**LOAD ANALYSIS AND FORECAST FOR A BUILDING**

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

**Faculty of Engineering and Science**
**Universiti Tunku Abdul Rahman**

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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 **"LOAD ANALYSIS AND FORECAST FOR A BUILDING"** was prepared by **NG SOON HEE** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical and Electronic Engineering at Universiti Tunku Abdul Rahman.

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Signature : _____________________________

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Date : 14/04/2014

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# LOAD ANALYSIS AND FORECAST FOR A BUILDING

## ABSTRACT

As the world is becoming technology advanced and fossil fuel depletion has become the main concern to transform our country to a developed nation, load analysis and forecast play an important role in levelling down the demand and improving the energy efficiency. In this project, load analysis has been carried out at one of the buildings of Universiti Tunku Abdul Rahman (UTAR) Kuala Lumpur (KL) campus, namely SE block. Real time load data is collected in the main switch room at ground floor using two TES-3600 power analyzers. Data is recorded every minute by the power analyzer and being processed in spreadsheet program, namely Microsoft Office Excel. All the data collected is sorted in 15 minutes interval for the ease of data analysis. Correlation for the same weekdays and different weekdays are compared to have a better understanding between the loads as well. Then, the data processed is used for load forecasting. The methods being applied in this project are exponential smoothing and Auto-Regressive Integrated Moving Average (ARIMA). Both methods are used for short-term load forecasting. Every nine past weekdays will be collected for predicting the tenth weekdays. For instance, nine past Mondays are used to forecast the tenth Monday by using both the forecasting methods. Results obtained are then compared for their efficiency by correlation, Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). The comparison shows the result of the exponential smoothing method has slightly higher correlation over the ARIMA method. However, the MAPE of the exponential smoothing method is much lower than the ARIMA method.

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# LIST OF SYMBOLS / ABBREVIATIONS

| | |
|---|---|
| *Ft-1* | forecast for the period before |
| *At-1* | actual demand for the period |
| *a* | weight between 0 and 1 |
| | |
| WCI | Wind Chill Index |
| THI | Temperature-Humidity Index |
| UTAR | Universiti Tunku Abdul Rahman |
| KL | Kuala Lumpur |
| NN | Neural Networks |
| ARIMA | Auto-Regressive Integrated Moving Average |
| ARMA | Auto-Regressive Moving Average |
| MAE | Mean Absolute Error |
| MAPE | Mean Absolute Percentage Error |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Building consumes 40% of the total energy produced in commercial and residential buildings as answered by the EIA, U.S. Energy Information Administration. If consumers have no clues about the energy consumption of the building, it is not possible to trace where the energy has been used and wasted. For instance, consumers do not know which equipment consumed the most energy and which energy consuming unit usage can be reduced to save the energy. It can be seen that load analysis is significant in sorting out the problems of wasted energy and further reduces the unnecessary use of energy. Load forecast helps in reducing the use of energy as well. Consumers are able to know the period of peak demand occurs and this may help them to optimize the use of renewable energy to tame the peak demand so as reducing the maximum demand charges. With combination of the load forecasting method, taming the peak demand of everyday energy usage will not be a problem. Peak demand surcharge will be significantly reduced as well. It is a kill two bird with one stone way of making use of the energy as not only the costs will be saved, energy will be conserved too.

Load analysis is the fundamental part of energy management, so it is the first step to do as to improve a healthy facility energy system. It is a way of listing all the electricity-consuming equipment in one building, from low power consumption to high power consumption apparatus. All the equipment not only consumes energy but also the costs, so the best way to conserve both of these is to start with the analysis of the loads.

The basic elements of load analysis are listing all the energy consuming devices in the building, power ratings and the estimation of each device's operating hours on a daily basis. With all of these data, estimation of building energy consumption can be done accurately. Load forecasting can be executed also based on the historical data collected. (Powering Health, 2013)

With the proper execution of load analysis, precious value of building energy usage can be used to analyze on how to save energy costs, conserve energy and protect valuable assets.

## 1.2 Aims and Objectives

The aim of this project is to access the appliances of a building at UTAR Setapak Campus and forecast the power demand.

The objectives of this project are to:

- Collect building load demand data;
- Identify the energy consumption of each equipment;
- Analyse the load profile;
- Forecast the power demands using Exponential method and ARIMA method;

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Load Forecasting

It is essential for utility company to have accurate models for electrical power load forecasting to ensure the reliability and security of power supply as well as future planning. Electric utility grabs the benefits of load forecasting to help on making important decisions such as infrastructure development, purchasing and generating electric power as well as load switching. It is very important for energy supplier, ISOs and any others which participate in electrical energy generation, transmission, distribution, and markets to have load forecasting.

In general, load forecasts can be categorized into three types, namely short-term load forecasting, medium load forecasting, and long-term load forecasting. For short-term load forecasting, time frame is normally from one hour to one week. Medium load forecasting is normally ranged from a week to a year and long-term load forecasting is longer than a year. Different times horizons load forecasting are crucial for different operations in utility company and natures of all these forecasts are different also. For instance, it is possible to forecast next day load with the accuracy of around 1-3% for a particular region. However, without accurate long-term weather forecasts it is impossible to forecast next year peak load with similar accuracy. If historical weather observations are provided, it is still possible to have probability distribution of the load for next year peak forecast. According to industrial practice, it is also possible to predict so-called weather normalized load, which is for average annual peak weather conditions or worse than average peak weather conditions for a given region. Weather normalized load is load calculated by the average of the weather characteristics from historical loads over a period of time. Many of the companies gather the last 25-30 years of data but the period is varied from one utility to another. (Load Forecasting Methods, n.d.)

Load forecasting plays an important role in deregulated energy market. Deregulated energy market simply means that competitive energy suppliers are allowed to enter the market to offer the company's respective energy supply products to consumers. Meanwhile, price of energy will not be regulated and consumers are no longer forced to receive energy supply from one utility. It is important as consumers are given the choices to choose from different suppliers. Deregulated energy market also motivates the suppliers to differentiate the supplies from the current utility or other competitors by giving different pricing plans and innovative features which may not been provided by the current utility. (Just Energy, 2012) Supply and demand of energy is fluctuating, weather condition is changing, and energy prices is increasing as well by a factor of ten or more during peak situations, so load forecasting is extremely important for power utilities. Short-term load forecasting can predict load flows and make decisions which can prevent overloading. By taking this action for a period of time will lead to improvement of network reliability and reduction in equipment failures and blackouts.

End use and econometric approach are widely used for medium and long-term load forecasting. While for short-term load forecasting, methods such as time series, similar day approach, fuzzy logic and others are used. Large variety of methods have been used for load forecasting and appropriate improvements and developments of the methods can lead to more accurate load forecasting techniques. (Load Forecasting Methods. n.d.)

## 2.2 Factors for Forecast

Factors to be considered by short-term load forecasting and long-term load forecasting are slightly different. For short-term load forecasting, time factors, weather data, and possible customers' classes should be considered. Meanwhile, medium and long-term load forecasting take into consideration of historical load, weather data, customers in different categories, appliances used in the area, characteristics like age, economic and demographic data and other factors.

For time factors, it includes time of the year, day of the week, and also the hour of the day. Weekdays and weekends are having differences in load behaviour and the same goes to different weekdays. For example, Tuesday to Thursday may have different loads structure if compare to Monday and Friday which is adjacent to weekends. This is true especially during summer. For the period of having holidays, it is even more difficult to forecast than non-holidays as the infrequent occurrence.

For weather conditions, it influences the load as well. In short-term load forecasting, forecasted weather parameters are the most important factors. Different weather variables are considered in load forecasting and the most commonly used load predictors are temperature and humidity. Hippert *et al.* has published a paper of load prediction indicated that in twenty two research reports, thirteen of them used temperature only, three used additional parameter of weather, three used temperature with humidity, and three used load parameters. Other than that, Wind Chill Index (WCI) and Temperature-Humidity Index (THI) are widely used by utility companies also. WCI is the measure of cold stress in winter while THI is the measure of summer heat discomfort.

Utility companies serve different types of customers such as residential, commercial, and industrial. The patterns of their energy usage are always different for different types of classes but it is quite similar for the customers within the same class. As a result, utility companies always differentiate load behaviour on class by class basis. (Load Forecasting. n.d.)

## 2.3 Forecasting Methods

Numbers of forecasting method have been developed over the past few decades. There are two methods which are widely used for medium and long-term forecasting, namely end-use and econometric approach. While for the short-term lead forecasting, methods used are exponential smoothing, time series, similar day approach, neural network, fuzzy logic, various regression models, statistical learning algorithms, and expert systems. By investigating, developing, and improving these mathematical tools, more accurate load forecasting methods will be developed.

For the statistical method in load forecasting, load is represented as a function of various factors such as time, weather, and customer class in a mathematical model. This model contents of two important categories which are additive model and multiplicative model. For the multiplicative model, the forecasted load is the product of a number of factors while for the additive model, the forecasted load is the sum of numbers of components as mentioned in Chen *et al*. (Load Forecasting. n.d.)

### 2.3.1 Short Term Load Forecast

A lot of different statistical and artificial intelligence techniques have been built for short-term load forecasting. The first method to be introduced is Similar-day approach. The historical data for days within one to three years with characteristics similar to forecast day is used in this approach. Those characteristics are weather, the date, and the day of the week. Similar day's load is taking as a forecast. This load forecasting not only can be a single similar day load, but also a regression procedure or linear combination which can include various similar days. Trend coefficients are used in similar days in the previous years.

