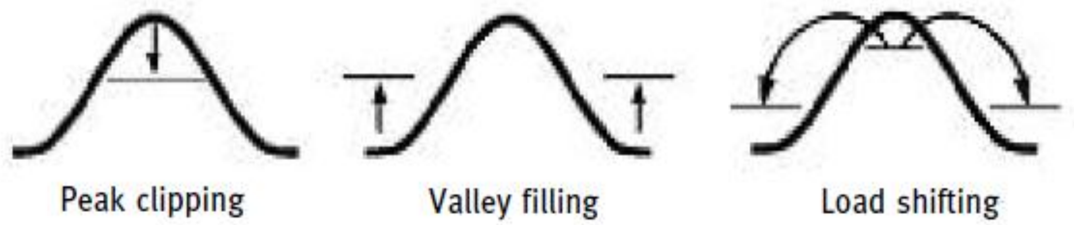


Figure 2.1: Classic Forms of Load Levelling

Source: engineering.purdue.edu, 2006

Generally, there are three types of classic forms of load levelling namely peak clipping, valley filling and load shifting. Peak clipping can be defined as the peak of the demand is "clipped" and the load is reduced at peak times. The overall effect of this direct load control technique towards the demand is not significant and it is more focuses on reducing the peak demand. Besides that, valley filling can be applied when there is a situation where low demand valleys/periods are to be "filled" by constructing off-peak capacities. This kind of load management can be achieved by thermal energy storage (water heating or space heating) that displaces fossil fuel loads. In addition, load shifting is another load management technique which is widely applied in the current distribution networks. The characteristic of the load shifting is the loads are "shifted" from peak demand either by achieving clipping or filling or both conditions are achieved. Load shifting has the advantage of time independence of loads. Furthermore, load shifting is differs from clipping in that the load is still presented in the overall demand but in clipping it is removed. (United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

2.2.2.2 Load Control

Load control is where loads such as lighting, heating, ventilation and cooling can be turn on or off, usually done remotely by the utility operator. In this case, customers may have back-up generators or energy storage system and typically they will have an interruptible agreement with the utility in return for a special rate. Moreover, utilities may even activate some on-site generators in order to meet the requirement of the rising peak demand on the gird.

Furthermore, rolling blackouts may be used by the utility company in order to reduce demand when the demand surpasses the energy capacity it can provide. Rolling blackouts are the systematic method of switching off the supply to areas within a supplied region such that each area takes turns to "lose" supply. Prior announcements or schedule notices should be made so that businesses and homes can plan for their own usage of energy during that particular period. (United Nations

Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

2.2.2.3 Tariff Incentives and Penalties

Utilities encourage a certain pattern of energy usage by tariff incentives where customers can use energy at certain times to achieve a better-priced rate for their energy use. These include:

- Maximum demand rates, where utilities have different charges for peak demand. Higher peak demand charges would encourage a user to distribute loads in an even fashion to avoid the penalty.
- Power factor charges, where users are penalized for having power factors below a fixed threshold, 0.85. (Tenaga Nasional Berhad 2012)
- Real-time pricing, where the rate varies based on the utilities load (by the hour, kWh).

(United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

2.2.3 Load Growth and Conservation Programmes

Load growth programmes are introduced and implemented in order to improve customer productivity and sustain the standard and regulation of environmental issues while increasing the sale of power for the utilities. This will expand the market share of the utility and possess an ability to fill valleys and increase the peaks. These programmes can usually shift the unsustainable energy practices to more better and efficient practices such as the reduction of the usage of unsustainable energy such as fossil fuels and raw materials. Strategic load growth can be defined as the general change of load shape that refers to the increment in sales beyond the valley filling. This is shown in the Figure 2.2:

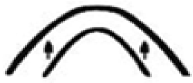


Figure 2.2: Strategic Load Growth

In the future, load growth may include electrification. The electrification is a term currently being employed to describe the new emerging electric technologies surrounding electric vehicles, industrial process heating and automation. An example is the promotion of electro-infrared technologies to heat, dry or cures a variety of products such as wood, paper and textiles. Electro infrared technology replaces the use of fossil fuel furnaces or other technologies which lead to environmentally problem. (www.epri.com, 2006).

Load conservation programmes are typically utility-stimulated and directed at end-use consumption which involved a declination in sales with a change in usage pattern. Examples include weatherization (insulation, sealing, double glaze windows, etc) and improvement in the efficiency of appliance. (engineering.purdue.edu, 2006). Strategic conservation can be defined as the change of load shape that results from utility-stimulated programmes directed at end use consumption. This is shown in Figure 2.3:

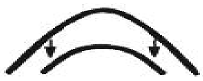


Figure 2.3: Strategic Load Conservation

(United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP), April 2005)

2.3 Classification of Power Consumption Loads

Appropriate and suitable classifications of power consumption loads are needed for the efficient load management. The power consumption loads are divided into three categories based on their intrinsic characteristic of appliances.

2.3.1 Baseline Load

Baseline load is the appliances which their power consumption must be served immediately at any given time or for some appliances to be maintained on standby mode. The examples of these baseline loads are lighting, cooking stove, computing and network devices. (Giuseppe Tommaso Costanzo et al., 2012)

2.3.2 Burst Load

Burst load can be related to the appliances that will have a constant period of operating time and can be required to start and finish at given duration. These appliances include clothes dryer, oven, dishwasher, washing machine and other else. The accumulation of these burst load actually contributes to the increase of peak load. Hence, burst load can be a critical issue that required a careful management in order to reduce its impact on power consumption efficiency and energy cost on demand side. (Giuseppe Tommaso Costanzo et al., 2012)

2.3.3 Regular Load

Regular Load can be defined as the power consumption required by appliances that are always in working condition during a long period of time. Examples of these appliances are water heater, refrigerator, HVAC, etc. But, these related appliances can be interrupted intermittently. Hence, the regular loads can be considered as a particular case of burst loads when were given such characteristic. (Giuseppe Tommaso Costanzo et al., 2012)

2.4 On Hourly Peak Load Prediction

Peak load can be defined as the highest aggregate demand for power consumption in a particular area within a particular time frame. A reduction in peak load would result in significant saving cost of the large infrastructural cost and electricity cost. Solutions to reduce the peak load include demand response and storage. Both of these solutions require accurate prediction of a home’s or building’s peak and mean loads. Existing works and studies have focused only on mean load prediction. It was found out that these methods result in high error when predicting the peak load. (Rayman Preet Singh, Peter Xiang Gao and Daniel J. Lizotte, n.d.)

Power consumption of a home is driven by consumer’s activity while power consumption of a building is driven by staff and customer’s activities. Peak load of a home and building bounds its power consumption (mean load) for any given timescale. Hence, applications such as demand response was used for peak load prediction in order to have a better understanding of demand so that limitation of the demand can be set up without affecting the consumer’s comfort. Thus, if the prediction of the peak demand can be done, the home or building storage can be charged/discharged smartly and intentionally which will lead to the better power utilization. (Rayman Preet Singh, Peter Xiang Gao and Daniel J. Lizotte, n.d.)

Peak load prediction such as demand response and storage are the applications of peak load prediction. Demand response involves peak load reduction by changing the power consumption patterns by varying pricing policies. Hence, the peak load prediction is used to understand the home’s or building’s future peak load and it can be used for dynamic pricing and scheduling appliance loads. On the other hand, the main objective of storage is to reduce peak load by supplying the stored energy to the home or building during peak hours without hitting the peak load demand. (Rayman Preet Singh, Peter Xiang Gao and Daniel J.Lizotte, 2012)

2.4.1 Prediction Model of Regression

The regression based of prediction model is carried out by first defined a set of 5 relevant features of each measured peak load value y_t in order to capture the different properties that are believed to drive the peak load. Following are their physical meaning & definition:

1) Time of Day (x_t^1): In a home or building, consumers' activities normally follow an underlying routine. For example, the consumers will normally use air conditioning in the afternoon and cook food during evening. This pattern is expected to repeat across different days. For hourly peak load y_t, time of day (x_t^1) is classified as a feature where $x_t^1 \in \{1,2,3\ldots 24\}$.

2) Day of week (x_t^2): Normally consumer activity pattern vary remarkably on weekends compared to weekdays. Thus, in order to consider the time t of the peak load y_t, day of week x_t^2 is classified as a feature where $x_t^2 \in (1,2,3,\ldots 7)$.

3) Ambient temperature (x_t^3): Seasonality and weather can affect the power consumption because consumer will use the air conditioning and electric heaters more frequently in a warm and cold weather respectively. So, x_t^3 is classified as the average ambient temperature and it is used as a feature for the (t+1)th hour. The reason for this feature is because the x_t^3 is not observable until the (t+1)th hour.

4) Variance (x_t^4): Variance is defined because of most of the consumer appliances having different power consumption pattern and their appliances operated in different modes of operation. These appliances include refrigerators, microwave ovens and dish washers. A huge variation will occur

in the appliance's and the total's load when these appliances are operated in different modes of operation. Thus, in order to capture consumer's activity variance of measured load values is defined as a feature x_t^4 for hour t during the (t-1)th hour.

5) Last peak load (x_t^5): The period of a consumer's activity typically exceeded the normal power consumption across hour. Thus, a high hourly peak load is more likely to occur if the previous hour's peak load was also high due to the activity of the consumer.

The Day of week ($x_{t,1}^2$) and time of day (x_t^1) are encoding as the following. The Day of week (x_t^2) is presented as x_t^2 = ($x_{t,1}^2$, $x_{t,2}^2$, $x_{t,3}^2$, $x_{t,4}^2$, $x_{t,5}^2$, $x_{t,6}^2$, $x_{t,7}^2$) where

$$x_{t,i}^2 = \begin{cases} 1, if\ i = x_t^2, \\ 0, otherwise \end{cases}$$

So, Monday is represented as x_t^2 = (1, 0, 0, 0, 0, 0, 0). The time of day (x_t^1) in the term of hour is also encoded similarly. The reason of such encoding in the term of hours and days is to allow the model to predict the values in a much wider range. Given the feature vector, x_t = {x_t^1, x_t^2, x_t^3, x_t^4, x_t^5} of hour t, the following nonlinear regression based techniques are applied to find a function f (.), such that, $y_t \approx f(x_t)$. Following techniques are used to obtain the function f.

1) Support Vector Regression (SVR)
2) Least Squares Support Vector Regression (LS-SVR)
3) Artificial Neural Networks (ANN)

The contribution of physical features (x_t^1, x_t^2, x_t^3) and the history-based features (x_t^4, x_t^5) towards the predictive accuracy are evaluated by measuring their cross-validation errors. For example, their impact on the accuracy of SVR is shown in Figure 2.4 which shows the feature analysis for peak load prediction for one home by using a polynomial kernel of degree 3 and varying γ that is the regularization parameter. The training data will be fitting more closely when we increase the γ.

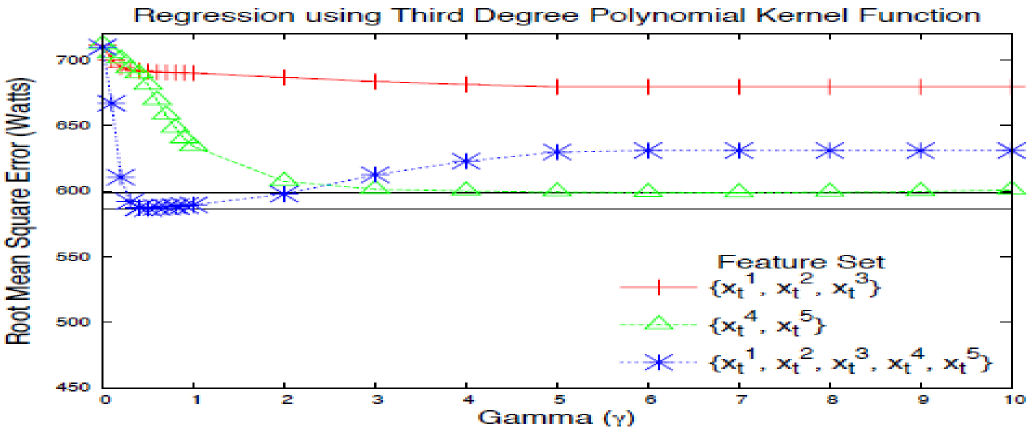


Figure 2.4: Variation of prediction Root Mean Square Error (RMSE) with varying γ

Source: Rayman Preet Singh, Peter Xiang Gao and Daniel J.Lizotte, 2012

2.4.2 Prediction Model of Time Series Based

Prediction model of time series method is applied to make possibility of improvement in prediction accuracy by making better use of historical load in order to make a good prediction.

Prediction of peak load is difficult due to the instability of the exact behaviour of the consumer although there is an observable routine pattern of the consumer. Examples of the instability behaviour of consumer are they sometimes wash the dishes on morning which lead to under-prediction condition or skip their cooking of dinner which caused over-prediction. This is the problem of the regression based method that results in low prediction accuracy. In order to model both the routine and random consumer activity, Auto-Regression Moving Average (ARMA) model is used. The measured peak load is denoted as a time series $\{y_t\}_{t=1}^{T}$, where y_t is the peak load of hour t and T is the total duration of measurement. Then, the ARMA model is break down into two parts which are Auto-Regression (AR) and Moving Average (MA). Auto-Regression (AR) captured the consumer's routine activity while Moving Average (MA) captured the consumer's random activity by tracing the sudden fluctuations in the time series. Moving Average (MA) is actually a white noise process. In addition, because the consumer's routine activity follow a daily pattern, Seasonal ARMA (SARMA) is used to model the time series.