Regression method is another approach to be used in short-term load forecasting. For power load forecasting, regression methods are normally applied to model relationship between the load consumption with other factors like the day type, weather, and the customer class. Various regression models have been presented in

Engle *et al.* for next day peak load forecasting. Charytoniuk *et al.*, Haida *et al.*, Hyde *et al.*, and Ruzic *et al.* have discussed the models for load forecasting as well. These several types of models have incorporate exogenous influences such as weather, deterministic influences such as holidays, and stochastic influences such as average loads.

Neural Networks (NN) is also a very commonly used load forecasting method. It is actually a non-linear circuit which has the ability to handle the fitting of non-linear curve. The output of NN could be linear or non-linear function of the given input. Input given can be from other network component or the real input of network. Small amount of layers connecting the components are arranged in practice and may be including feedback path. One of the architectures such as Boltzmann machine, Hopfield or back propagation must be chosen to apply in NN for load forecasting. Other factors need to include also are amount of layers and components, number format such as continuous or binary which is used by output and input, and uni-directional or bi-directional links.

Back propagation is the most popular NN architecture for load forecasting. It uses functions with value continuously and regulated learning. Under regulated learning, practical weights given to component inputs are decided by fitting historical data like weather and time to the outputs wanted in "training session" before starting. NN with unregulated learning does not need training before starting. (Load Forecasting. n.d.)

### 2.3.2 ARIMA

Auto-Regressive Integrated Moving Average (ARIMA) is a type of model to forecast a time-series data. It is the transformation of a regression model from the form below, equation 2.1 to equation 2.2.

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \cdots + b_p X_p + e \qquad (2.1)$$

where

$Y$ = forecast variable

$X_1, X_2, X_p$ = explanatory variables

$b_0$ through $b_p$ = linear regression coefficients

$e$ = error term

$$Y_t = b_0 + b_1 Y_{t-1} + b_2 Y_{t-2} + \cdots + b_p Y_{t-p} + e_t \quad (2.2)$$

The difference between these two equations is that the right-hand side variables of equation 2.1 are different explanatory variables of which equation 2.2 has the previous value of the forecast variable $Y_t$. Those variables are the time-lagged values of the forecast variable, so autoregression (AR) is named to describe the form of equation 2.2.

There is also a time series model named moving average (MA) model, shows in equation 2.3. It uses past errors as explanatory variables and a dependence relationship has set up among those error terms. This equation is defined as the moving average of the error series, $e_t$.

$$Y_t = b_0 + b_1 e_{t-1} + b_2 e_{t-2} + \cdots + b_q e_{t-q} + e_t \quad (2.3)$$

With two of this time series models, autoregression (AR) model can be coupled with moving average (MA) model to form a useful type of time series model named autoregressive moving average (ARMA) models. However, this type of model can be used when the data are stationary only. ARMA can still be extended to non-stationary series by differencing the data series, which is the ARIMA model.

ARIMA is having a large variety of models, of which the general non-seasonal model is known as ARIMA ($p$, $d$, $q$):

AR : $p$ = order of the autoregressive part

I : $d$ = degree of first differencing involved

MA: $q$ = order of the moving average part.

The notation of the model can be shortening by dropping the unused parts when any of the *p*, *d*, or *q* are equal to zero. For instant, ARIMA (2,0,0) can be written as AR(2) as there is no differencing part and no moving average part. Likely, ARIMA(0,1,1) can be written as IMA(1,1) as well. (Makridakis, Wheelwright and Hyndman, 1998)

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

Before data analysis can be carried out, initial energy audit of SE block in UTAR KL campus must be done by site surveying personally for the whole building of SE block. Basically, SE block is made up of three floors where every floor is having its own purpose of usage. For ground floor, it consists of all different kinds of laboratory and it is only used to conduct laboratory experiments. First floor is full of classes and it is for the purposes of lecture classes and tutorial sessions. Second floor has computer rooms for students to access to internet. Sometimes, lecture classes are conducted at the computer rooms as some of the labs or assessment need to use the computers installed with original licensing software. Site investigation is carried out for the purposes of understanding the overall energy consumption of the SE block. A survey has been conducted among staffs in charge for each laboratory in the SE block. The power rating of equipment used in each laboratory is recorded in order to estimate the energy consumption of the equipment during its operation. The time table is obtained so that the duration of practical as well as the equipment used can be taken into account to predict the load.

### 3.1.1 Load Estimation Based On Timetable

Detail load estimation is a process of having all the surveying data on equipments which consuming energy in SE block and calculate the estimate load consumed by each room. Based on the timetable obtained, energy consumption of each room for different time can be estimated. The equipments which consumed energy can be listed as air conditioner, ceiling fan, computers, lighting, projectors, motors and others. Quantities of all of these energy consuming equipments as well as their power rating has been recorded and monitored. Then, all of the data is arranged in Microsoft Excel for analysis purposes and ease of data organizing. With the timetable for every room, load estimation can be done as the room usage time frame is clearly showed in the timetable. The timetable for classes at the first floor of SE block is shown in appendix A.

For the ground floor of SE block, all the energy consuming equipments such as air conditioner, ceiling fan, computers, lighting, lab machine which are inside the digital electronic laboratory, analogue laboratory, project workshop and other laboratory are recorded in Microsoft Excel with their quantity and also the power rating. The same method is applied to the first floor of SE block as well. All the equipment such as computers, projectors, ceiling fans, air conditioners and lightings with their quantity and power rating in SE101, SE102, SE103, SE105 and so on are recorded. The same method goes to second floor of the SE block. Other than that, all the lightings inside toilets and corridors are recorded also. With all the data, estimated load consumption for each room can be calculated as shown in Figure 3.1.

By having the power rating for all the equipments, and also their quantity in every room, each room load can be calculated. Combine with the timetable, every half an hour time scale is built in Microsoft Excel from morning 7 o'clock until night time 8 o'clock. The slot will be filled by the load calculated for the room if there is a conduction of class for that particular half an hour based on the timetable.

| Comp / Room | | SE101 | SE102 | SE103 | SE105 | SE106 | SE107 | SE108 | SE109 | SE110 | SE111 | SE201 | SE202 | SE203 | Toilet | Corridor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air-cond | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 |
| Light | 0.036 | 12 | 12 | 12 | 12 | 12 | 12 | 24 | 24 | 24 | 24 | 18 | 18 | 18 | 24 | 78 |
| Fan | 0.075 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 0 | 0 |
| Projetor | 0.295 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| Computer | 0.27 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 24 | 30 | 30 | 0 | 0 |
| | Total kW: | 7.147 | 7.147 | 7.147 | 7.147 | 7.147 | 7.147 | 7.654 | 7.654 | 7.654 | 7.654 | 13.278 | 15.193 | 15.193 | 0.864 | 2.808 |

**Monday**

| Time / Room | SE101 | SE102 | SE103 | SE105 | SE106 | SE107 | SE108 | SE109 | SE110 | SE111 | SE201 | SE202 | SE203 | Toilet | Corridor | Time | Calculated Lo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7:00 - 7:30 | | | | | | | | | | | | | | | | 7:00 - 7:30 | |
| 7:30 - 8:00 | | | | | | | | | | | | | | | | 7:30 - 8:00 | |
| 8:00 - 8:30 | | 7.147 | | 7.147 | | | 7.654 | 7.654 | 7.654 | | | | | | | 8:00 - 8:30 | 37 |
| 8:30 - 9:00 | | 7.147 | | 7.147 | | | 7.654 | 7.654 | 7.654 | | | | | | | 8:30 - 9:00 | 37 |
| 9:00 - 9:30 | | 7.147 | | 7.147 | | | 7.654 | 7.654 | 7.654 | | | | | | | 9:00 - 9:30 | 37 |
| 9:30 - 10:00 | | 7.147 | | 7.147 | | | 7.654 | 7.654 | 7.654 | | | | | | | 9:30 - 10:00 | 37 |
| 10:00 - 10:30 | 7.147 | | | | | | 7.654 | 7.654 | 7.654 | | | | | | | 10:00 - 10:30 | 30 |
| 10:30 - 11:00 | 7.147 | | | | | | 7.654 | 7.654 | 7.654 | | | | | | | 10:30 - 11:00 | 30 |
| 11:00 - 11:30 | 7.147 | | | | | | 7.654 | 7.654 | 7.654 | | | | | | | 11:00 - 11:30 | 30 |
| 11:30 - 12:00 | 7.147 | | | | | | 7.654 | 7.654 | 7.654 | | | | | | | 11:30 - 12:00 | 30 |
| 12:00 - 12:30 | 7.147 | 7.147 | 7.147 | | | | 7.654 | 7.654 | 7.654 | | | | | | | 12:00 - 12:30 | 44 |
| 12:30 - 1:00 | 7.147 | 7.147 | 7.147 | | | | 7.654 | 7.654 | 7.654 | | | | | | | 12:30 - 1:00 | 44 |
| 1:00 - 1:30 | 7.147 | 7.147 | 7.147 | | 7.147 | 7.147 | 7.654 | 7.654 | 7.654 | | | | | | | 1:00 - 1:30 | 58 |
| 1:30 - 2:00 | 7.147 | 7.147 | 7.147 | | 7.147 | 7.147 | 7.654 | 7.654 | 7.654 | | | | | | | 1:30 - 2:00 | 58 |
| 2:00 - 2:30 | 7.147 | 7.147 | 7.147 | 7.147 | 7.147 | 7.147 | 7.654 | 7.654 | 7.654 | | | | | | | 2:00 - 2:30 | 65 |

**Figure 3.1: Estimated Power Consumption with respect to time for rooms in SE Block**

## 3.2 Data Collection

### 3.2.1 Equipment Required

TES-3600 3P4W power analyzer is used for the measurement of parameters required for the load analysis and load forecast for SE block. The data obtained from this power analyzer is all real time load data from the power consumption of whole SE block. The parameters required are voltage, current, active power, reactive power, apparent power, power factor and frequency. Figure 3.2 shows the look of TES-3600 Power Analyzer.