For ARMA model, consider a time series of white noise $\{\in_t\}_{t=1}^{T}$ and the given $\{y_t\}_{t=1}^{T}$, y_t can be represented as the linear combination of the current white noise $\in_t$, white noise values $\{\in_{t-1,\dots,}\in_{t-q}\}$ and previous observations $\{y_{t-1,\dots,}y_{t-q}\}$. This forms the ARMA (p,q) model which defined as:

$$y_t = \underbrace{\delta + \textstyle\sum_{i=1}^{p} \emptyset_i y_{t-1}}_{AR\ (routine\ activities)} + \underbrace{\in_t - \textstyle\sum_{i=1}^{q} \theta_i \in_{t-1}}_{MA\ (random\ activities)} \tag{2.1}$$

where p and q represent the degree or number of previous timepoints in the model. Besides that, variable such as δ, $\emptyset_i$ and θ_i are model parameters. The backshift operator B is defined as:

$$B^i y_t = y_{t-1} \tag{2.2}$$

Equation (2.2) is substituted into Equation (2.1):

$$y_t = \underbrace{\delta + (\textstyle\sum_{i=1}^{p} \emptyset_i B^i) y_t}_{AR\ (routine\ activities)} + \underbrace{(1 - \textstyle\sum_{i=1}^{q} \theta_i B^i) \in_t}_{MA\ (random\ activities)} \tag{2.3}$$

Let

$$\emptyset(B) = \textstyle\sum_{i=0}^{p} \emptyset_i B^i \text{ , } \vartheta(B) = 1 - \textstyle\sum_{i=1}^{q} \emptyset_i B^i \tag{2.4}$$

Rewriting Equation (2.3) by using the Equation (2.4):

$$\emptyset(B)\, y_t = \delta + \vartheta(B) \in_t \tag{2.5}$$

where $\in_t$ is independently and identically distributed with zero mean and constant variance σ^2.

For SARMA model, Seasonal Auto-Regressive Moving Average model is applied to capture the periodic variation in the peak load time series as the hourly peak load follows a daily periodic pattern. The seasonality in this case is mainly caused by daily routine rather than weather. Hence, the time series is now break down into two parts:

$$y_t = S_t + N_t \tag{2.6}$$

where S_t is defined as peak load with periodicity s while N_t is defined as peak load without periodicity. The s is defined as the period of S_t which is 24 hours.
Thus, S_t = S_{t+s} and by applying Equation (2.2):

$$S_t - S_{t-s} = (1-B^s)\, S_t = 0 \tag{2.7}$$

Equation (2.6) is multiplying by $1-B^s$on both sides:

$$(1-B^s)\, y_t = (1-B^s)\, S_t + (1-B^s)\, N_t = (1-B^s)\, N_t \tag{2.8}$$

Equation (2.4) is applied to model $(1-B^s)\, y_t$ since $(1-B^s)\, N_t$ lack periodicity. So, now the final equation is as follow:

$$\emptyset(B)(1-B^s)\, y_t \ = \sigma + \vartheta(B)\ )(1-B^s)\, \epsilon_t \tag{2.9}$$

where parameters of δ, $\emptyset_i$ and θ_i are found by minimizing $\epsilon_t^2$for each value of t over the dataset.
(Rayman Preet Singh, Peter Xiang Gao and Daniel J. Lizotte, n.d.)

CHAPTER 3

METHODOLOGY

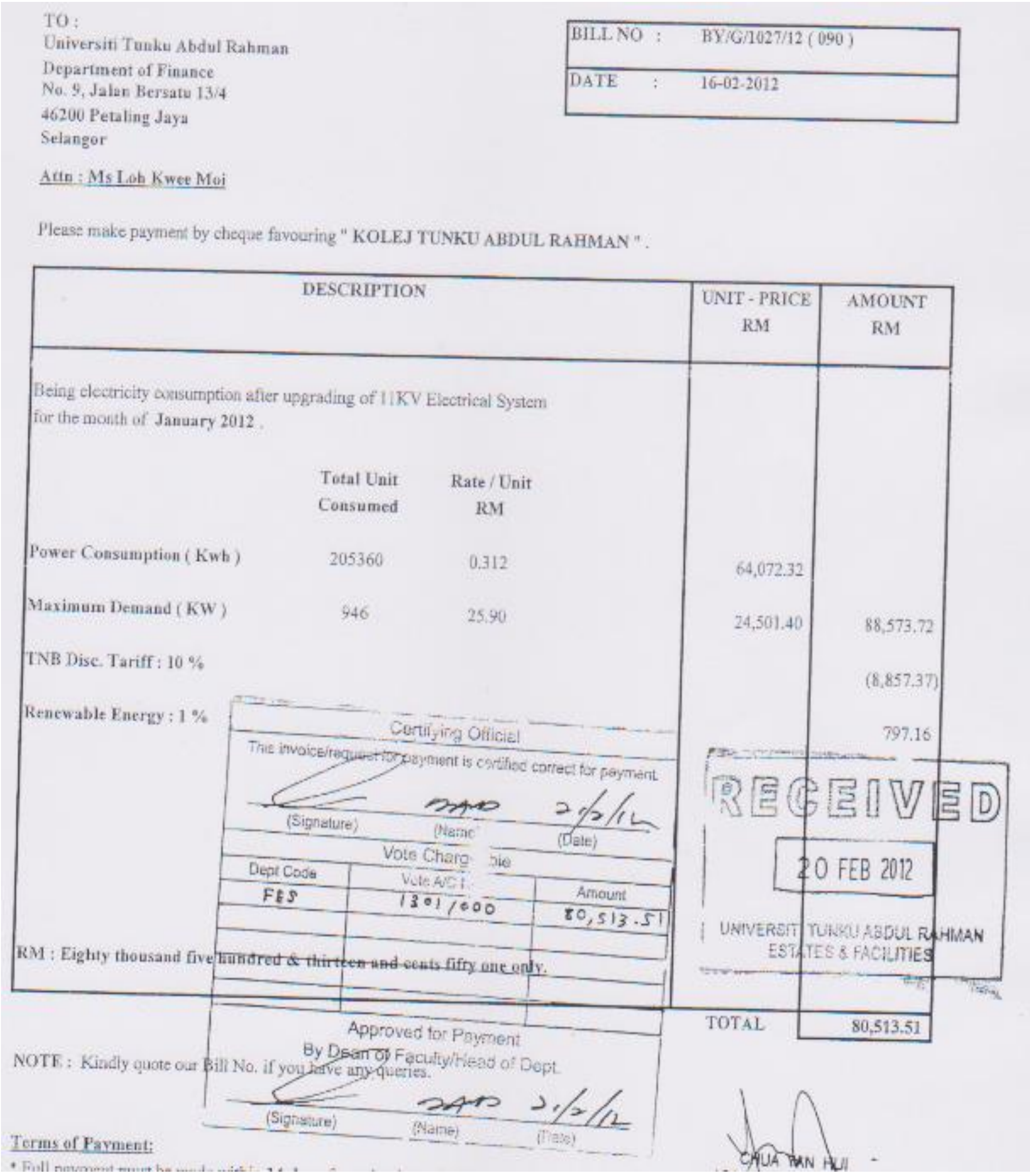
3.1 Site Assessment or Preliminary Audits

3.1.1 Site Survey

Preliminary audits of the SE block of UTAR KL Setapak campus is done by personal site visiting to the whole building of the SE block. SE block of UTAR KL Setapak campus consists of three floors where the ground floor is used to conduct any laboratory experiments while the first floor is used for the purpose of teaching and having tutorial session only. Moreover, the second floor of the SE block is actually a computer area which the students are free to assess the rooms and used the computer for their study purpose. Generally, the second floor of the computer rooms are used to conduct the lecture classes which required the license technology assessment equipments such as computer installed with the original license of specific software for the study purpose of the students. Site survey and inspection of SE block are done in order to have a better understanding of the characteristics of the building of SE block and their duration of energy usage throughout the building. In addition, effective communication to the staff of SE block also enabled us to know well about the actual situation of the energy usage of each floor.

3.1.2 Assessment of UTAR Energy Bills

Energy bill of 7 blocks of UTAR buildings as shown in Figure 3.1 are assessed for the purpose of knowing the price of the electricity being consumed and to identify the unconscious payment such as the breach of maximum demand that result in a significant payment of penalty imposed to the consumer. Corrective actions such as identifying the reasons for such a high breach of maximum demand and solutions necessary to be taken to reduce the maximum demand are to be carried out immediately to avoid the maximum demand penalty imposed by the utility company.



TO :
Universiti Tunku Abdul Rahman
Department of Finance
No. 9, Jalan Bersatu 13/4
46200 Petaling Jaya
Selangor

Attn : Ms Loh Kwee Moi

BILL NO :	BY/G/1027/12 (090)
DATE :	16-02-2012

Please make payment by cheque favouring " KOLEJ TUNKU ABDUL RAHMAN " .

DESCRIPTION			UNIT - PRICE RM	AMOUNT RM
Being electricity consumption after upgrading of 11KV Electrical System for the month of January 2012 .				
	Total Unit Consumed	Rate / Unit RM		
Power Consumption (Kwh)	205360	0.312	64,072.32	
Maximum Demand (KW)	946	25.90	24,501.40	88,573.72
TNB Disc. Tariff : 10 %				(8,857.37)
Renewable Energy : 1 %				797.16
RM : Eighty thousand five hundred & thirteen and cents fifty one only.				
			TOTAL	80,513.51

Certifying Official
This invoice/request for payment is certified correct for payment.
(Signature) (Name) 2/2/12 (Date)
Vote Chargeable

Dept Code	Vote A/C	Amount
FES	1301/000	80,513.51

Approved for Payment
By Dean of Faculty/Head of Dept.
(Signature) (Name) 2/2/12 (Date)

RECEIVED
20 FEB 2012
UNIVERSITI TUNKU ABDUL RAHMAN
ESTATES & FACILITIES

CHUA TAN HUI

NOTE : Kindly quote our Bill No. if you have any queries.

Terms of Payment:

Figure 3.1: Energy Bill of 7 blocks of UTAR buildings

3.1.2.1 Detailed Load Forecasting based on Timetable

Detailed load forecasting is done by having a site survey and investigation to the SE block to identify the types of the power equipments being installed and consumed the energy throughout the whole building. Examples of these power equipments are air conditioner, lighting fixtures, single phase motor, industrial fan, ceiling fan, computer unit, machinery equipment and others. The quantity and power rating of these power equipments distributed across each floor of the SE block are carefully calculated and jot down. All these information is then recorded in the Microsoft Excel for the ease of organizing the bundle of data. Furthermore, the schedules or the timetables for the whole long semester of the SE block are obtained from the general office. With the timetables, an hourly load forecasting of the SE block can be done because there is a precise timeframe for all the activities being carried out across each floor of the SE block. The laboratory schedules on the ground floor are shown in appendix B while the some of the timetables for the conduction of classes on the first floor are shown in appendix C.

On the ground floor, the quantity and power rating of power equipments such as long fluorescent tube, personal computer, air conditioner, ceiling fan, printer, machine and refrigerator that are available in the digital electronic office, digital electronic laboratory, project workshop, analogue laboratory, materials and applied mechanics laboratory, thermo fluids laboratory, flexible manufacturing laboratory and material testing laboratory are calculated and recorded in Microsoft Excel. On the first floor, the same method of calculating the quantity and power rating of power equipments such as long fluorescent tube, personal computer, air conditioner and LCD projector that are available in the SE101, SE102, SE103, SE105, SE106, SE107, SE108, SE109, SE110 and SE111 are carried out. Besides that, the same method is also applicable to the second floor. Besides that, the quantity and power rating of long fluorescent tubes that are available in toilets and corridors of each floor of the SE block are also calculated and recorded in Microsoft Excel. Then, the total kilowatt (KW) of each laboratories, tutorial rooms and computer laboratories are calculated and obtained through the help of Microsoft Excel.

In addition, a framework of timetable is set up in Microsoft Excel to predict the power consumption on each floor in SE block. The framework of timetable being done is shown in the Figure 3.2. In this project, the day of week that count a month is used to predict the average power consumption of each tutorial room, experimental and computer laboratory throughout the SE block. For instance, the Monday of 11/3/2013, 18/3/2013, 25/3/2013 and 1/4/2013 that counts a month will result in the average power consumption of loads on Monday in each room throughout the SE block. From the Figure 3.2, the highlighted column of the forecasted power consumption of each tutorial room, experimental and computer laboratory are obtained by multiplying the quantity and power rating of the power equipments available in each tutorial room, experimental and computer laboratory throughout the SE block. Moreover, the highlighted red row in Figure 3.2 indicates the activities that will have the high probability that the same occurrence will not happen again on the subsequent day of week. Hence, the forecasted power consumption of these activities will be excluded. These activities included the music class, dance class, replacement class and others else. A binary number of 1 that was used in Figure 3.2 indicates there is a conduction of classes in each tutorial room for an hour based on the timetable. Besides that, a number of 0.5 indicates the conducting of classes only conducted for half hour only. Then, the total forecasted power on first floor is obtained by multiplying the power consumption of each tutorial room and the operating hour of the conduction of each class available on each tutorial room. Furthermore, same method of calculating the forecasting power consumption also applicable to the ground floor and second floor of SE block.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	indicates the activies being carried out are not rountine activities																											
2	Date	Venue	Time/	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Op.
3			power (W)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	Hour
4	11/3/2013	SE101	7.147												1	1	1	1	1	1	1	1						8
5		SE102	7.147													1	1	1	1									4
6		SE103	7.147													1	1	1	1	1	1							6
7		SE105	7.147												1	1	1	1	1	1	1							7
8		SE106	7.147									1	1	1	1	1		1										6
9		SE107	7.147													1	1	1	1	1	1							6
10		total		0	0	0	0	0	0	0	0	7.147	7.147	7.147	21.44	42.88	35.74	42.88	35.74	28.59	28.59	7.147	0	0	0	0	0	
11		SE108	7.654									1	1	1	1	1	1	1	1	1	1							10
12		SE109	7.654											1	1	1	1	1	1	1	1							8
13		SE110	7.654											1	1	1	1	1	1	1	1							8
14		SE111	7.654											1	1	1	1	1		1	1	1						8
15		total		0	0	0	0	0	0	0	0	7.654	7.654	30.62	30.62	30.62	30.62	30.62	22.96	30.62	30.62	7.654	0	0	0	0	0	
16		SE 1st Tc	1.476	1.476	1.476	1.476	1.476	1.476	1.476	1.476	1.476												1.476	1.476	1.476	1.476	1.476	
17		total fo	1st floor	1.476	1.476	1.476	1.476	1.476	1.476	1.476	1.476	14.8	14.8	37.76	52.06	73.5	66.35	73.5	58.7	59.2	59.2	14.8	1.476	1.476	1.476	1.476	1.476	
18		Analogu	13.8									13.8	13.8	13.8														
19		Digital E	16.23									16.23	16.23	16.23														
20		Digital E	1.986									1.986	1.986	1.986	1.986	1.986	1.986	1.986	1.986	1.986	1.986							
21		Project \	1.716									1.716	1.716	1.716	1.716	1.716	1.716	1.716	1.716	1.716	1.716							
22		Material	2.136									2.136	2.136	2.136	2.136	2.136	2.136	2.136	2.136	2.136	2.136							
23		Ground '	1.512	1.512	1.512	1.512	1.512	1.512	1.512	1.512	1.512											1.512	1.512	1.512	1.512	1.512	1.512	
24		total fo	G. floor	1.512	1.512	1.512	1.512	1.512	1.512	1.512	1.512	35.87	35.87	35.87	5.838	5.838	5.838	5.838	5.838	5.838	5.838	1.512	1.512	1.512	1.512	1.512	1.512	
25		SE201	12.198										12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2							

E.P.C | Mon | day | Wednesday | Thursday | Friday | Saturday | Sunday | Mon.estimated | Tues.estimated | Wed.estimated

Figure 3.2: Framework of Timetable in Microsoft Excel

3.2 Real Time Data Collection

3.2.1 Requirement of Equipments

TES-3600 power analyzer is used to obtain the real time data of the power parameters such as frequency, voltage unbalance factor, power factor, power quality, real power, reactive power and apparent power from the SE block. TES-3600 power analyzer is illustrated in Figure 3.3:

Figure 3.3: TES-3600 Power Analyzer

In addition, the TES-3600 power analyzer has connectors for four current and voltage sensing clamps with true rms sensing. Moreover, the TES-3600 power analyzer has several options of power measurement such as 1P2W, 1P3W, 3P3W2M & 3P3W. Furthermore, TES-3600 power analyzer can measure the voltage and current up to 600V and 1000A respectively. (TES-3600 3P4W Power Analyzer 2012)

Besides that, a laptop with the installed power analyzer software is needed for retrieving the real time data from the TES-3600 power analyzer and stored it as the file with the format of .xls in the laptop. Communication between the power analyzer and laptop is done by using the RS232 to USB converter. The interface of power analyzer software installed on the laptop is shown in the Figure 3.4:

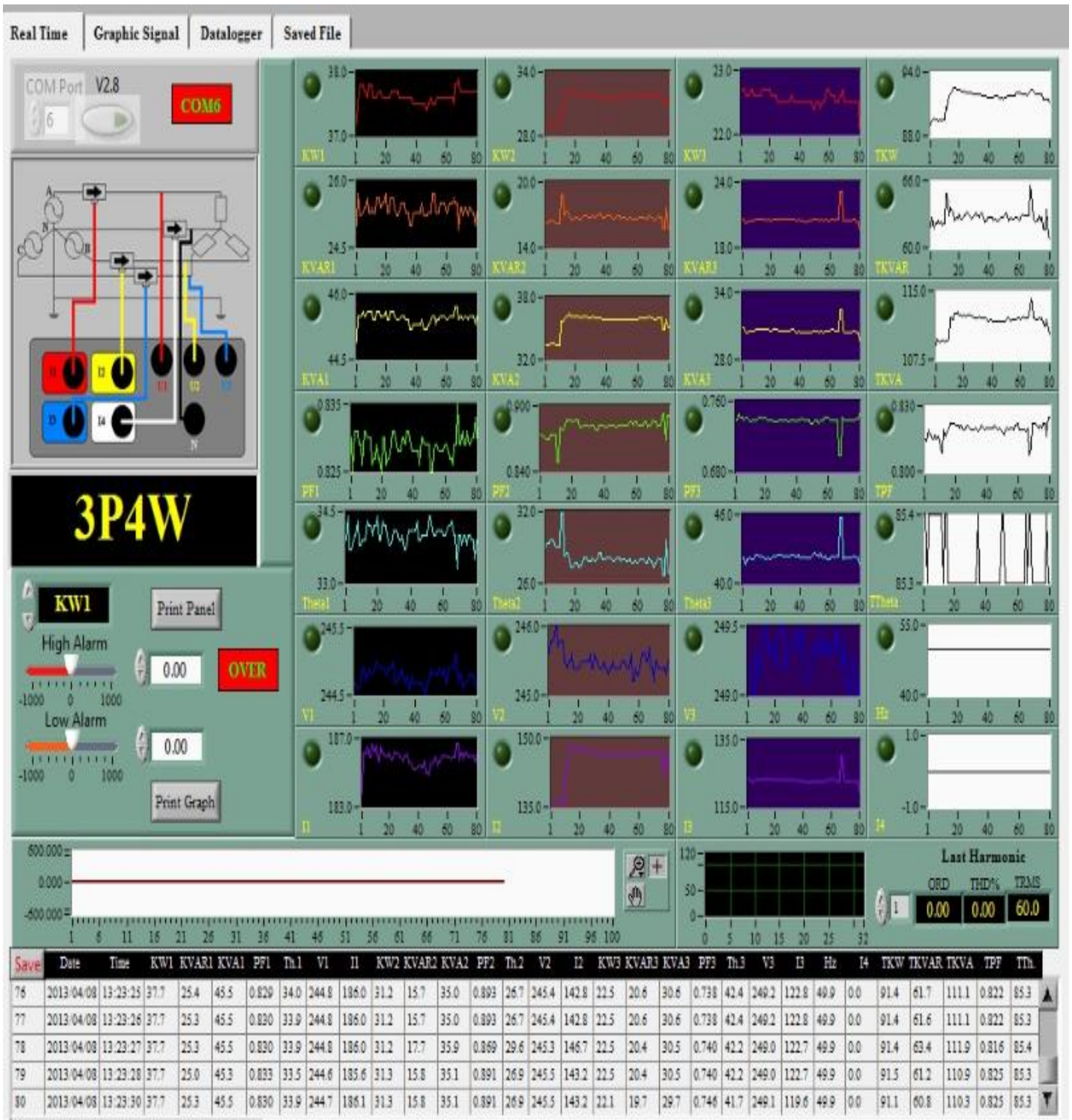


Figure 3.4: Interface of Power Analyzer Software

3.2.2 Procedures to Measure the Power Parameters

1) Two power analyzers are used together (as shown in the Figure 3.5) in order to obtain the real time power parameters data of the SE block. The reason for the use of both power analyzers is due to the limitation of internal memory of the devices. The power analyzer is able to record the data for a week only. Hence, another power analyzer is used to record the data for next consecutive week.

Figure 3.5: Alternative Use of Two Power Analyzer

2) The current and voltage are clamped from the main switchboard of the SE block by using the current and voltage sensing clamps of the power analyzers. Clamping of the current and voltage sources (as shown in the Figure 3.6) are done by using the gloves that can withstand the high current and voltage. Both the voltage and current must be tapped together so that the power analyzer can read the value of the voltage and current respectively.

Figure 3.6: Clamping of Current and Voltage Sources from Switchboard

3) Whenever the steps of (1) and (2) are completed, RS232 to USB converter is connected from the power analyzer to the laptop for the communication of data to be transferred. The real time power parameters data of the SE block are collected once in a week for each power analyzer. The setup of data collection workplace is shown in the Figure 3.7:

Figure 3.7: Setup of Data Collection Workplace

3.3 Analysis of Data

When the steps of load forecasting based on timetable and the real time data collection are completed, analysis and comparison of these data are to be further discussed. The forecast power consumption of the load is then compared with the real power consumption of load obtained from the switchboard of SE block.

3.3.1 Average Power Consumption of Load Forecasting

Power consumption of load forecasting of SE block is preferred to be done on weekdays rather than weekends because there is almost no lecture and tutorial classes will be conducted during weekends. From the timetable, all activities such as when the lecture and tutorial classes will be conducted, the day and time of laboratory sessions started, etc that are conducted in the SE block can be predicted. This prediction is recommended because the day and time of the operation of each tutorial room located at the first floor of SE block is a routine activity throughout the whole long semester. Generally, load is forecasted based on the day of the week and the average power consumption is obtained for four consecutive day of week that counts a month. For example, the Monday of 11/3/2013, the Monday of 18/3/2013, the Monday of 25/3/2013 and the Monday of 1/4/2013 that counts a month results in the average power consumption on Monday. In addition, the load forecasting is calculated hourly based on the timetable provided.

3.3.2 Average Power Consumption of Real Time Load

Real time power consumption of load of SE block is done only for weekdays because there are almost no lecture and tutorial classes conducted during weekends. Generally, real time power consumption of SE block is acquired from the main switchboard in the SE block by using the power analyzer. Then the data is transferred from power analyzer to laptop by using the RS232 to USB converter and the file is saved in the format of .xls which can be opened by Microsoft Excel. Hence, all the power parameters of the SE block such as real power, reactive power, power factor, frequency and other else can be found in that file. Because the real time power consumption of the SE block obtained by the power analyzer is recorded within the interval of one minute, there is a total set of 1440 data on each day. So, an excel formula of AVERAGE(OFFSET(AQ$2,(ROW()-ROW(AS$2))*60,,60)) is used in Microsoft Excel to organize the data from minute to hour for the ease of comparing the data with the estimated power consumption. This is because the interval of time that we estimated the operating hour of power consumption based on timetable is in the time interval of hour. Consequently, the average power consumption of real time load is done in Microsoft Excel through the method of taking the real time data of four consecutive day of week that counts a month. For example, the Tuesday of 12/3/2013, the Tuesday of 18/3/2013, the Tuesday of 26/3/2013 and the Tuesday of 2/4/2013 that counts a month results in the average power consumption on Tuesday.

3.3.3 Correlation Analysis

Correlation analysis is used to measure the relationship between the average power consumption of forecasting load and the average power consumption of real time load. Correlation analysis is done by using the function of “correlation” which can be found on the data analysis toolbox in the Microsoft Excel. Correlation analysis tends to see if there is a change in the independent item (normally is an indicator) will result in a change in the dependent item. This information is useful for an indicator’s predictive abilities. The correlation analysis is basically used to determine the predictive ability of an indicator and to determine correlation between two items. The correlation coefficient range between ± 1. A coefficient of +1 indicates a perfect positive correlation which means changes occur in the independent item will result in an identical change in the dependent item while coefficient of -1 indicates a perfect negative correlation which will have the same explanation as coefficient of +1 but the change will be in the opposite direction. A coefficient of zero means there is no relationship between the two items. A coefficient value ranged between 0.01 & 0.29 indicate a weak positive linear relationship whereas the coefficient value ranged between 0.3 & 0.69 and 0.7 & 0.99 indicates a moderate and strong positive relationship respectively. A high correlation coefficient indicates that the dependent variable will usually change when the independent variable changes. (Steven B. Achelis 2013)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Average Power Consumption on Day of Week

In this project, the loads are forecasted based on the day of the week and the average power consumption on day of week is obtained for four consecutive day of week that counts a month. For instance, the Monday of 11/3/2013, the Monday of 18/3/2013, the Monday of 25/3/2013 and the Monday of 1/4/2013 that counts a month will result in the average power consumption of loads on Monday. Besides that, same method is also applicable to find the average power consumption on Tuesday, Wednesday, Thursday and Friday. This forecasting power consumption of loads is done based on the timetable obtained from the general office.

4.1.1 Average Power Consumption on Monday

Figure 4.1 shows the comparison between average real power consumption obtained from switchboard and average estimated power consumption calculated from the hourly timetable of SE block on Monday. From Figure 4.1, the blue line represents the average real power consumption whereas the red line represents the average estimated power consumption. Besides that, the timeframe between 8:00 until 18:00 is the main timeframe of the SE block because almost all the activities are conducting during this duration of timeframe. Hence, the relationship between the average real power consumption and average estimated power consumption is compared during this duration of timeframe. From the Figure 4.1, it is observed that the maximum demand of both the average real and estimated power consumptions is approximately 123kW and 129kW respectively. The difference in the form of percentage between the maximum demand of the average real power consumption and average estimated power consumption is 4.87%. This indicates that the estimation of the maximum demand being done is very close to the average real time maximum demand.

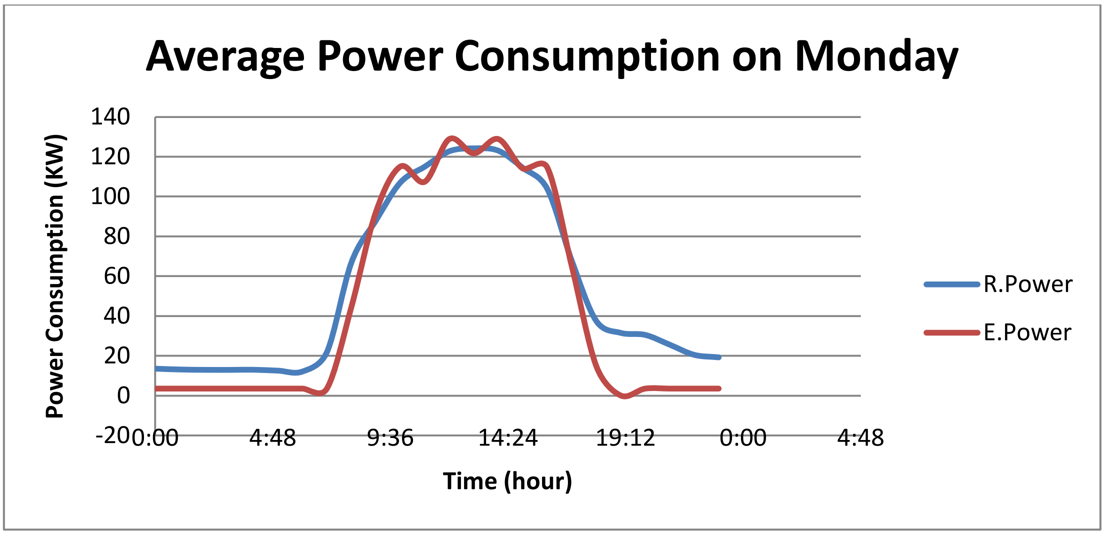


Figure 4.1: Average Power Consumption on Monday

Correlation function is applied to show the relationship between the average real power consumption and average estimated power consumption. Table 4.1 shows the correlation coefficient values of the average real power consumption against the average estimated power consumption of the SE block. It is observed that the correlation coefficient value between average real power and average estimated power on Monday is 0.955223 which shows a very strong linear positive relationship. In other words, the predictive ability of the average estimated power consumption towards the average real power consumption of the SE block is as high as 95.52%. This result shows that the average estimated power consumption is very close to the average real power consumption.