**Figure 3.2: TES-3600 Power Analyzer**

TES-3600 power analyzer has connectors for four current sensing clamps and four voltage sensing clips. All of them will have true RMS sensing ability. It also provides the switchable power measurement function such as 1P2W, 1P3W, 3P3W2M and 3P4W. For the voltage measurement, TES-3600 power analyzer can handle up to 600V of limitation and 1000A for current measurement. The power analyzer provides different time intervals of five seconds, thirty seconds, and one minute to choose for data recording. (TES-3600 3P4W Power Analyzer 2013)

### 3.2.2 Real Time Data Logging

Two TES-3600 power analyzers will be used alternatively to record down the data without data missing as shown in Figure 3.3. The maximum data memory of one power analyzer is 10,000 sets and it can last for almost a week. It only last for almost seven days as for a day, 1,440 (60 x 24) sets of data is needed to record. The power analyzer is set to record data every one minute in this case. Once the first power analyzer has been set to record data, the second power analyzer is needed to set before the first power analyzer's memory is full. This simply means that the next power analyzer is required to place in the switch room the day before the first power analyzer due. This power analyzer can operates on its own without connecting to the computer. It only required computer when data retrieving is needed. Data retrieving can be done after the power analyzer has been disconnected from the current sensing clamps and voltage sensing clips as it has its own internal memory to store the data recorded. The use of two power analyzers will allow the data to be recorded continuously without any data missing. Figure 3.3 shows two power analyzers in switch room for data collection.

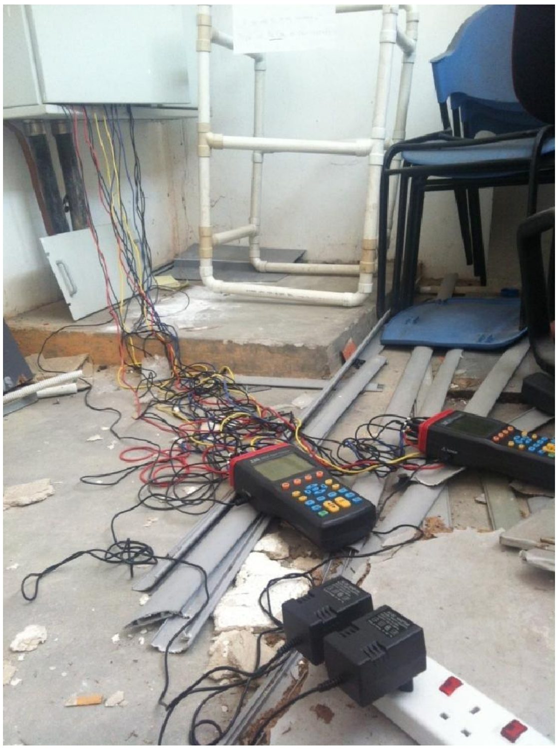

**Figure 3.3: Two TES-3600 Power Analyzers Installed In Switch Room**

Each power analyzer has four current sensing clamps and four voltage sensing clips. Three phase power, which are phase A, phase B, and phase C at the live busbars will be measure by the first three pairs of current clamps and voltage clips. The last pair of the current clamp and voltage clip is used to measure the neutral phase. It is necessary that both current clamps and voltage clip are installed together to get the accurate reading of power. As shown in figure 3.3, all of the clamps and clips are installed in the main switchboard at SE block. Precaution must be mentioned at the switchboard to prevent any unknown and unauthorized person touching the clamps or clips as they are connected to the live busbars.

Figure 3.4 shows the connection of current clamps and voltage clamps on the busbar with a very neat arrangement. This is to prevent any short circuit within the busbars to occur and also without any power interruption of the SE block. By connecting the clamps and clips in this way, the readings of both the power analyzers will have a lower degree of variation so the accuracy of the readings is improved. While doing the clamping, safety insulating rubber gloves must be wear for the safety of personnel. Every cable of the clamps and clips need to sort out nicely for the ease of recognition and removal work as well. All the clamps are labelled with the number of phase and they are paired with the clips with four different colours of red, yellow, blue, and black. Proper connection of the clamps and clips to make sure no disconnection from the live busbars will occur as the data collection will be influenced.

**Figure 3.4: Clamping On Live Busbars**

Some of the important features of power analyzer are pointed out as shown in Figure 3.5. Power analyzer will start to measure once every connection is completed and the power adaptor has been turn on. The mode selection shows in Figure 3.5 indicates the way of measurement that the user can choose to have. In this case, the mode has been selected to 3P4W which means three phases and four wires so that the user can browse through all the three phases of voltage and current. In Figure 3.5, the display of the power analyzer shows clearly the measurement of real time voltage and current for all the three phases while power rating is only show for a single phase. All three phases of power rating as well as total power can be read by pressing the power button to switch for different phase.

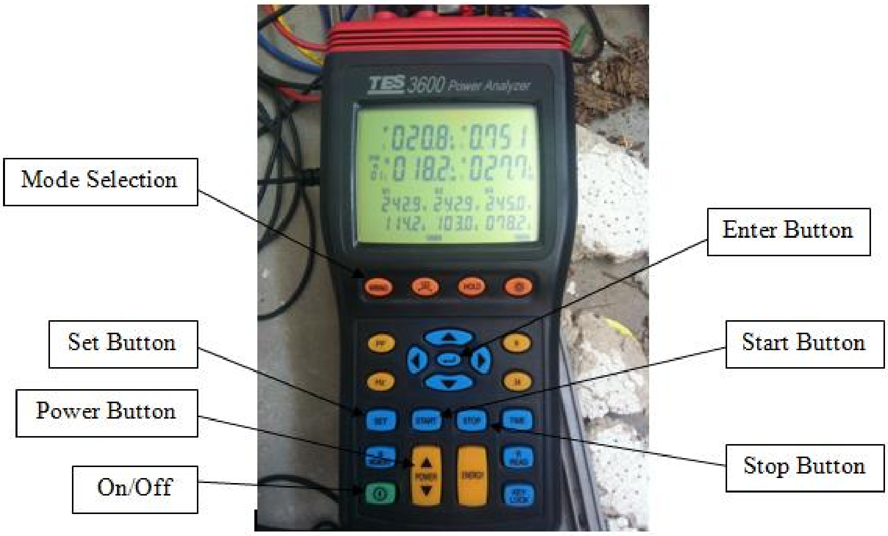


**Figure 3.5: Features of the TES-3600 Power Analyzer**

Once the power analyzer has been turned on, it does not start to log data immediately. Few steps of initialization are needed to start the data logging process. Press the set button first and the display of the power analyzer will shows the time setting for the user to set the current minute, hour, day, date, and year. After that, click the enter button and the display will shows the time interval setting. This power analyzer provides three time intervals to choose from which are five seconds, thirty seconds and one minute. In this case, one minute of interval is chosen for the study as it will give ease to the data analysis and collection as well as it can log data for almost a week of time for 10,000 sets of data. Then, press the enter button again to confirm the selection and start button is pressed to start the data logging. A small indication, M is shown at the middle lift of the screen and it will blink once every minute to show that one set of data has been recorded. Stop button is pressed when the user wants to stop the data logging. Usually this is done when the user wants to collect the power analyzer for data collection. As shown in Figure 3.6, it is the interface of real time tab. It provides the clear view of real time data measurement for the three phases in graph and text form.