Table 4.1: Correlation Coefficient Values on Monday

	R.Power	*E.Power*
R.Power	1	
E.Power	0.955223	1

4.1.2 Average Power Consumption on Tuesday

Figure 4.2 illustrated the comparison between average real power consumption obtained from switchboard and average estimated power consumption calculated from the hourly timetable of SE block on Tuesday. From Figure 4.2, the blue line represents the average real power consumption whereas the red line represents the average estimated power consumption. The comparison is done during the duration of timeframe from 8:00 until 18:00. From the Figure 4.2, it is observed that the maximum demand of both the average real and estimated power consumptions is approximately 120kW and 129kW respectively. The difference in the form of percentage between the maximum demand of the average real power consumption and average estimated power consumption is 7.5%. This indicates that the estimation of the maximum demand being done is said to be quite near to the value of average real time maximum demand.

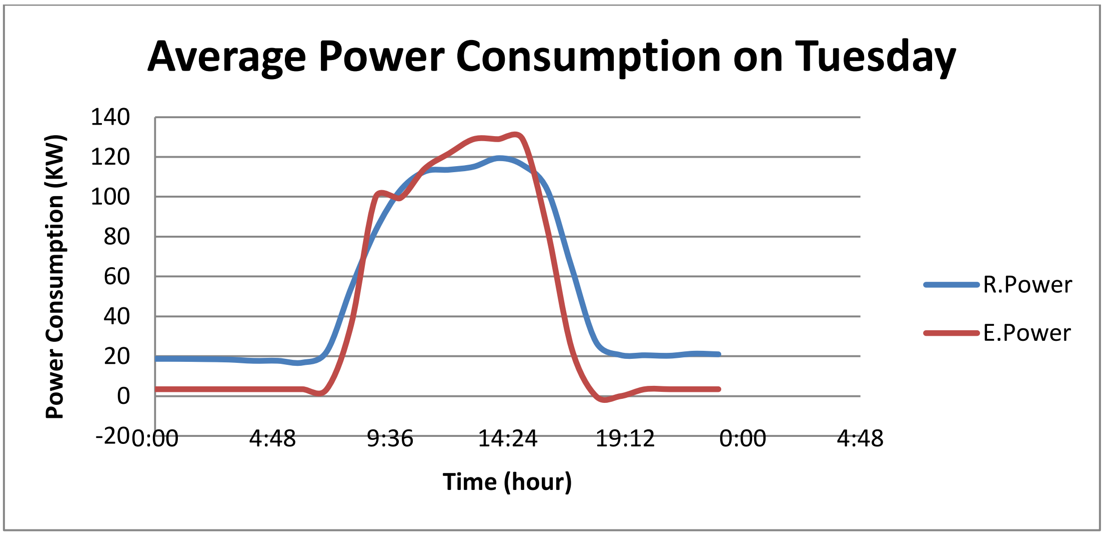


Figure 4.2: Average Power Consumption on Tuesday

Correlation function is used to find the relationship between the average real power consumption and average estimated power consumption. Table 4.2 shows the correlation coefficient values of the average real power consumption against the average estimated power consumption of the SE block. It is noted that the correlation coefficient value between average real power consumption and average estimated power consumption on Tuesday is 0.95069 which shows a very firm linear positive relationship. It can be explained in other words that the predictive ability of the average estimated power consumption towards the average real power consumption of the SE block is as high as 95.07%. This strong positive linear relationship indicates that the average estimated power consumption is extremely near to the values of average real power consumption.

Table 4.2: Correlation Coefficient Values on Tuesday

	R.Power	*E.Power*
R.Power	1	
E.Power	0.95069	1

4.1.3 Average Power Consumption on Wednesday

Figure 4.3 displayed the comparison between average real power consumption obtained from switchboard and average estimated power consumption calculated from the hourly timetable of SE block on Wednesday. From Figure 4.3, the blue line represents the average real power consumption whereas the red line represents the average estimated power consumption. The comparison is focused on the period of timeframe ranged from 8:00 until 18:00. From the Figure 4.3 it is noted that the maximum demand of both the average real and estimated power consumptions is approximately 122kW and 124kW respectively. The difference in the form of percentage between the maximum demand of the average real power consumption and average estimated power consumption is 1.64%. This indicates that the estimation of the maximum demand being done is very close to the average real time maximum demand.

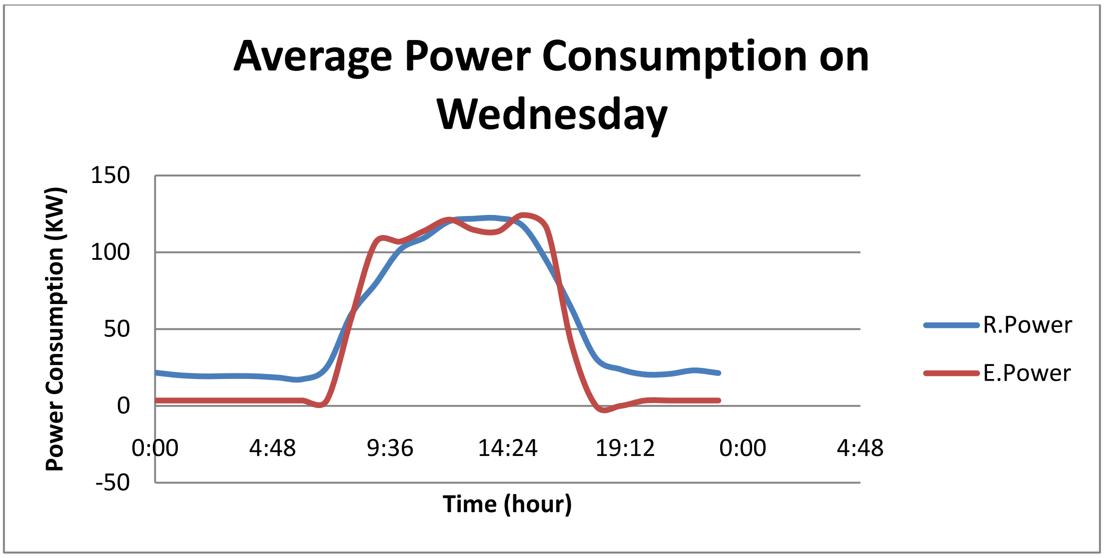


Figure 4.3: Average Power Consumption on Wednesday

Correlation function is employed to discover the relationship between the average real power consumption and average estimated power consumption. Table 4.3 reveals the correlation coefficient values of the average real power consumption against the average estimated power consumption of the SE block. It is clearly observed that the correlation coefficient value between average real power consumption and average estimated power consumption on Wednesday is 0.921144 which indicates a strong linear positive relationship. This information indicates that the predictive ability of the average estimated power consumption towards the average real power consumption of the SE block is as high as 92.11%. This strong positive linear relationship shows that the average estimated power consumption is close enough to reach the values of average real power consumption.

Table 4.3: Correlation Coefficient Values on Wednesday

	R.Power	*E.Power*
R.Power	1	
E.Power	0.921144	1

4.1.4 Average Power Consumption on Thursday

Figure 4.4 demonstrated the comparison between average real power consumption obtained from switchboard and average estimated power consumption calculated from the hourly timetable of SE block on Thursday. The comparison is concentrated on the timeframe ranged from 8:00 until 18:00. From the Figure 4.4 it is obviously shown that the maximum demand of both the average real and estimated power consumptions is approximately 129kW and 128kW respectively. In this case, there is not much difference in the form of percentage between the maximum demand of the average real and estimated power consumption. Furthermore, it is observed that there is an obvious rising of the average estimated power consumption during the timeframe from 8:00 until 10:00 as compared to the average real power consumption. This occurrence indicates an over prediction of average estimated power consumption is occurred. Besides that, under prediction of average estimated power consumption is said to be happened during the timeframe from 13:00 onwards until 18:00. This occurrence of over prediction and under prediction of average estimated power consumption might due to the lecture or tutorial classes and laboratory sessions are being cancelled and replaced on the other days. Besides that, another reason might due to fewer computers are operated on the second floor of SE block and there is no computer classes being conducted during that particular timeframe.

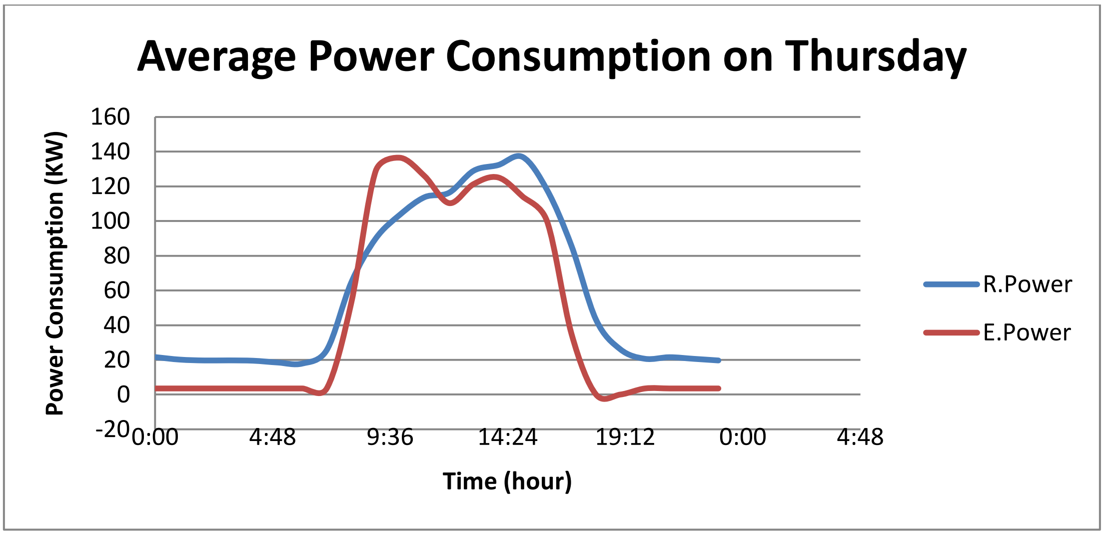


Figure 4.4: Average Power Consumption on Thursday

In addition, correlation function is employed to find the relationship between the average real power consumption and average estimated power consumption. Table 4.4 shows the correlation coefficient values of the average real power consumption against the average estimated power consumption of the SE block. It is obviously seen that the correlation coefficient value between average real power consumption and average estimated power consumption on Thursday has only 0.782424 which also indicates a strong linear positive relationship but is considered as moderate strong linear positive relationship as compared to the day of week of Monday, Tuesday and Wednesday. Hence, it can be expressed as the predictive ability of the average estimated power consumption towards the average real power consumption of the SE block is achieving a moderate high percentage of 78.24%. This relatively moderate strong positive linear relationship indicates that the average estimated power consumption is near but not closes enough to reach the values of average real power consumption.

Table 4.4: Correlation Coefficient Values on Thursday

	R.Power	*E.Power*
R.Power	1	
E.Power	0.782424	1

4.1.5 Average Power Consumption on Friday

Figure 4.5 illustrated the comparison between average real power consumption obtained from switchboard and average estimated power consumption calculated from the hourly timetable of SE block on Friday. From Figure 4.5, the blue line represents the average real power consumption whereas the red line represents the average estimated power consumption. The comparison is subjected to the period of timeframe ranged from 8:00 until 18:00. From the Figure 4.5, it is noted that the maximum demand of both the average real and estimated power consumptions is approximately 120kW and 119kW respectively which indicated that the estimation being done towards the maximum demand of average real power consumption is extremely near.

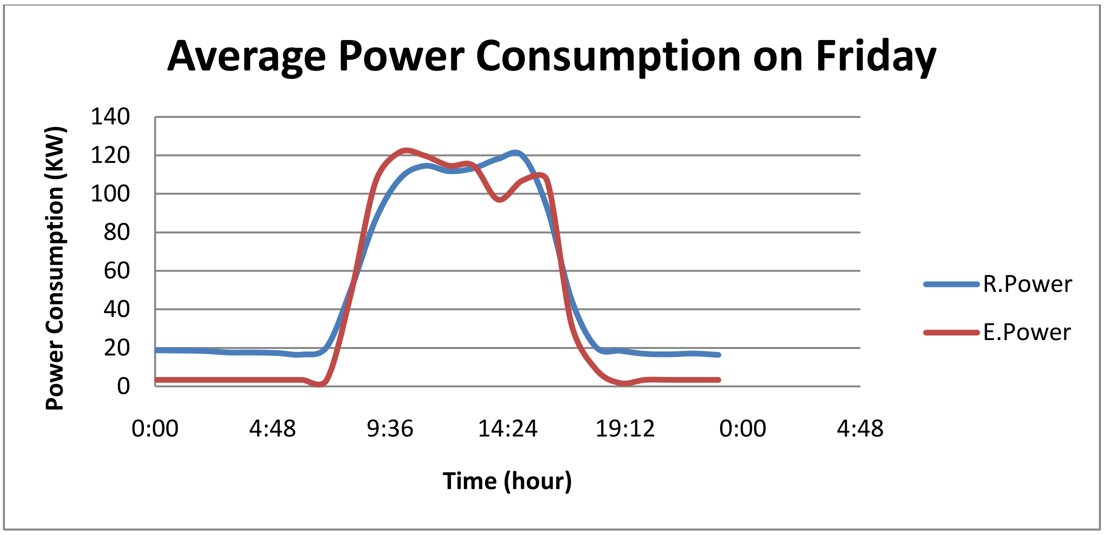


Figure 4.5: Average Power Consumption on Friday

Furthermore, correlation function is used to observe the relationship between the average real power consumption and average estimated power consumption. Table 4.5 reveals the correlation coefficient values of the average real power consumption against the average estimated power consumption of the SE block. It is noted that the correlation coefficient value between average real power consumption and average estimated power consumption on Friday is 0.938218 which indicates a strong linear positive relationship. On the other hand, this information indicates that the predictive ability of the average estimated power consumption towards the average real power consumption of the SE block is as high as 93.82%. This strong positive linear relationship shows that the average estimated power consumption is close to the values of real power consumption.

Table 4.5: Correlation Coefficient Values on Friday

	R.Power	*E.Power*
R.Power	1	
E.Power	0.938218	1

4.1.6 Summary of Average Power Consumption on Day of Week

From the day of week of Monday, Tuesday, Wednesday, Thursday and Friday, it is found out that the average maximum demand of real power consumption and estimated power consumption of the SE block is approximately 122.8kW and 125.8kW respectively. The difference in the form of percentage between the average maximum demand of the real power consumption and estimated power consumption is approximate 2.44%. Thus, the percentage difference of average maximum demand is insignificant which indicates that the estimation being done towards the maximum demand of average real power consumption is extremely close. Furthermore, the average correlation coefficient between the real power consumption and estimated power consumption on the day of week is approximate 90.95%. In other words, the estimation being done towards the power consumption of SE block is to be said quite similar to the real power consumption. Hence, the estimation being done is recommended.

During some duration of timeframes, there are some obvious or slight differences on the pattern of the graph that can be noted between the average real power consumption and average estimated power consumption of the SE block. This difference might due to the activities being carried out on each floor of the SE block. Laboratory sessions are generally conducted on the ground floor of SE block. The operation of the laboratory equipments and machines will contribute to the power consumption of the SE block. Besides that, on the first floor of the SE block, there might be some extra lecture and tutorial classes to be conducted by the lecturer and vice versa that will lead to the increment or reduction of the power consumption in the SE block. In addition, generally there are some co curriculums activities will be conducted on the first floor of the SE block during particular timeframe. Generally, the timeframe for the co curriculum activities will be arranged after 17:00 in order to prevent any insufficient tutorial room for the teaching of the lecture and tutorial classes. The effect of increment of power consumption of the co curriculum activities is insignificant as it will not contribute much to the increment of power consumption due to the timeframe given to the co curriculum activities. The co curriculum activities included dance class, music class, Christian fellowship class, robotic class and others else. Furthermore, the conduction or dismissal of computer sessions on the second floor of the SE block will definitely affect the power consumption of the SE block. Generally, the computer rooms on the second floor are opened freely for all students to do their projects and assignments. So, all the computers on the second floor are always in standby mode for the ease of students to use it quickly. Thus, when the power consumption of the SE block increases, it has a relatively high probability that there are many students using the computers on the second floor in order to rush for their assignment or doing anything related to their interest. Moreover, lecturing through the use of computer such as AutoCAD lecture class is always conducted on the second floor of the SE block.

In addition, human behaviour is another major issue that contribute to the increment or reduction of power consumption in SE block. Human behaviour refers to the range of behaviours exhibited by humans and is generally influenced by attitudes, culture, emotions, ethics and values. Generally, the power consumption of the SE block increases either more power equipments are being turned on or some power equipments are still remained in the operation mode after the end of the lecture or tutorial class due to the negligence of the students and lecturers. Besides that, lack of awareness and responsibility of the students or lecturers to conserve and preserve the energy is also another issue. Moreover, immature or selfish perception of the students to turn on some power equipments such as air conditioning of the whole tutorial class only for his/her own comfort is another issue that lead to the increment of power consumption of the SE block. Hence, mature behaviour of the students is needed in order to reduce the power consumption of the SE block.

4.2 Power Distribution of SE Block

Generally, the estimated power consumption throughout the SE block is calculated based on average power consumption on day of week. Besides that, the estimated power consumption is obtained through the method of taking the average estimated power consumption on each day of week for four consecutive day of week that counts a month. For instance, the average power consumption on Monday is obtained by finding the average power consumption value on the Monday of 11/3/2013, 18/3/2013, 25/3/2013 and 1/4/2013. The same method is also applicable to find the estimated power consumption on Tuesday, Wednesday, Thursday and Friday. In addition, power distribution of SE block is forecasted based on the hourly timetable given. Then, the estimation of power consumption throughout the SE block is further divided into the ground floor, first floor and second floor of the SE block. Most of the activities conducted on each floor of the SE block that consumed the power are carefully calculated according to the timeframe given by using the Microsoft Excel. Later, the estimated power consumption is then calculated automatically by the Microsoft Excel. In this estimation, we only focused on the timeframe ranged from 8:00 until 18:00 because almost all the activities are carried out during this particular duration of timeframe.

4.2.1 Power Distribution on Day of Week

The Figure 4.6 illustrated the estimated power distribution of the SE block on Monday. From the duration ranged from 8:00 until 10:00, it is obviously noted that the power consumption of the ground floor is high. This might due to some laboratory sessions being conducted during this particular timeframe and the estimation is verified with the timetable of lab sessions that we have obtained throughout the whole semester. It is clearly observed that the first floor has the higher power consumption compared to ground floor and second floor during the timeframe ranged from 12:00 until 18:00. This might due to almost all tutorial rooms available on the first floor is occupied for the purpose of teaching and the estimation is verified with the timetable obtained. Besides that, the second floor start to consume the power during the timeframe ranged from 9:00 until 17:00 and showed a steady power consumption pattern. The reason might due to the computers available on the second floor are often used by the students when there is no conduction of computer sessions. At the duration of 8:00, there is no power consumption on the second floor due to the computer laboratories are not yet opened. Moreover, the computer laboratories on the second floor will normally closed at 18:00. Thus, there is no power consumption on second floor after 18:00.

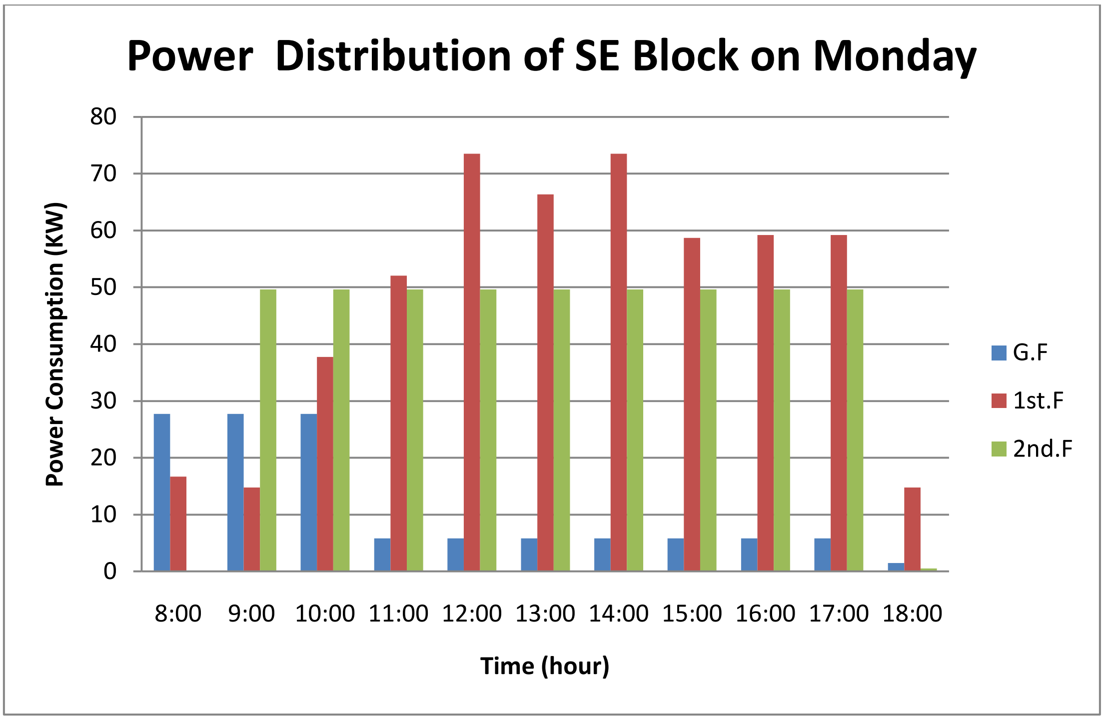


Figure 4.6: Power Distribution of SE Block on Monday

The Figure 4.7 shows the estimated power distribution of the SE block on Tuesday. From the graph, it is seen that the ground floor consumed much less power compared to the first and second floor from the duration of 8:00 until 18:00. This might due to there is no operation of any laboratory session on Tuesday and the estimation is verified with the timetable of lab sessions that we have obtained. Besides that, it is clearly observed that the first floor has consumed more power compared to ground floor and second floor during the timeframe from 11.00 until 15.00. This might due to almost all tutorial rooms available on the first floor is occupied for the purpose of teaching and the estimation is verified with the timetable obtained. Besides that, the second floor has the steady power consumption during the timeframe ranged from 9:00 until 17:00. The possible reason might due to the students always used the computers available on the second floor for their own interest when there is no conduction of computer sessions. At the duration of 8:00, there is no power consumption on the second floor due to the computer laboratories are not yet opened. The computer laboratories on the second floor will normally closed at 18:00. Thus, there is no power consumption on second floor after 18:00.

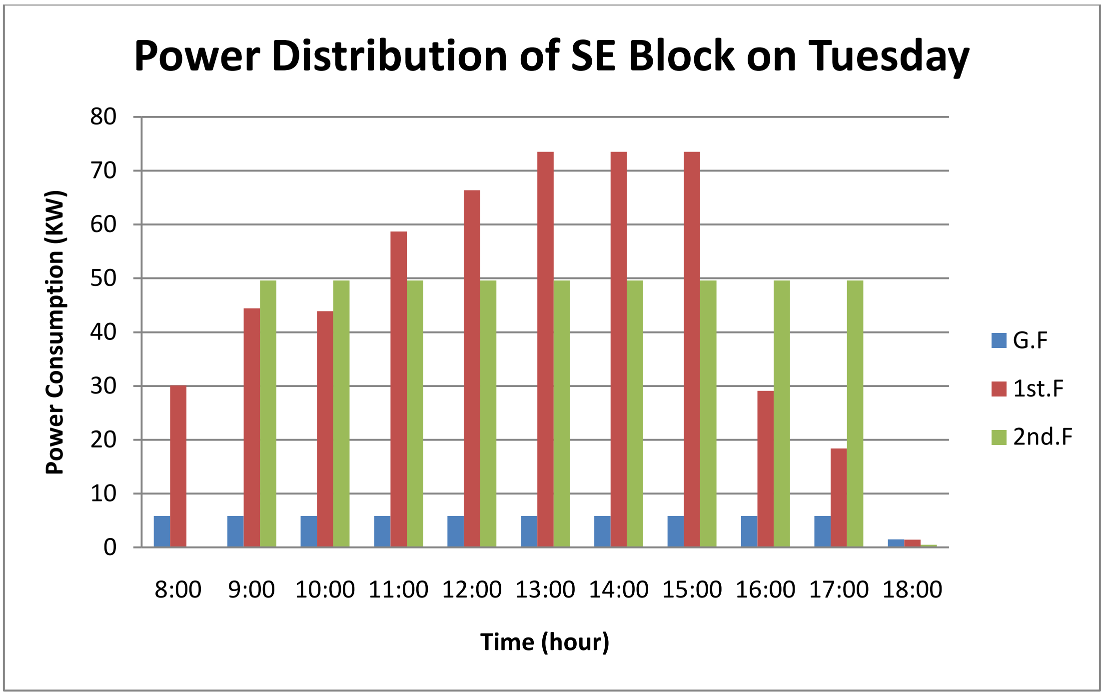


Figure 4.7: Power Distribution of SE Block on Tuesday

The Figure 4.8 displayed the estimated power distribution of the SE block on Wednesday. It is shown that the power consumption on the ground floor started to increase subsequently between the timeframe of 15:00 to 17:00. This is because there is some laboratory sessions being carried out during this particular timeframe and the estimation is verified with the timetable of lab. Not only that, it is observed that the first floor consumed more power compared to the ground floor and second floor during the timeframe from 8:00 until 15:00. The possible reason might due to the tutorial rooms on the first floor always been occupied for teaching purpose and the estimation is affirmed with the timetable obtained from general office. Furthermore, the second floor also has the steady power consumption of roughly 50kW during the timeframe ranged from 9:00 until 17:00 as the personal computers available on the second floor always in working condition due to the conduction of computer laboratory sessions and being used by the students when there is no conduction of computer sessions. At the duration of 8:00, there is no power consumption on the second floor due to the computer laboratories are not yet opened. The computer laboratories on the second floor will normally closed at 18:00. Thus, there is no power consumption on second floor after 18:00.

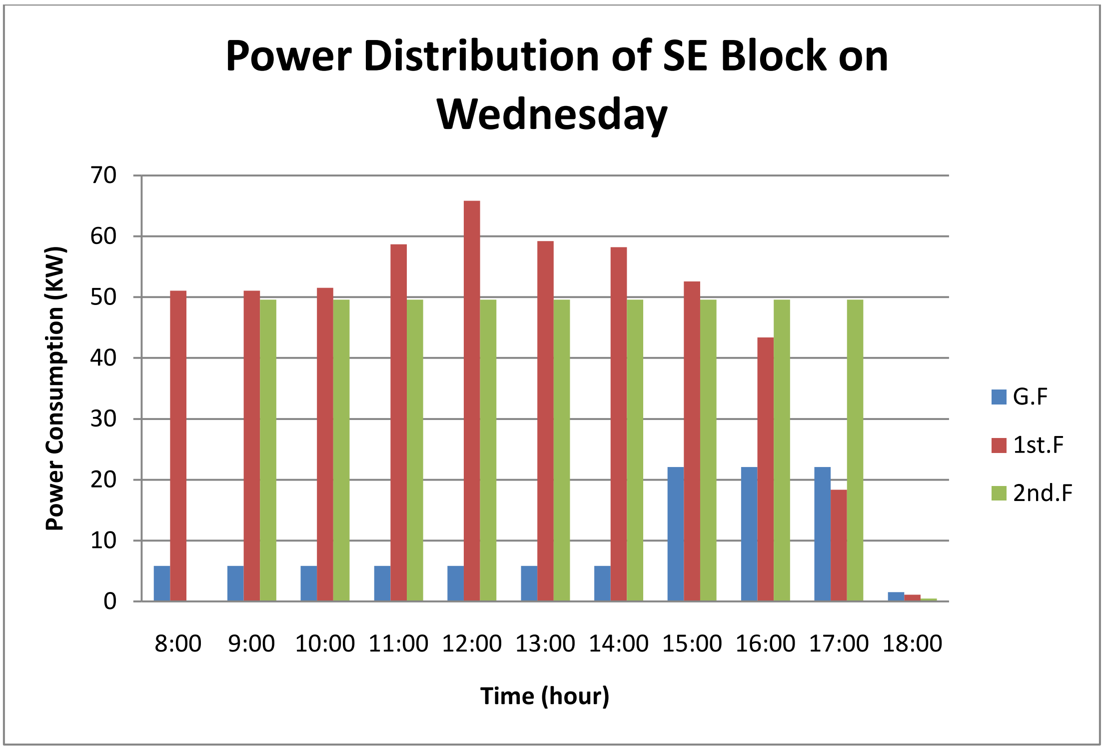


Figure 4.8: Power Distribution of SE Block on Wednesday

The Figure 4.9 demonstrated the estimated power distribution of the SE block on Thursday. It is seen there is slight increase in power consumption on the ground floor during the timeframe from 8:00 to 10:00. This might due to the laboratory sessions involved the use of power equipments such as oscilloscope, frequency spectrum, power spectrum and others power equipments that consumed much less energy are being carried out during this particular timeframe and the estimation is verified with the timetable of lab. In addition, it is obviously noted that the first floor consumed more power compared to the ground floor and second floor throughout the duration from 8:00 until 15:00. The reason might due to most of the classes on first floor are being used and it is affirmed with the timetable obtained from general office. Moreover, the second floor has the steady power consumption ranged between 48kW until 50kW during the timeframe ranged from 9:00 until 17:00. This might due to the computer laboratories on the second floor are always operated regardless any operation of computer sessions as the computer laboratories are free access to all students when there is no conduction of computer sessions. Hence, students can freely use the computers on the second floor anytime they desired.