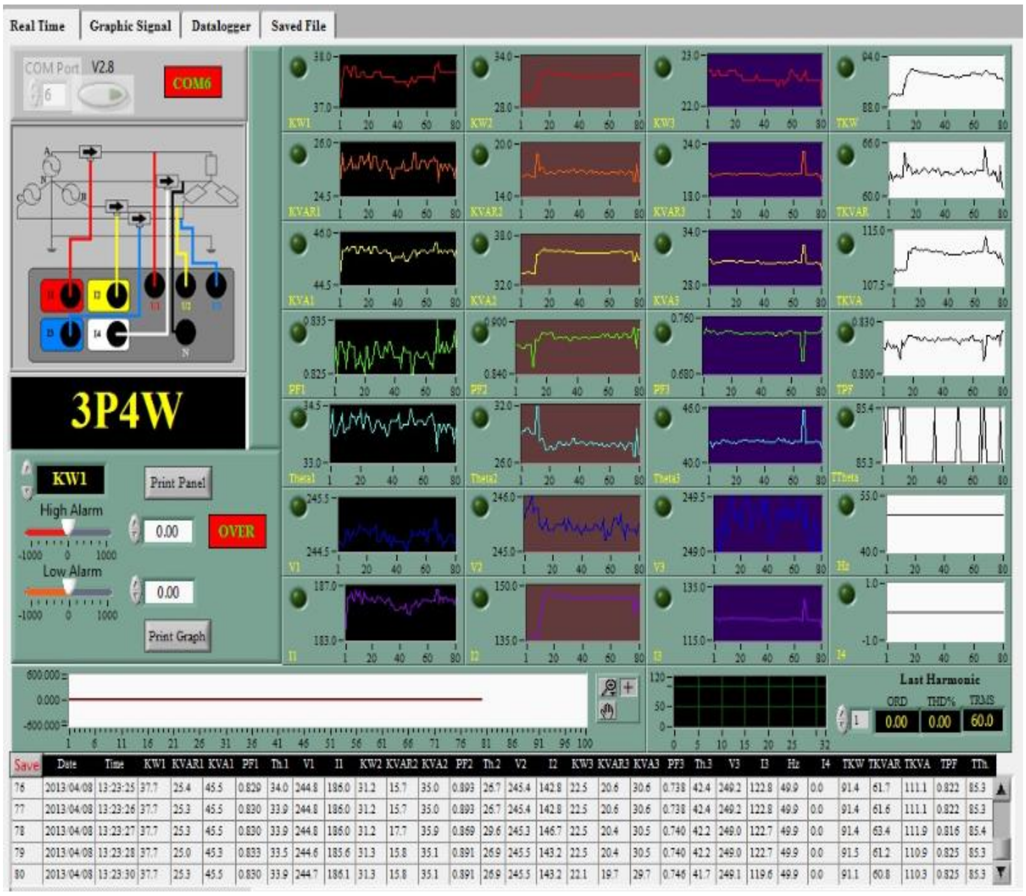


**Figure 3.6: User Interface of Power Analyzer**

After the data is fully recorded in power analyzer, a computer with the installed power analyzer software is used to retrieve the data from power analyzer. In this case, the data retrieved is in the format of .xls. Communication interface between the computer and power analyzer is done by using a RS232 to USB converter. The user interface of the power analyzer software is shown in Figure 3.6. COM port of the communicate interface must be identify first before the software is really connected to the power analyzer. After connected, the user interface will show the current mode used by the power analyzer. At the top left side of the user interface, there are four tabs to choose for and each of them will have different usage. The tabs are real time, graphic signal, datalogger and saved file. In this case, real time and datalogger are used only.

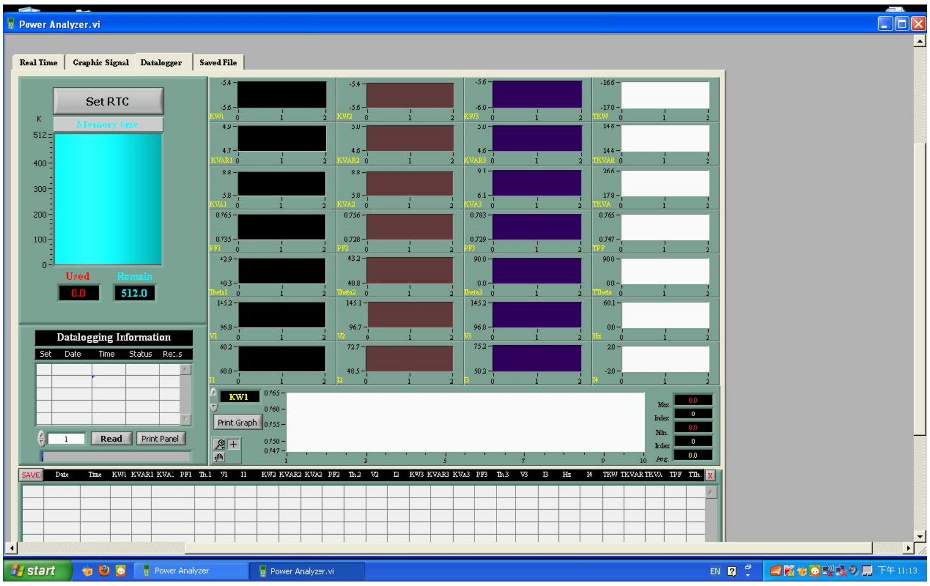


**Figure 3.7: Datalogger**

Figure 3.7 shows the user interface under the datalogger tab. Under the tabs, there is a blue rectangular shape of block and others are quite similar to the real time user interface. The rectangular block shows the current status of the power analyzer's memory status. It indicates the memory remains by using blue colour and red shows the memory that has been used. The memory size of the power analyzer is 512kB and it allows the memory storage up to 10,000 sets of data for one minute time interval used in this project. Under the datalogging information, there is a read button to click in order to retrieve data from the power analyzer. Usually for a full memory of 10,000 sets of data will take around fifteen minutes to complete the datalogging. Once the process completed, the user can save the file to the prefer location for later use. It is important for the users to clear the data after saving the data as the new data recording requires an empty memory.

Power analyzer software is user friendly as the interface is displaying all the information that the user needs to know. For the first time connecting to the power analyzer, trial and error approach is necessary to find out which is the right port to access before the connection is done successfully.

## 3.3 Data Management

After both the load estimation and real time data collection are done, all the data need to compute in Microsoft Excel for better arrangement and analysis. With the entire data ready, load forecasting can only be done.

### 3.3.1 Averaging Real Time Data

As power analyzer can record 1,440 sets of data everyday for time interval of one minute, there is a huge amount of data until this point of the project. Few months of data recording which beyond sixty thousands sets of data has been arranged in Microsoft Excel and data analysis is hard to be done in this condition. So, data averaging method is introduced to significantly shrink down the amount of data from 1,440 to 96 sets of data. All 1,440 sets of data will be averaged every fifteen minutes to make the data analysis and load forecasting easier.

$$= AVERAGE(OFFSET(AA\$2,(ROW()-ROW(AG\$2))*15,,15)) \qquad (3.1)$$

Equation 3.1 is used to average the 1,440 to 96 sets of data per day. In Microsoft Excel, there is a math function of average which is used to build the formula above. It is then modified to start reading the data from column AA2 to the end and shows the results in column AG2. The interval specified for the averaging is stated at the end of the formula.

### 3.3.2 Data Sorting

As months of data has been collected and rearranged in Microsoft Excel, the huge amount of data makes the data analysis becomes difficult. Particular data is required to be found easily and fast as no time will be wasted. Data sorting is one of the approaches to make the data organising easier and fast. As shown in Figure 3.8, all the data are arranged in row and column, filter function can be used to sort out the unwanted data or only show the particular data needed. The data can be selected based on the day, or even the date or group them in a particular order. The main focus of this project is the date and the day when it comes to data analysing. After data needed is sorted, data analysis and load forecasting can be done easily. Figure 3.8 shows the method to sort the data using Microsoft Excel.

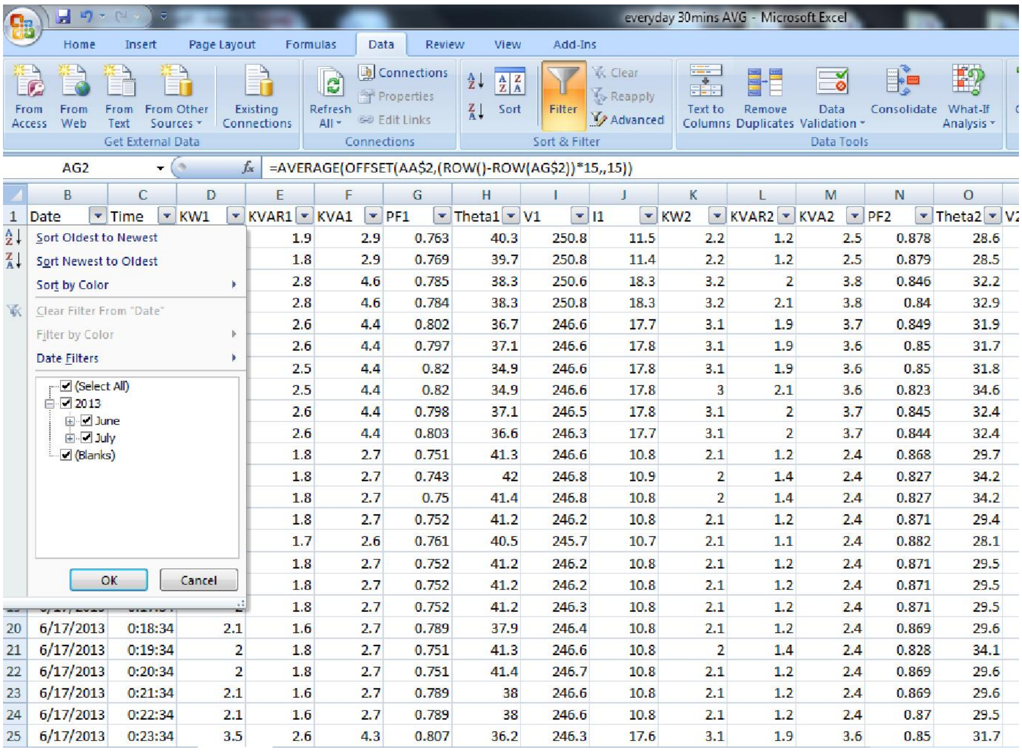


**Figure 3.8: Data Sorting in Microsoft Excel**

### 3.3.3 Correlation between Data

Correlation is usually used to tell the relationship between two sets of data in order to make decision on the usability of data for comparison. Data analysis for the correlation between real time data and forecasted data is important to check on the relationship between them and to judge the accuracy of the load forecasting method. This method can be done by using the correlation function available in the Microsoft Excel. Correlation coefficient always has the value between -1 and +1. If a correlation coefficient is having value of +1, it means that two variables are related in positive manner perfectly while -1 shows that two variables are related in negative manner perfectly. Meanwhile, correlation coefficient of 0 shows there is no relationship between two variables. (Regression and Correlation Analysis, n.d.)

For correlation coefficient which is ranged from 0.01 to 0.29 shows that there is a weak positive relationship. However, correlation coefficient which ranged from 0.3 to 0.69 indicates moderate positive relationship while the range from 0.7 to 0.99 represents the strong positive relationship. With high correlation coefficient, the dependant variable will change more accurately when the independent variable changes. (Steven B. Achelis 2013)

## 3.4 Exponential Smoothing

It is a part of many forecasting methods which based on weighted moving averaging model. Furthermore, it is an ideal way of developing forecasts which make up of many smaller items. Moreover, this method only needs three numbers to carry out the forecasting.

$$Ft = a*(At-1)+(1-a)*(Ft-1) \tag{3.2}$$

where

*Ft-1* = forecast for the period before

*At-1* = actual demand for the period

*a* = weight between 0 and 1

For *a* which is closer to 1, more weight will be put on the most recent demand number. Figure 3.9 shows an example of calculation using weight of *a* = 0.3 which is less weight on most recent demand number. (Cecil Bozarth, 2011)

| Period | Demand | Exponential Smoothing Forecast |
|---|---|---|
| 1 | 12 | 10.00 |
| 2 | 15 | 10.60 |
| 3 | 11 | 11.92 |
| 4 | 9 | 11.64 |
| 5 | 10 | 10.85 |
| 6 | 8 | 10.60 |
| 7 | 14 | 9.82 |
| 8 | 12 | 11.07 |
| 9 | | 11.35 |

F2 = .3*12 + .7*10
= 3.6 + 7
= 10.6

F3 = .3*15 + .7*10.6
= 11.92

**Figure 3.9: Exponential Smoothing with a=0.3**

### 3.5 Software R

R is the software used in this project to execute the forecasting method of ARIMA. It is a free software which can be downloaded easily and it is commonly used for statistical computing and data analysis.

Before using this software, the data needs to be rearranged in the form that is readable by the software. The days need to be placed in row and every fifteen data needs to place in column. Then, the data is required to convert into text document file (.txt). Figure 3.10 shows some of the coding used in the software R to perform the prediction.

```
Load = read.table("h:/mydata.txt")

t1 = ts(Load$V1)

library(forecast)

f1 = auto.arima(t1)

p1 = predict(f1, n.ahead =1)

P = c(p1$pred, p2$pred, p3$pred, p4$pred, p5$pred, p6$pred, p7$pred, p8$pred, p9$pred, p10$pred,
      p11$pred, p12$pred, p13$pred, p14$pred, p15$pred, p16$pred, p17$pred, p18$pred, p19$pred, p20$pred,
      p21$pred, p22$pred, p23$pred, p24$pred, p25$pred, p26$pred, p27$pred, p28$pred, p29$pred, p30$pred,
      p31$pred, p32$pred, p33$pred, p34$pred, p35$pred, p36$pred, p37$pred, p38$pred, p39$pred, p40$pred,
      p41$pred, p42$pred, p43$pred, p44$pred, p45$pred, p46$pred, p47$pred, p48$pred, p49$pred, p50$pred,
      p51$pred, p52$pred, p53$pred, p54$pred, p55$pred, p56$pred, p57$pred, p58$pred, p59$pred, p60$pred,
      p61$pred, p62$pred, p63$pred, p64$pred, p65$pred, p66$pred, p67$pred, p68$pred, p69$pred, p70$pred,
      p71$pred, p72$pred, p73$pred, p74$pred, p75$pred, p76$pred, p77$pred, p78$pred, p79$pred, p80$pred,
      p81$pred, p82$pred, p83$pred, p84$pred, p85$pred, p86$pred, p87$pred, p88$pred, p89$pred, p90$pred,
      p91$pred, p92$pred, p93$pred, p94$pred, p95$pred, p96$pred)

plot(ts(P))
```

**Figure 3.10: Coding in Software R**

First coding is used to load the data which rearranged earlier in the format of .txt. The second line of coding is to load the data by column and also convert the data into time series format. This have to be done until the 96$^{th}$ column of data as fifteen minutes averaged data has total of ninety six sets of data per day.

Third line of the coding means that the user needs to look into the functions inside the library of the software R. In this case, the function of forecast is loaded for the purpose of prediction. Forth line shows the coding of autoarima. This coding returns the ARIMA model of the time series data.

Fifth coding is the prediction code which performs the forecast using the ARIMA model done previously with the number of prediction ahead of one. The next code is the one used to compile all the forecasted results together for the ease of view. The user may also plot the graph of the predicted results using the last code.

## CHAPTER 4

## RESULTS AND DISCUSSION

### 4.1 SE Block Load Analysis

In a building, equipments with large or small power consumption are found at every corner. So, it is effective to study the overall power consumption of the building by breaking down all the specific types of load. Different consumption of load with various quantity of the load will results in different kinds of load profile. By specifying all the loads with their precise quantity, load distribution of a building can be analysed clearly. Figure 4.1 shows the overall load distribution of SE block. The load is categorized into long fluorescent tube (LFT), personal computer (PC), air conditioner (AC), ceiling fan (CF), printer (P), machinery (M), refrigerator (R), and LCD projector (LCD).

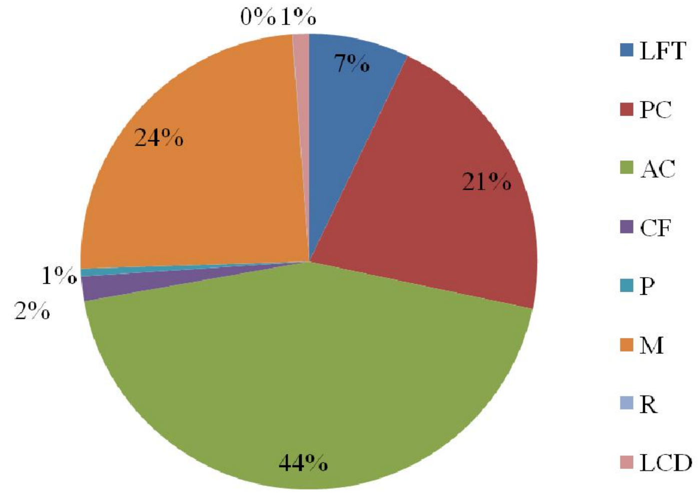


**Figure 4.1: Load Distribution for SE Block**

From Figure 4.1, air conditioner has dominated the overall power consumption of SE block with the highest percentage of 44% which account to 112.5kW. It is expected to have some reduction in the air conditioner load consumption for better energy saving. It is then followed by machinery and personal computer which constitute 24% and 21% respectively with the load consumption of 62.3kW and 54.42kW. Refrigerator consumed the smallest load with only one unit available in SE block and the consumption is only 71W, that is the reason why the percentage in pie chart is indicated to be 0%. Although air conditioner has the highest power consumption, other loads may also be regulated for additional energy savings.

### 4.1.1 Timetable Based Load Consumption

Figure 4.2 shows every weekday's load consumption based on timetable for the first floor of SE block as this floor consists of all lecture and tutorial rooms. The loads consumption taken to plot this graph is based on the exact timetable given by the office from 7am to 8pm. The load consumed at different time indicates the occupancy of the lecture or tutorial rooms with the optimized load usage. The maximum load consumption during the peak period is 73.5kW. Although load consumption of every weekday differs a lot due to the irregular usage pattern of rooms, the load are somehow rise at the same time after 7.30am and start to fall after 6pm. It is noticed that for Monday, the load consumption for the morning session are far below other weekdays. So, distribution of lecture or tutorial sessions can be adjusted to reduce the load on other weekdays to reduce the maximum demand.

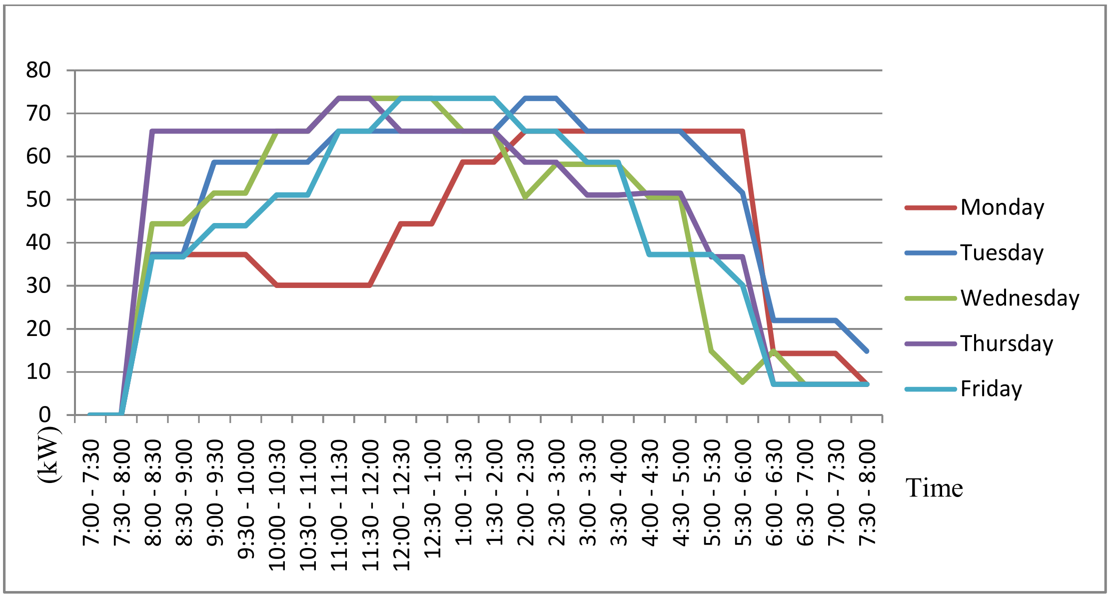


**Figure 4.2: Timetable Based Load Consumption**

## 4.2 Weekdays Correlation Analysis

The correlation coefficient between the same weekdays for different weeks has been examined in this section. It is to find out the actual relationship between two variables which are the same weekdays such as the last Monday with the current Monday. The correlation coefficient is taken between +1 and -1. However, a strong positive relationship between 0.7 and 0.99 is expected in this case. Every same weekday is analyzed is the following subsections and the total average of every average correlation found is 0.97105.