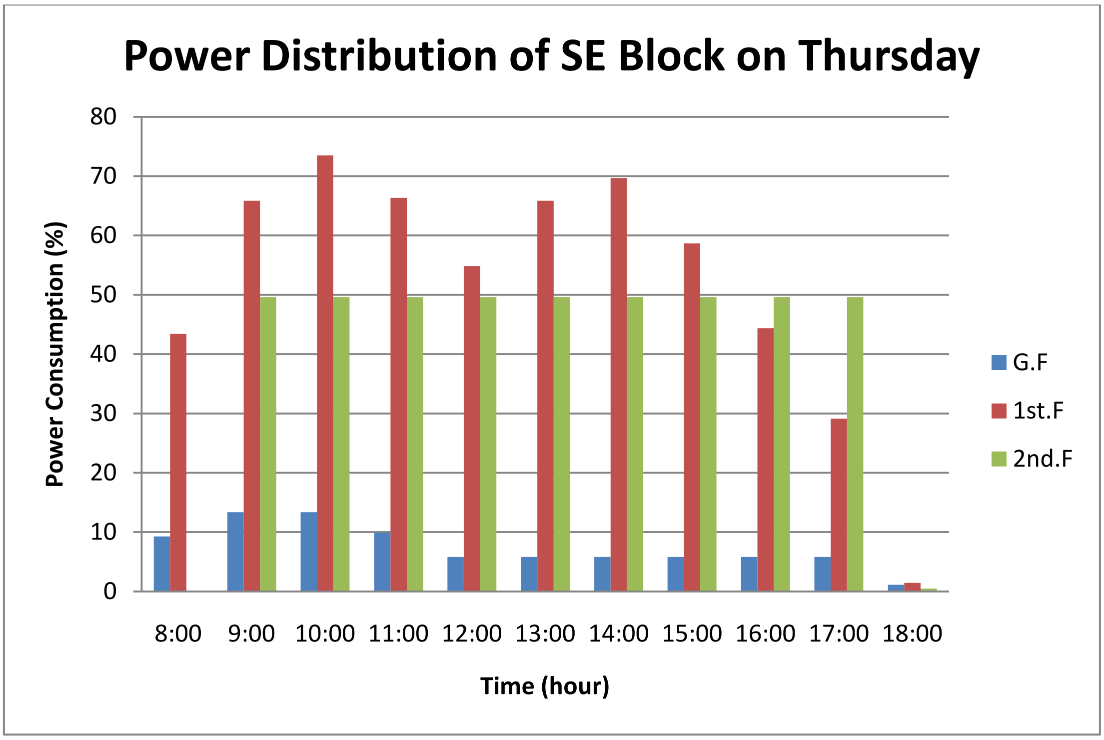


Figure 4.9: Power Distribution of SE Block on Thursday

The Figure 4.10 illustrated the estimated power distribution of the SE block on Friday. It is shown that the power consumption on the ground floor ranged between 5kW until 7kW from the timeframe of 8:00 to 17:00. This is because there is no conduction of any experimental laboratories and this estimation is verifies with the laboratory schedules obtained. In addition, it is noted that the first floor and second floor consumed the overall power consumption of SE block from the timeframe of 9:00 until 17:00. This might due to almost all the classes are being conducted on the first floor and the computer laboratories on the second floor are always in operation mode. At the duration of 8:00, there is no power consumption on the second floor because the computer laboratories are not yet opened. Not only that, the computer laboratories on the second floor will normally close at 18:00. Hence, there is no power consumption on second floor after 18:00.

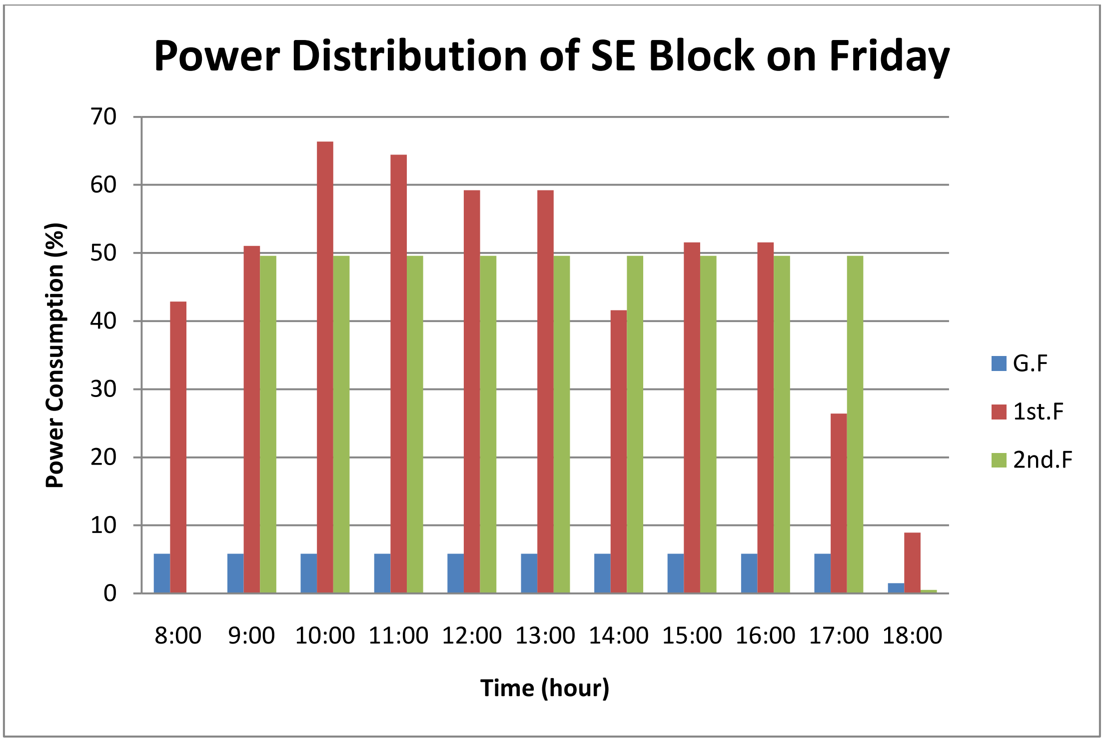


Figure 4.10: Power Distribution of SE Block on Friday

4.2.2 Summary of Power Distribution on Day of Week

The Figures from 4.6 until 4.10 have shown the power distribution on day of week by further divided the power distribution of SE block into ground floor, first floor and second floor. From these figures, it is observed that the first floor and second floor are the main drive of the power consumption of SE block compared to the ground floor. This is because the activities carried out on the first and second floor is more likely to be routine activities that will have a high probability that the same occurrence will happen again over the day of the week. Examples of the routine activities are the lecture or tutorial class conducted on the first floor and lecturing through the use of the computer on the second floor especially for the subject such as AutoCAD. The information regarding the first and second floors is the main drive of the power consumption of SE block is important for us to know which floors need to have a detailed investigation and inspection towards the power equipments being used in order to identify which power equipments caused a high percentage of power consumption on that particular floor.

4.3 Power Utilisation on Each Floor of SE Block

Power utilisation on each floor of the SE block is forecasted by using the hourly timetable provided. In the ground floor, quantity and power rating of the power equipments in each laboratory workplace are recorded. Then, operating hours of each laboratory sessions are calculated based on the schedules given by lab officer. Hence, power rating of the power equipments that are in used during the timeframe from 8:00 until 18:00 are multiplied with the operating hours in order to have a better understanding of power utilisation on each power equipments being used across the ground floor of the SE block. The same procedures will apply to the first floor and second floor of the SE block.

4.3.1 Power Utilisation on ground floor of SE Block

The Figure 4.11 illustrated the power utilisation on ground floor of the SE block without any operation of laboratory sessions. Generally, digital electronic office and material testing laboratory are always operated during the working hour from 8:00 until 18:00 because these are the workplace for some laboratory officers and staffs. Besides that, project workshop is also usually opened during 8:00 until 18:00 for the students to do their projects by providing laboratory apparatus and equipments to them. Thus, these offices and workplaces are the main power consumption of the ground floor when there is no laboratory session. From Figure 4.11, it is obviously shown that the air conditioner comprises 77% of the total power utilisation while the rest of the power equipments such as long fluorescent tube, personal computer and ceiling fan make up the remaining 23%.

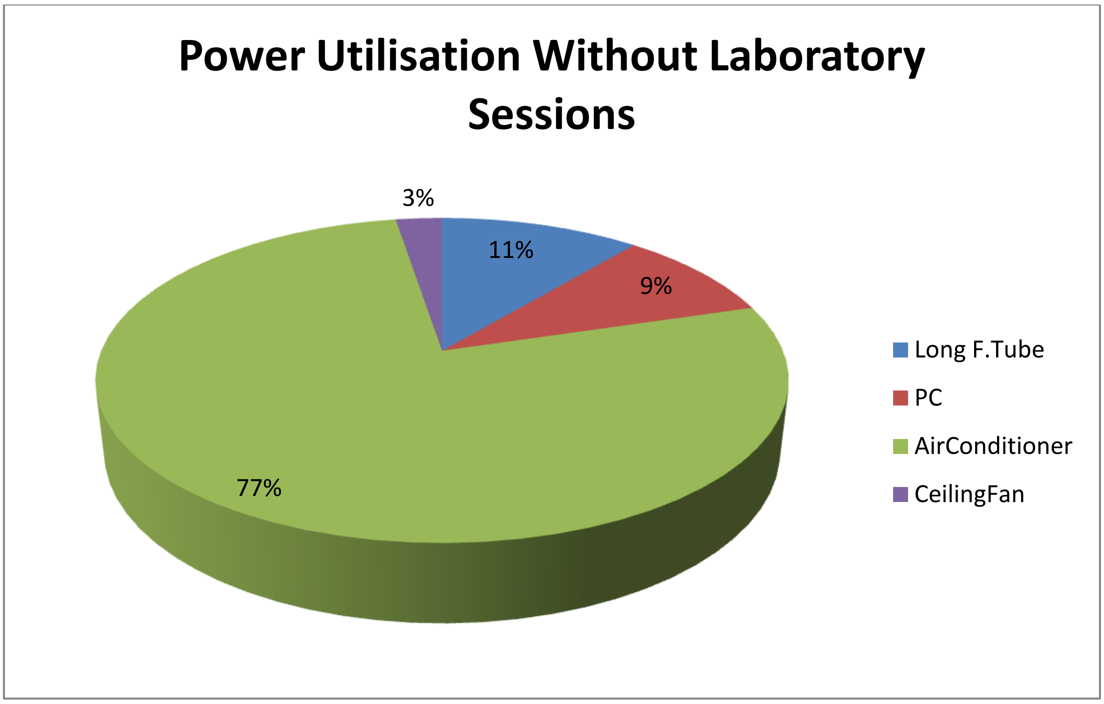


Figure 4.11: Power Utilisation on Ground Floor of SE Block without Laboratory Sessions

The Figure 4.12 demonstrated the power utilisation on ground floor of the SE block with the operation of laboratory sessions. Generally, the laboratory session involved with the operation of heavy machine will consume lots of energy especially for the materials and applied mechanics laboratory, thermo fluids laboratory and flexible manufacturing laboratory which required the heavy machine to be operated for the conduction of the experiment. Digital electronics laboratory and analogue laboratory that do not deal with heavy machine consumed much less energy. From the Figure 4.12, it is observed that the air conditioner and machine comprise 42% and 40% each respectively of the total power utilisation while the rest of the power equipments such as long fluorescent tube, personal computer and ceiling fan make up the remaining 18%. Hence, air conditioner and machine are the main power equipments that consumed the most energy from ground floor when the laboratory sessions involved the heavy machine are conducted.

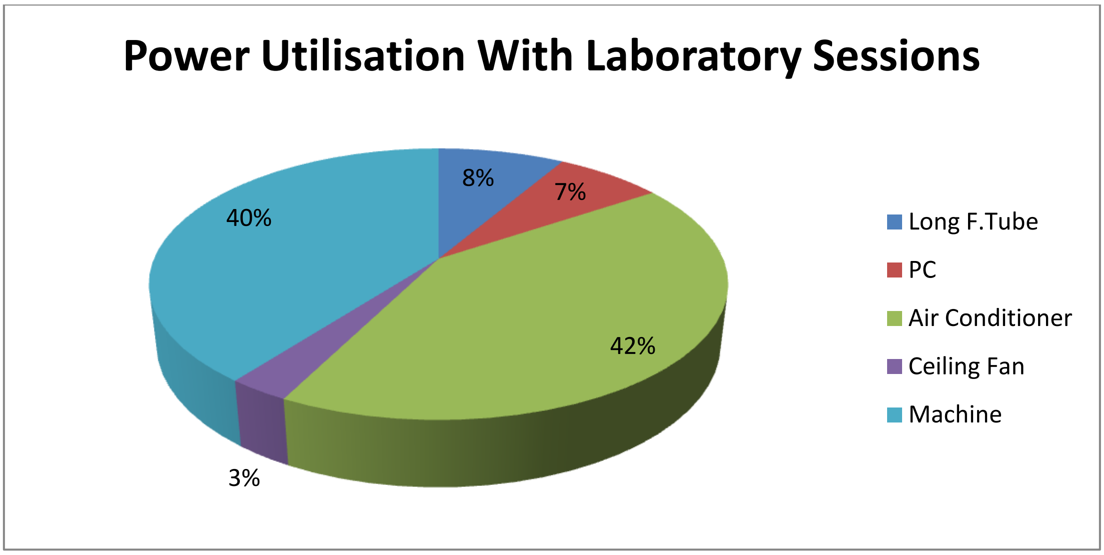


Figure 4.12: Power Utilisation on Ground Floor of SE Block with Laboratory Sessions

4.3.2 Power Utilisation on first floor of SE Block

The Figure 4.13 showed the power utilisation on first floor of the SE block. Because the first floor of the SE block is mainly used for the purpose of teaching, LCD projector is needed in this floor. Based on the power utilisation in Figure 4.13, it is obviously noted that air conditioner constitutes a high percentage of power utilisation of 81% while other power equipments such as long fluorescent tube, personal computer, ceiling fan and LCD projector make up the remaining 19%. Thus, air conditioner is the dominant power equipment that consumed most of the energy on the first floor of the SE block.