### 4.2.1 Correlation Analysis on Mondays

As shown in Table 4.1, five Mondays' correlation coefficient has been analyzed. All the pairs of the Mondays are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.928387 to 0.986122. The red coloured number is the average of the total correlation coefficient for all pairs of Mondays.

**Table 4.1: Correlation Coefficient on Mondays**

| Monday correlation | 17/6/13 | 24/6/13 | 1/7/2013 | 8/7/2013 | 15/7/13 |
|---|---|---|---|---|---|
| 17/6/13 | 1 | | | | |
| 24/6/13 | 0.92839 | 1 | | | |
| 1/7/2013 | 0.97849 | 0.97394 | 1 | | |
| 8/7/2013 | 0.96754 | 0.96944 | 0.98612 | 1 | |
| 15/7/13 | 0.97564 | 0.94708 | 0.97722 | 0.965863 | 1 |
| Avg correl= | 0.96697 | | | | |

Figure 4.3 shows the 15-minute averaged load on different Mondays. All the Mondays have the power consumption after 7.30am until 6pm, which are the standard working hours. The hours with high power consumption are known as peak hours while the other hours are known as off-peak hours. The highest power consumption recorded is 137.96kW which is the highest peak among all the Mondays. 24 June 2013 is noticed to have lower power consumption due to the haze disaster happened on that time and UTAR was forced to cancel all the classes.

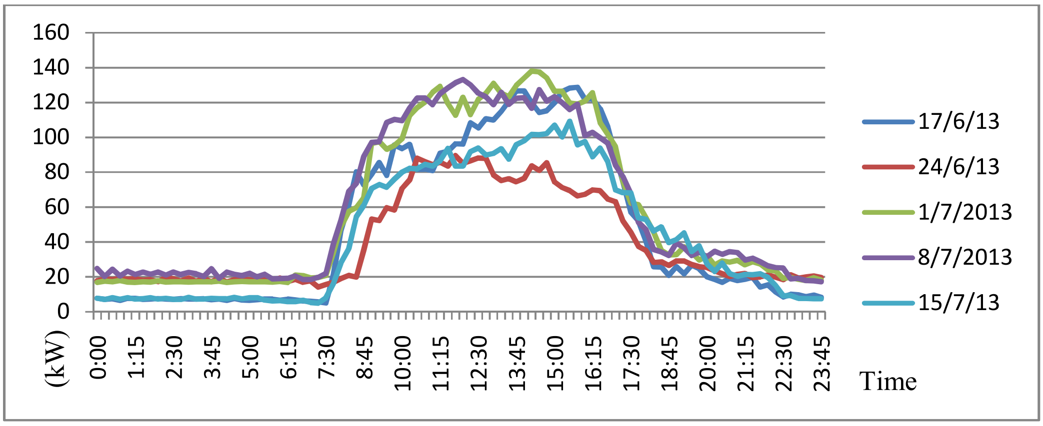


**Figure 4.3: 15-Minute Averaged Load on Mondays**

### 4.2.2 Correlation Analysis on Tuesday

As shown in Table 4.2, five Tuesdays' correlation coefficient has been analyzed. All the pairs of the Tuesdays are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.950344 to 0.993274. The red coloured number is the average of the total correlation coefficient for all pairs of Tuesdays.

**Table 4.2: Correlation Coefficient on Tuesdays**

| Tuesday correlation | 18/6/13 | 25/6/13 | 2/7/2013 | 9/7/2013 | 16/7/13 |
|---|---|---|---|---|---|
| 18/6/13 | 1 | | | | |
| 25/6/13 | 0.99327 | 1 | | | |
| 2/7/2013 | 0.97408 | 0.97961 | 1 | | |
| 9/7/2013 | 0.9748 | 0.97893 | 0.95034 | 1 | |
| 16/7/13 | 0.98581 | 0.98776 | 0.97796 | 0.970312 | 1 |
| Avg correl= | 0.97729 | | | | |

Figure 4.4 shows the 15-minute averaged load on different Tuesdays. All the Tuesdays have the power consumption after 7.30am until 6pm, which are the standard working hours. Second and third week of Tuesdays are having higher power consumption than the other three weeks. The highest power consumption recorded is 160.07kW which is the highest peak among all the Tuesdays.

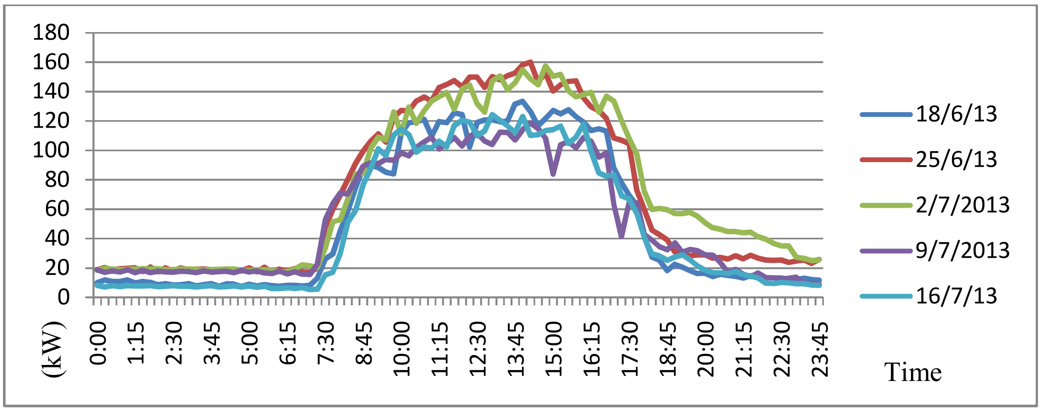


**Figure 4.4: 15-Minute Averaged Load on Tuesdays**

### 4.2.3 Correlation Analysis on Wednesday

As shown in Table 4.3, five Wednesday' correlation coefficient has been analyzed. All the pairs of the Wednesdays are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.974717 to 0.994948. The red coloured number is the average of the total correlation coefficient for all pairs of Wednesdays.

**Table 4.3: Correlation Coefficient on Wednesdays**

| Wednesday correlation | 19/6/13 | 26/6/13 | 3/7/2013 | 10/7/2013 | 17/7/13 |
|---|---|---|---|---|---|
| 19/6/13 | 1 | | | | |
| 26/6/13 | 0.97551 | 1 | | | |
| 3/7/2013 | 0.98754 | 0.98845 | 1 | | |
| 10/7/2013 | 0.97767 | 0.97472 | 0.98358 | 1 | |
| 17/7/13 | 0.98944 | 0.99092 | 0.99495 | 0.982799 | 1 |
| Avg correl= | 0.98456 | | | | |

Figure 4.5 shows the 15-minute averaged load on different Wednesdays. All the Wednesdays have the power consumption after 7.30am until 6pm, which are the standard working hours. It is noticed that the fifth week of Wednesday was having lower power consumption while the other four weeks were having similar kind of load. The highest power consumption recorded is 161.98kW which is the highest peak among all the Wednesdays.

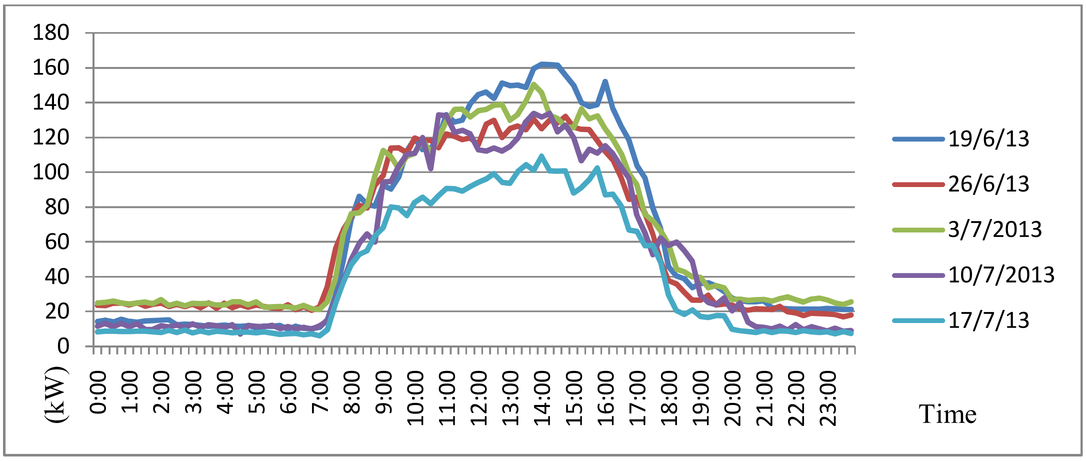


**Figure 4.5: 15-Minute Averaged Load on Wednesdays**

### 4.2.4 Correlation Analysis on Thursday

As shown in Table 4.4, five Thursdays' correlation coefficient has been analyzed. All the pairs of the Thursdays are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.958382 to 0.991344. The red coloured number is the average of the total correlation coefficient for all pairs of Thursdays.