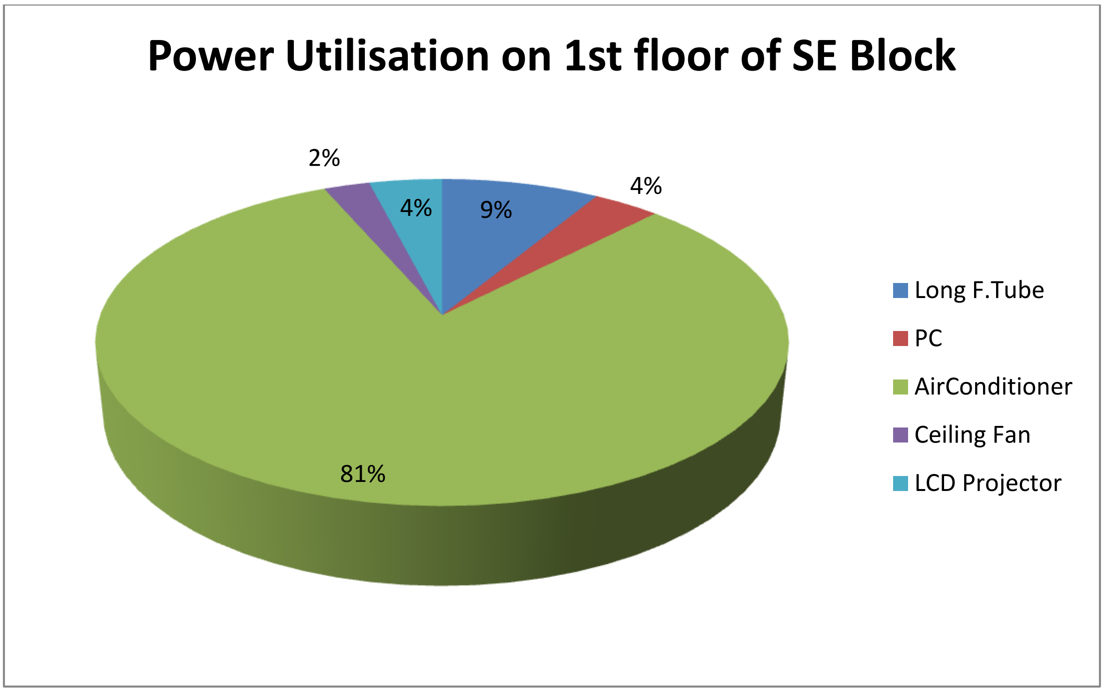


Figure 4.13: Power Utilisation on first floor of SE Block

4.3.3 Power Utilisation on second floor of SE Block

The Figure 4.14 showed the power utilisation on second floor of the SE block. Because of the second floor is a computer laboratory, more personal computers are employed in this floor. Based on the power utilisation in Figure 4.14, it is seen that both of the air conditioner and personal computer constitutes 49% and 45% each respectively of the total power utilisation while other power equipments such as long fluorescent tube and ceiling fan make up the remaining 6%. Thus, air conditioner and personal computer are the principal power equipments that consumed most of the energy on the second floor of the SE block.

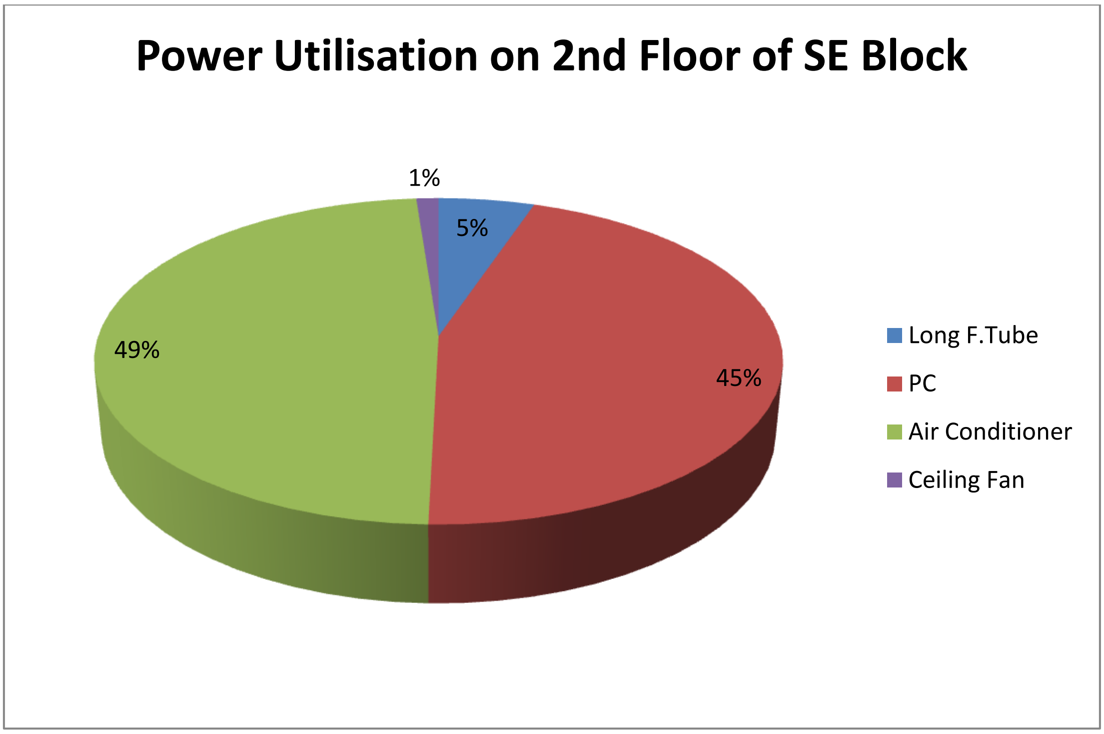


Figure 4.14: Power Utilisation on second floor of SE Block

4.3.4 Summary of Power Utilisation on SE Block

On the ground floor, air conditioner always is the major power equipment that consumed most of the energy regardless any operation of laboratory sessions. Percentage of power utilisation of machine is significant when the laboratory sessions involved the use of heavy machines is operating. On the first floor, air conditioner has the total dominant percentage of power utilisation when the lectures or tutorials class are conducted. On the second floor, both the air conditioner and personal computer are the leading power equipments over the total power utilisation. Thus, it can be concluded that the air conditioner is the main drive of the power utilisation on each floor of SE block.

4.3.5 Potential Saving of Power Equipment in SE Block

From the summary of power utilisation on SE block, it is found out that the air conditioner is the main drive of the power utilisation on each floor of SE block. Hence, potential saving on air conditioner is necessary and essential to reduce the maximum demand of the SE block.

There are two different power ratings of air conditioner available on SE block. One of the air conditioner has the power rating of 1500W whereas another air conditioner has the power rating of 3000W. On the ground floor, there are 4 units of 1500W and 8 units of 3000W air conditioner. Besides that, there are 20 units and 8 units of 3000W air conditioner on the first and second floor of SE block. So, SE block has a total of 4 units of 1500W air conditioners and 36 units of 3000W air conditioners.

Scenario is created for forecasting the potential saving of air conditioner in terms of power consumption and money. For instance, a scenario of approximate 30% reduction in power consumption of air conditioner throughout the SE block is established. The operating hour of the air conditioner of the SE block is assumed to be 8 hours per day. Commercial tariff of C1 of RM0.312/kWh as shown in appendix A is used to calculate the money needed to pay for each kWh unit that has been used. Table 4.6 shows the potential money saving on 30% reduction in power consumption of the air conditioner.

Table 4.6: Potential Saving of 30% on Reduction in Power Consumption of Air Conditioner on SE Block

Power Rating (kW)	Unit	Operating Hour	Total kWh	C1 Tariff (RM/kWh)	Money Needed (RM)
1.5	4	8	48	0.312	14.976
3	36	8	864		269.568
Total					284.544
If 30% reduction in power consumption of air conditioner is achieved					
1.5 x 0.7	4	8	33.6	0.312	10.4832
3 x 0.7	36	8	604.8		188.6976
Total					199.1808
Money saved from 30% reduction of power consumption on air conditioner					85.3632

From the Table 4.6, it is noted that RM284.54 is the amount of money need to be paid per day for the power consumption of air conditioner in SE block if there is no reduction in power consumption of air conditioner. RM85.36 is the potential amount of money that can be saved per day when there is a 30% reduction in power consumption of the air conditioner and the amount of money need to be paid is only RM199.18 per day. Hence, there is a linear relationship between the percentage of reduction in power consumption of air conditioner and the potential money saved from the amount of percentage of reduction in power consumption of air conditioner. In other words, a 30% reduction in the power consumption of air conditioner will result in the same 30% saving of the money.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In a conclusion, correlation coefficient is used to investigate the relationship between the average estimated power consumption and average real time power consumption. Range of correlation coefficient between 0.7 until 0.99 is considered to have a strong positive linear relationship which indicates a strong predictive ability. In this project, the average correlation coefficient obtained is approximate 90%. This indicates that the estimated power consumption is close enough to the values of real power consumption. Hence, estimation of power consumption being made towards the real power consumption is close and valid. Then, power distribution of SE block is further classified into the ground floor, first floor and second floor in order to investigate which floors consumed the most energy. It is found out that the first floor and second floor are the major drive towards the contribution of power consumption on SE block. Thus, identification of the main power equipment that consumed the most energy is done on the first and second floors. It is found that the air conditioner is the dominant power equipment throughout the SE block that consumed the most energy when are in operation mode. Hence, potential reduction in power consumption of air conditioner will result in potential saving of the electricity bill.

5.2 Recommendations

In this project, it is found out that air conditioner consumed most of the energy in SE block. Hence, solutions for reducing or saving of the power consumption of air conditioner are recommended in order to avoid the real time power consumption of the SE block from reaching and exceeding the maximum demand. For commercial energy users, a heavy penalty tariff rate of RM25.90/kW as shown in the appendix A is imposed by the Tenaga Nasional Berhad (TNB) to its customer who exceeded the level of maximum demand.

Solutions on energy saving of the air conditioner can be done at the minimal budget or even at no requirement of cost is preferable. The favourable options to reduce the power consumption of air conditioner without any investment to be made is to raise the temperature of the air conditioner up a degree or two when are in use. On the first floor of the SE block, there are 10 tutorial rooms provided with two air conditioners of power rating of 3000W and two ceiling fans on each tutorial room. So, a total of 20 units of 3000W air conditioners are prepared to be turned on during the lecture or tutorial classes. A dial up of the temperature up a degree or two of air conditioner when in use will definitely reduce the power consumption of the SE block. Another alternative way to save energy is to turn on merely an air conditioner unit with the running of two ceiling fans concurrently on each tutorial room on first floor of SE block. This method totally left another unit of air conditioner on each tutorial room to be in idle mode. The effect of this energy saving method is said to be significant as half of the air conditioners are not in operation mode. Besides that, the comfortability of the students and lecturers on the tutorial room are not compromised as there are two ceiling fans in operation mode together with a single operation of air conditioner. Furthermore, air filters of the air conditioner need to be cleaned regularly if the operation of air conditioner is frequent. This step is important for the energy saving because the dust accumulated on the air filter will undoubtedly reduce the efficiency of the air conditioner. Therefore, more energy is required to do the same task.