**Table 4.4: Correlation Coefficient on Thursdays**

| Thursday correlation | 20/6/13 | 27/6/13 | 4/7/2013 | 11/7/2013 | 18/7/13 |
|---|---|---|---|---|---|
| 20/6/13 | 1 | | | | |
| 27/6/13 | 0.98781 | 1 | | | |
| 4/7/2013 | 0.99134 | 0.98858 | 1 | | |
| 11/7/2013 | 0.98976 | 0.97974 | 0.98244 | 1 | |
| 18/7/13 | 0.96894 | 0.96236 | 0.96148 | 0.958382 | 1 |
| Avg correl= | 0.97708 | | | | |

Figure 4.6 shows the 15-minute averaged load on different Thursdays. All the Thursdays have the power consumption after 7.30am until 6pm, which are the standard working hours. It is noticed that Thursday of fifth week was having lower power consumption during noon time. The highest power consumption recorded is 155.07kW which is the highest peak among all the Thursdays.

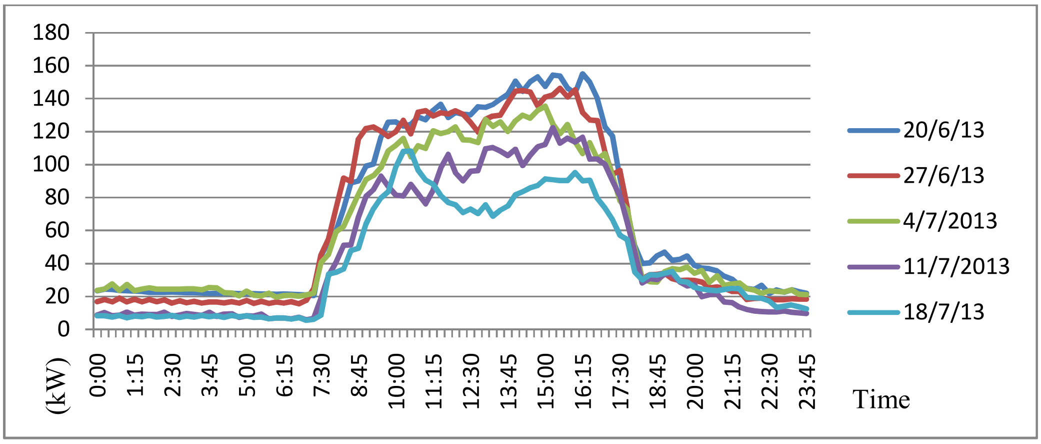


**Figure 4.6: 15-Minute Averaged Load on Thursdays**

### 4.2.5 Correlation Analysis on Friday

As shown in Table 4.5, five Fridays' correlation coefficient has been analyzed. All the pairs of the Fridays are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.920198 to 0.980507. The red coloured number is the average of the total correlation coefficient for all pairs of Fridays.

**Table 4.5: Correlation Coefficient on Fridays**

| Friday correlation | 21/6/13 | 28/6/13 | 5/7/2013 | 12/7/2013 | 19/7/13 |
|---|---|---|---|---|---|
| 21/6/13 | 1 | | | | |
| 28/6/13 | 0.93079 | 1 | | | |
| 5/7/2013 | 0.9202 | 0.98051 | 1 | | |
| 12/7/2013 | 0.94058 | 0.96066 | 0.96155 | 1 | |
| 19/7/13 | 0.90465 | 0.96053 | 0.96963 | 0.964169 | 1 |
| Avg correl= | 0.94933 | | | | |

Figure 4.7 shows the 15-minute averaged load on different Fridays. All the Fridays were having rising of load after 7.30am. It is noticed that first and fourth week of Fridays were still having power consumption after working hours while the other three weeks were dropping after 5pm. The highest power consumption recorded is 144.27kW which is the highest peak among all the Fridays.

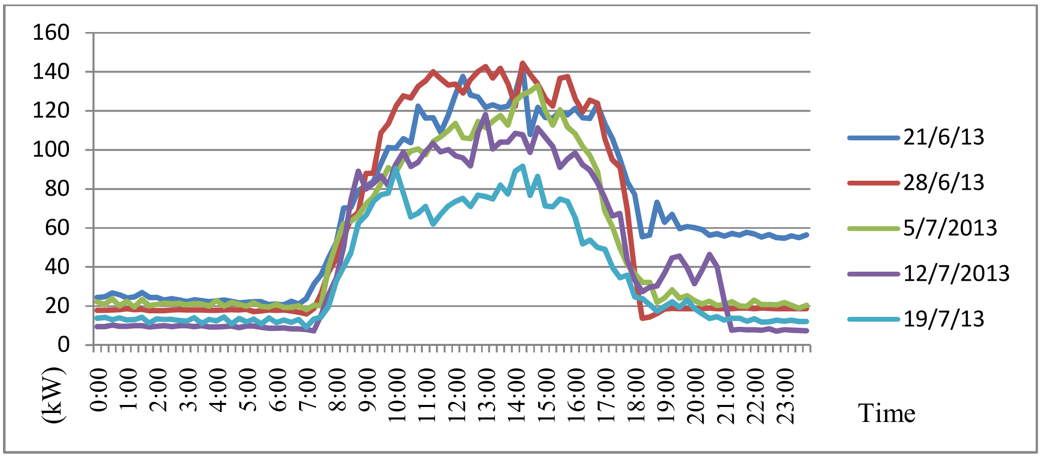


**Figure 4.7: 15-Minute Averaged Load on Fridays**

## 4.3 Correlation Analysis by Week

The correlation coefficient between every week for different 5 weeks is examined in this section. It is to find out the actual relationship between every weekday from Monday to Friday. The correlation coefficient is taken between +1 and -1. However, a strong positive relationship between 0.7 and 0.99 is expected in this case and the result obtained is 0.97081, which is lower than the same weekdays correlation analysis.

### 4.3.1 Correlation Analysis for First Week

As shown in Table 4.6, every weekday from Monday to Friday is compared between each other for the correlation. All the pairs from Monday to Thursday are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. There is only a slightly lower correlation for the pair of Friday. However, the correlation coefficient is ranging from 0.94051 to 0.99976. The red coloured number is the average of the total correlation coefficient for all pairs of different weekday.

**Table 4.6: Correlation Coefficient of First Week**

| Correlation | 17/6/13 | 18/6/13 | 19/6/13 | 20/6/13 | 21/6/13 |
|---|---|---|---|---|---|
| 17/6/13 | 1 | | | | |
| 18/6/13 | 0.98173 | 1 | | | |
| 19/6/13 | 0.98553 | 0.986711 | 1 | | |
| 20/6/13 | 0.98876 | 0.988317 | 0.987014 | 1 | |
| 21/6/13 | 0.94194 | 0.94051 | 0.953748 | 0.946986 | 1 |
| Avg correl= | 0.97012 | | | | |

### 4.3.2 Correlation Analysis for Second Week

As shown in Table 4.7, correlation coefficient of second week has been analyzed. All the pairs of the weekday are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99, only the pairs of Monday with Wednesday and Thursday are slightly lower. The correlation coefficient is ranging from 0.9356 to 0.989755. The red coloured number is the average of the total correlation coefficient for all pairs of different weekday.

**Table 4.7: Correlation Coefficient of Second Week**

| Correlation | 24/6/13 | 25/6/13 | 26/6/13 | 27/6/13 | 28/6/13 |
|---|---|---|---|---|---|
| 24/6/13 | 1 | | | | |
| 25/6/13 | 0.95934 | 1 | | | |
| 26/6/13 | 0.93992 | 0.985205 | 1 | | |
| 27/6/13 | 0.9356 | 0.989755 | 0.984235 | 1 | |
| 28/6/13 | 0.97216 | 0.987423 | 0.974933 | 0.97763 | 1 |
| Avg correl= | 0.97062 | | | | |

### 4.3.3 Correlation Analysis for Third Week

As shown in Table 4.8, correlation coefficient of third week has been analyzed. All the pairs of the weekday are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.959358 to 0.98793. The red coloured number is the average of the total correlation coefficient for all pairs of different weekday.

**Table 4.8: Correlation Coefficient of Third Week**

| Correlation | 1/7/2013 | 2/7/2013 | 3/7/2013 | 4/7/2013 | 5/7/2013 |
|---|---|---|---|---|---|
| 1/7/2013 | 1 | | | | |
| 2/7/2013 | 0.98104 | 1 | | | |
| 3/7/2013 | 0.98614 | 0.966446 | 1 | | |
| 4/7/2013 | 0.98793 | 0.980699 | 0.985258 | 1 | |
| 5/7/2013 | 0.98716 | 0.959358 | 0.983963 | 0.983825 | 1 |
| Avg correl= | 0.98018 | | | | |

### 4.3.4 Correlation Analysis for Forth Week

As shown in Table 4.9, correlation coefficient of forth week has been analyzed. All the pairs of the weekday are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99. The correlation coefficient is ranging from 0.954356 to 0.9795. The red coloured number is the average of the total correlation coefficient for all pairs of different weekday.

**Table 4.9: Correlation Coefficient of Forth Week**

| Correlation | 8/7/2013 | 9/7/2013 | 10/7/2013 | 11/7/2013 | 12/7/2013 |
|---|---|---|---|---|---|
| 8/7/2013 | 1 | | | | |
| 9/7/2013 | 0.97277 | 1 | | | |
| 10/7/2013 | 0.9795 | 0.976105 | 1 | | |
| 11/7/2013 | 0.96372 | 0.954356 | 0.959096 | 1 | |
| 12/7/2013 | 0.97817 | 0.964996 | 0.966668 | 0.96847 | 1 |
| Avg correl= | 0.96838 | | | | |

### 4.3.5 Correlation Analysis for Fifth Week

As shown in Table 4.10, correlation coefficient of fifth week has been analyzed. All the pairs of the weekday are having strong positive relationship with very high correlation coefficient which is within the range of 0.7 and 0.99, only the pair of Thursday with Friday is slightly lower. The correlation coefficient is ranging from 0.937842 to 0.987535. The red coloured number is the average of the total correlation coefficient for all pairs of different weekday.