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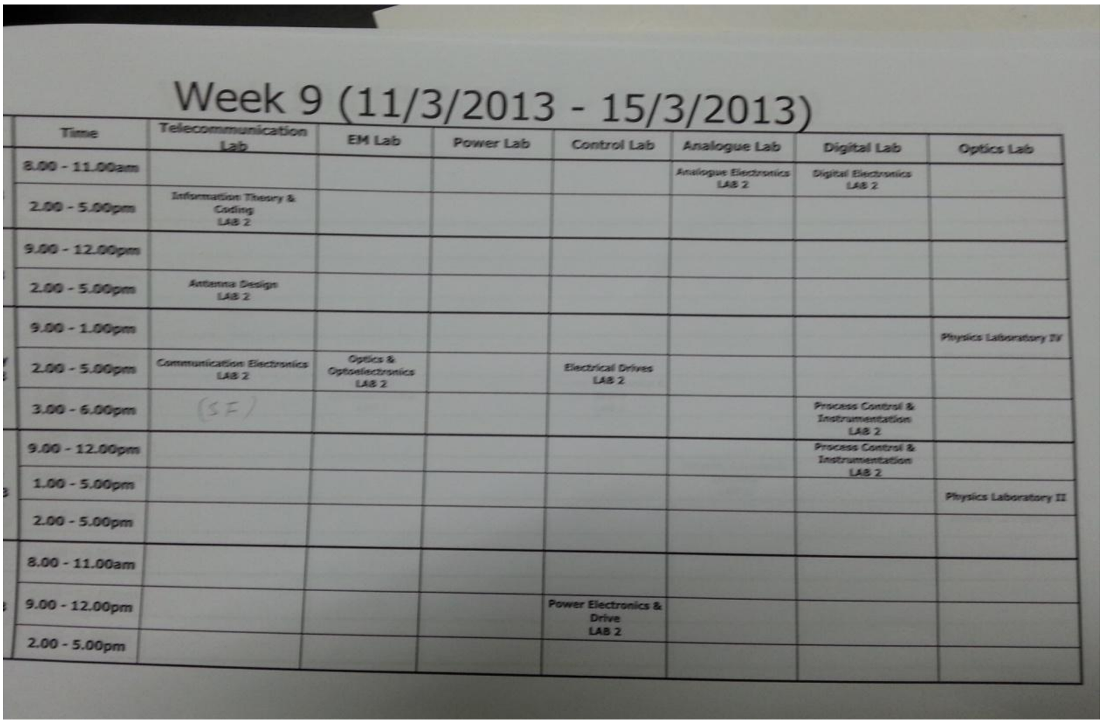
APPENDICE

APPENDIX A: Pricing and Tariff of TNB for Commercial

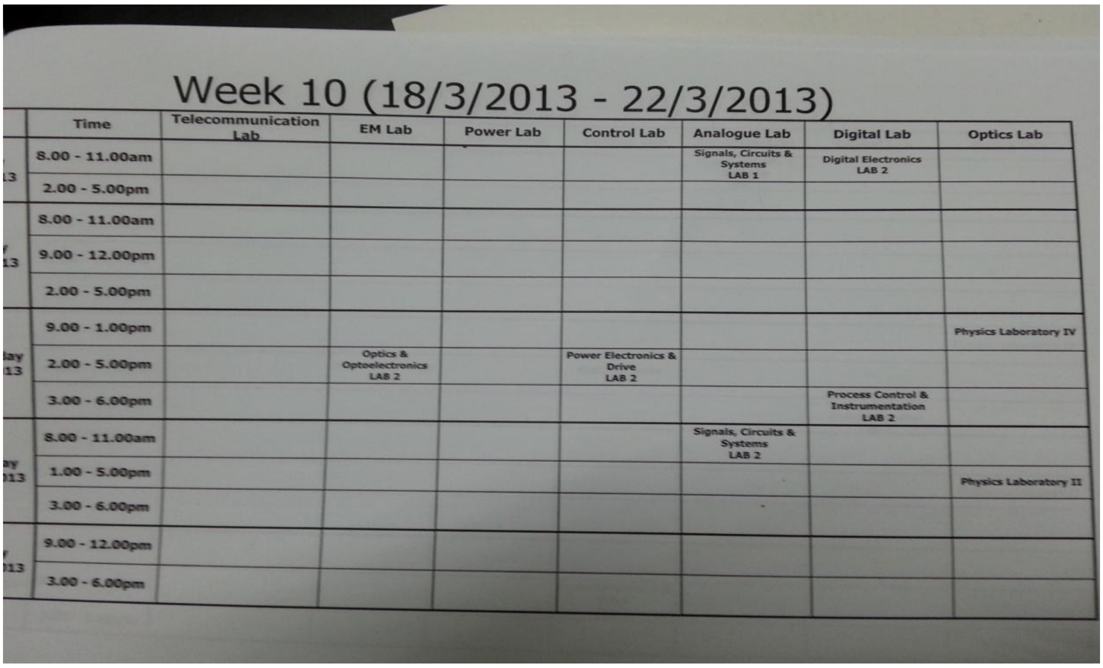
	TARIFF CATEGORY	UNIT	RATES
1.	**Tariff B - Low Voltage Commercial Tariff**		
	For Overall Monthly Consumption Between 0-200 kWh/month		
	For all kWh	sen/kWh	39.3
	The minimum monthly charge is RM7.20		
	For Overall Monthly Consumption More Than 200 kWh/month		
	For all kWh (From 1kWh onwards)	sen/kWh	43.0
	The minimum monthly charge is RM7.20		
2.	**Tariff C1 - Medium Voltage General Commercial Tariff**		
	For each kilowatt of maximum demand per month	RM/kW	25.9
	For all kWh	sen/kWh	31.2
	The minimum monthly charge is RM600.00		
3.	**Tariff C2 - Medium Voltage Peak/Off-Peak Commercial Tariff**		
	For each kilowatt of maximum demand per month during the peak period	RM/kW	38.60
	For all kWh during the peak period	sen/kWh	31.2
	For all kWh during the off-peak period	sen/kWh	19.2
	The minimum monthly charge is RM600.00		

APPENDIX B: Laboratory Schedules on Ground Floor of SE Block



Week 9 (11/3/2013 - 15/3/2013)

Time	Telecommunication Lab	EM Lab	Power Lab	Control Lab	Analogue Lab	Digital Lab	Optics Lab
8.00 - 11.00am					Analogue Electronics LAB 2	Digital Electronics LAB 2	
2.00 - 5.00pm	Information Theory & Coding LAB 2						
9.00 - 12.00pm							
2.00 - 5.00pm	Antenna Design LAB 2						
9.00 - 1.00pm							Physics Laboratory IV
2.00 - 5.00pm	Communication Electronics LAB 2	Optics & Optoelectronics LAB 2		Electrical Drives LAB 2			
3.00 - 6.00pm	(SF)					Process Control & Instrumentation LAB 2	
9.00 - 12.00pm						Process Control & Instrumentation LAB 2	
1.00 - 5.00pm							Physics Laboratory II
2.00 - 5.00pm							
8.00 - 11.00am							
9.00 - 12.00pm				Power Electronics & Drive LAB 2			
2.00 - 5.00pm							



Week 10 (18/3/2013 - 22/3/2013)

Time	Telecommunication Lab	EM Lab	Power Lab	Control Lab	Analogue Lab	Digital Lab	Optics Lab
8.00 - 11.00am					Signals, Circuits & Systems LAB 1	Digital Electronics LAB 2	
2.00 - 5.00pm							
8.00 - 11.00am							
9.00 - 12.00pm							
2.00 - 5.00pm							
9.00 - 1.00pm							Physics Laboratory IV
2.00 - 5.00pm		Optics & Optoelectronics LAB 2		Power Electronics & Drive LAB 2			
3.00 - 6.00pm						Process Control & Instrumentation LAB 2	
8.00 - 11.00am					Signals, Circuits & Systems LAB 2		
1.00 - 5.00pm							Physics Laboratory II
3.00 - 6.00pm							
9.00 - 12.00pm							
3.00 - 6.00pm							

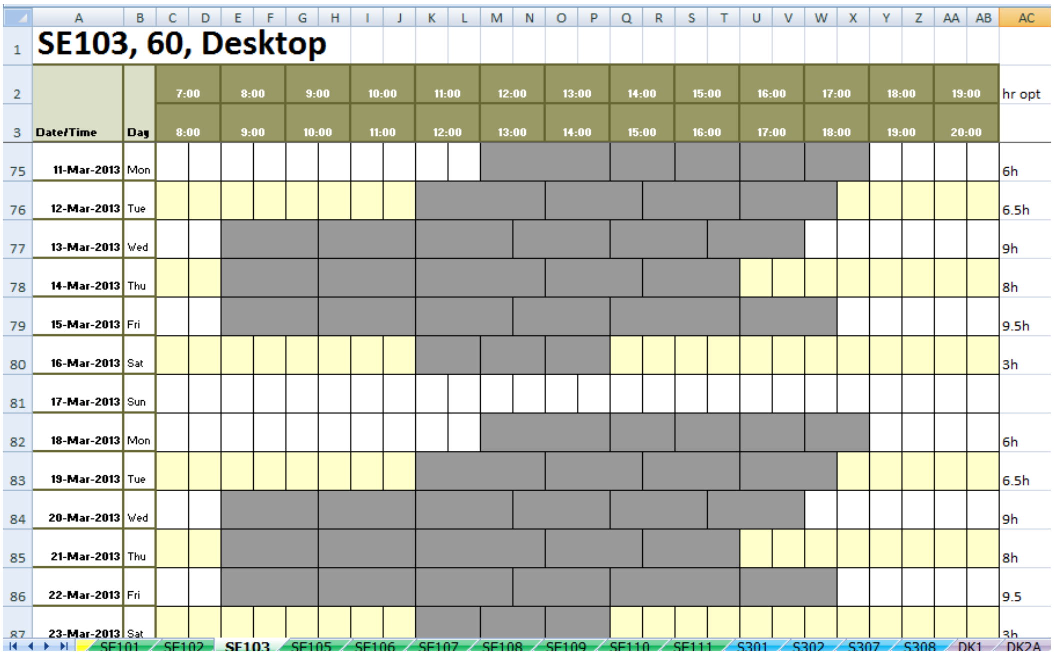
Week 11 (25/3/2013 - 29/3/2013)

Time	Telecommunication Lab	EM Lab	Power Lab	Control Lab	Analogue Lab	Digital Lab	Optics Lab
8.00 - 11.00am					Signals, Circuits & Systems LAB 2		
2.00 - 5.00pm							
9.00 - 12.00pm							
2.00 - 5.00pm							
3.00 - 6.00pm							
9.00 - 1.00pm							Physics Laboratory IV
2.00 - 5.00pm		Renewable Energy LAB 2		Electrical Drive LAB 2			
3.00 - 6.00pm						Process Control & Instrumentation LAB 2	
9.00 - 12.00pm							
1.00 - 5.00pm							Physics Laboratory II
3.00 - 6.00pm							
8.00 - 11.00am							
9.00 - 12.00pm				Power Electronics & Drive LAB 2			
2.00 - 5.00pm							

Week 12 (1/4/2013 - 5/4/2013)

Time	Telecommunication Lab	EM Lab	Power Lab	Control Lab	Analogue Lab	Digital Lab	Optics Lab
8.00 - 11.00am					Signals, Circuits & Systems LAB 2		
2.00 - 5.00pm							
9.00 - 12.00pm							
2.00 - 5.00pm							
9.00 - 1.00pm							Physics Laboratory IV
2.00 - 5.00pm		Renewable Energy LAB 2					
3.00 - 6.00pm						Process Control & Instrumentation LAB 2	
9.00 - 12.00pm							
1.00 - 5.00pm							Physics Laboratory II
2.00 - 5.00pm							
3.00 - 6.00pm							
9.00 - 12.00pm							
2.00 - 5.00pm							

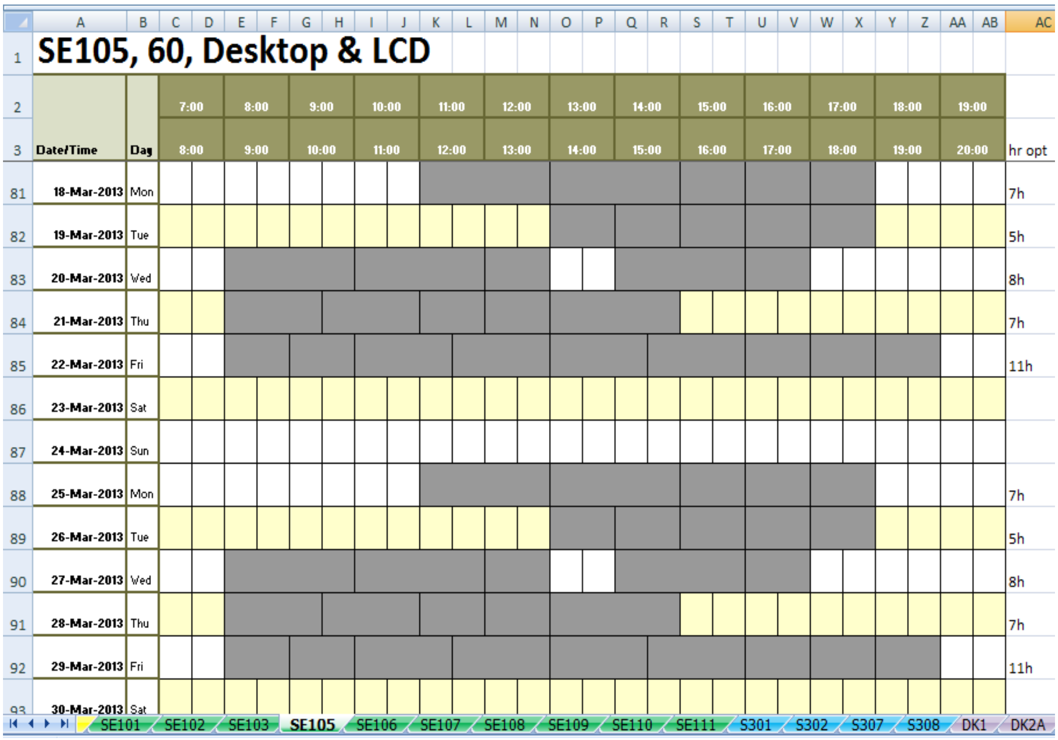
APPENDIX C: Timetables on First Floor of SE Block



SE103, 60, Desktop

	Date/Time	Day	7:00–8:00	8:00–9:00	9:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	hr opt
75	11-Mar-2013	Mon														6h
76	12-Mar-2013	Tue														6.5h
77	13-Mar-2013	Wed														9h
78	14-Mar-2013	Thu														8h
79	15-Mar-2013	Fri														9.5h
80	16-Mar-2013	Sat														3h
81	17-Mar-2013	Sun														
82	18-Mar-2013	Mon														6h
83	19-Mar-2013	Tue														6.5h
84	20-Mar-2013	Wed														9h
85	21-Mar-2013	Thu														8h
86	22-Mar-2013	Fri														9.5
87	23-Mar-2013	Sat														3h

SE101 SE102 SE103 SE105 SE106 SE107 SE108 SE109 SE110 SE111 S301 S302 S307 S308 DK1 DK2A



SE105, 60, Desktop & LCD

	Date/Time	Day	7:00–8:00	8:00–9:00	9:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	hr opt
81	18-Mar-2013	Mon														7h
82	19-Mar-2013	Tue														5h
83	20-Mar-2013	Wed														8h
84	21-Mar-2013	Thu														7h
85	22-Mar-2013	Fri														11h
86	23-Mar-2013	Sat														
87	24-Mar-2013	Sun														
88	25-Mar-2013	Mon														7h
89	26-Mar-2013	Tue														5h
90	27-Mar-2013	Wed														8h
91	28-Mar-2013	Thu														7h
92	29-Mar-2013	Fri														11h
93	30-Mar-2013	Sat														

SE101 SE102 SE103 SE105 SE106 SE107 SE108 SE109 SE110 SE111 S301 S302 S307 S308 DK1 DK2A