**Table 4.10: Correlation Coefficient of Fifth Week**

| Correlation | 15/7/13 | 16/7/13 | 17/7/13 | 18/7/13 | 19/7/13 |
|---|---|---|---|---|---|
| 15/7/13 | 1 | | | | |
| 16/7/13 | 0.97354 | 1 | | | |
| 17/7/13 | 0.96345 | 0.987535 | 1 | | |
| 18/7/13 | 0.96753 | 0.962125 | 0.949494 | 1 | |
| 19/7/13 | 0.94522 | 0.982409 | 0.977993 | 0.937842 | 1 |
| Avg correl= | 0.96471 | | | | |

## 4.4 Exponential Smoothing Load Forecasting

With the real time data collection from the switch room of SE block using power analysers, load forecasting for the next coming week is done by exponential smoothing method. The data collected for the past nine weeks was organized and averaged with 15-minute interval. Other than that, five same weekdays are averaged to forecast on the next coming same weekday. Results of the forecasts are showed at subsections below.

### 4.4.1 Load Forecasting on Monday

Figure 4.8 shows the load forecasting on Monday. The actual load is actually lower in the morning and gets higher in the noon. The exponential smoothing method estimated the morning load with higher power consumption and produced a smooth curve of load over the noon. The peak difference for the predicted load from actual load is 9.6kW at 12.30pm.

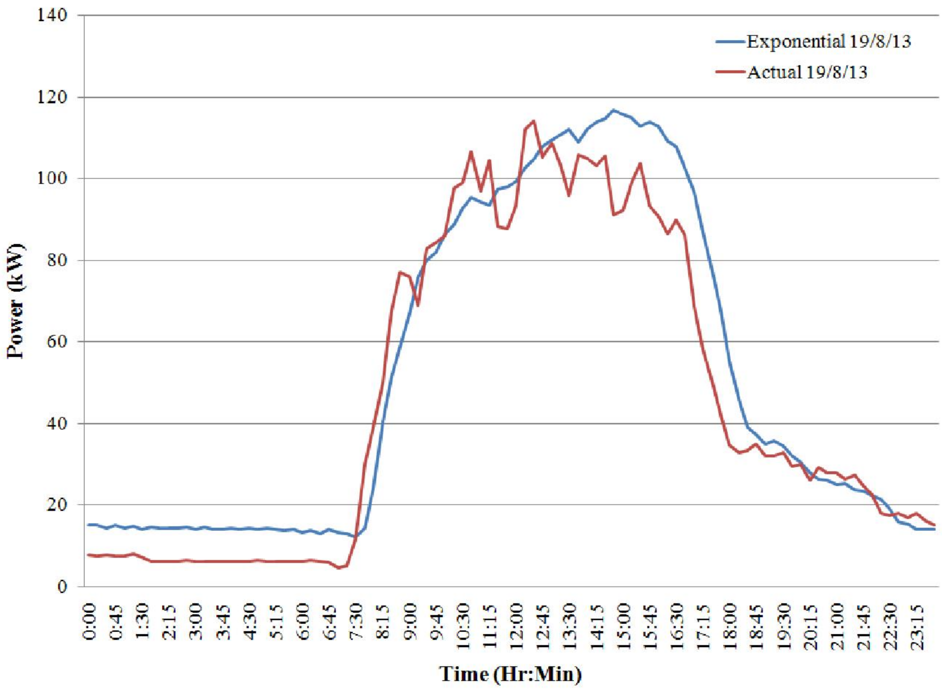


**Figure 4.8: Load Forecasting on Monday**

### 4.4.2 Load Forecasting on Tuesday

Figure 4.9 shows the load forecasting on Tuesday. As we can see from the graph, the actual load is fluctuating during the time between 10am to 4pm. Meanwhile, the curve for the exponential smoothing is quite smooth throughout the time without huge fluctuation. The peak difference for the predicted load from actual load is 11kW at 3.15pm.

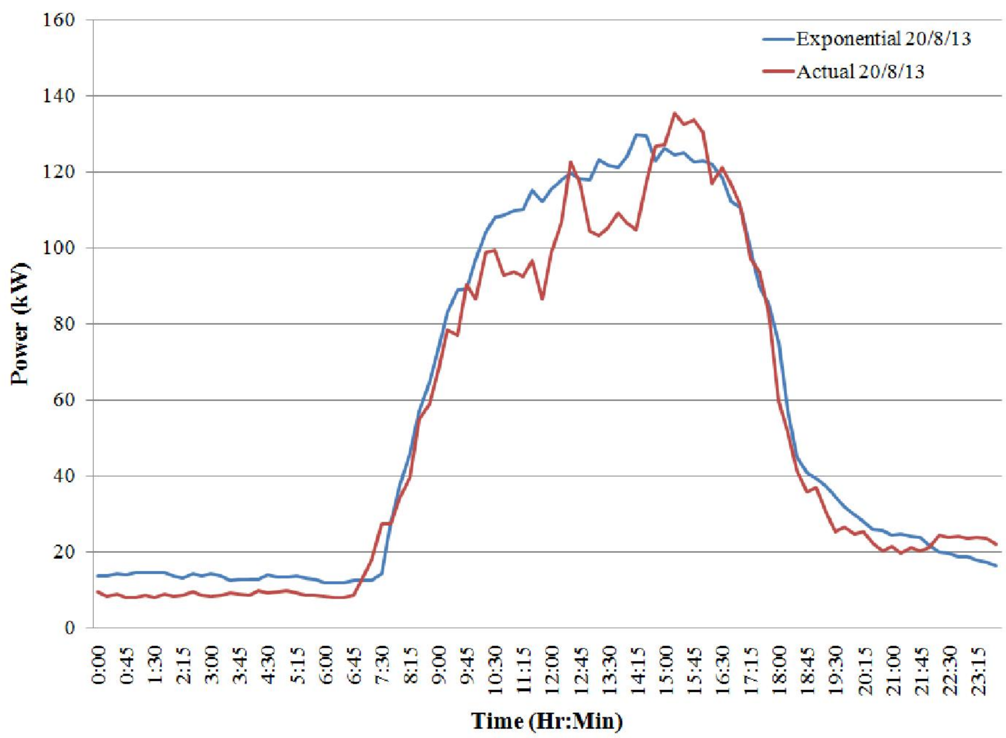


**Figure 4.9: Load Forecasting on Tuesday**

### 4.4.3 Load Forecasting on Wednesday

Figure 4.9 shows the load forecasting on Wednesday. It can be seen that the predicted load is lower than the actual load at the centre of the curve between 11am to 4pm. Other than that, the forecasted load is similar to the actual load. The peak difference for the predicted load from actual load is 33.2kW at 2.30pm.

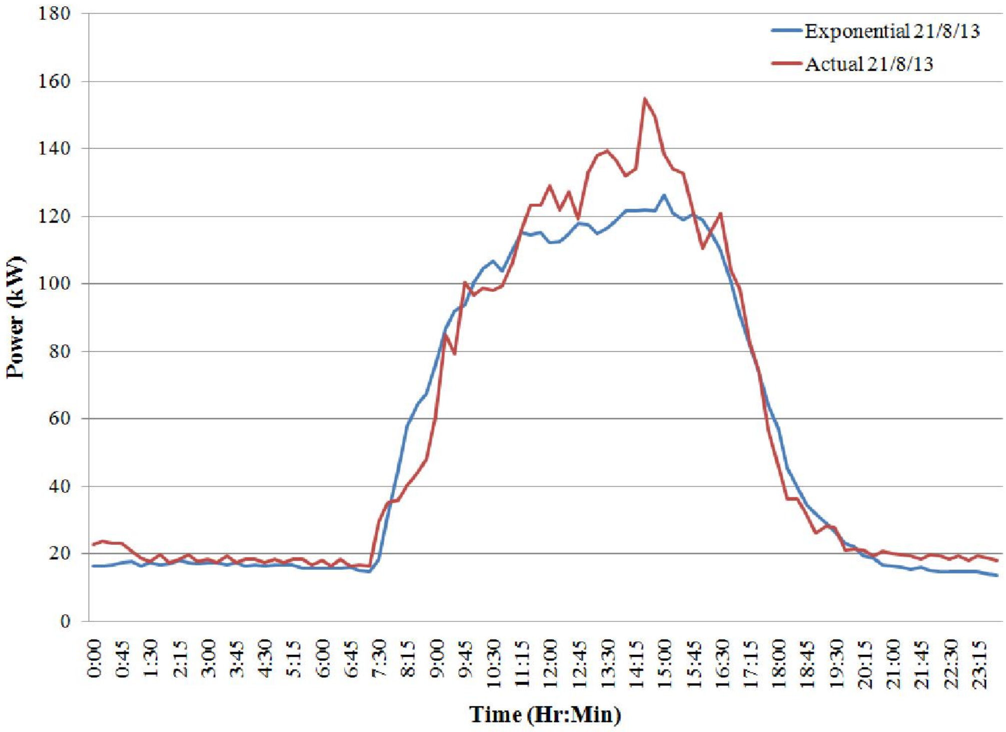


**Figure 4.10: Load Forecasting on Wednesday**

### 4.4.4 Load Forecasting on Thursday

Figure 4.11 shows the load forecasting on Thursday. The actual load is fluctuating a lot for the previous weeks and that makes the prediction more difficult. Exponential smoothing method has made the curve smoother at the peak loads for the predicted load. The peak difference for the predicted load from actual load is 12.31kW at 4.30pm.

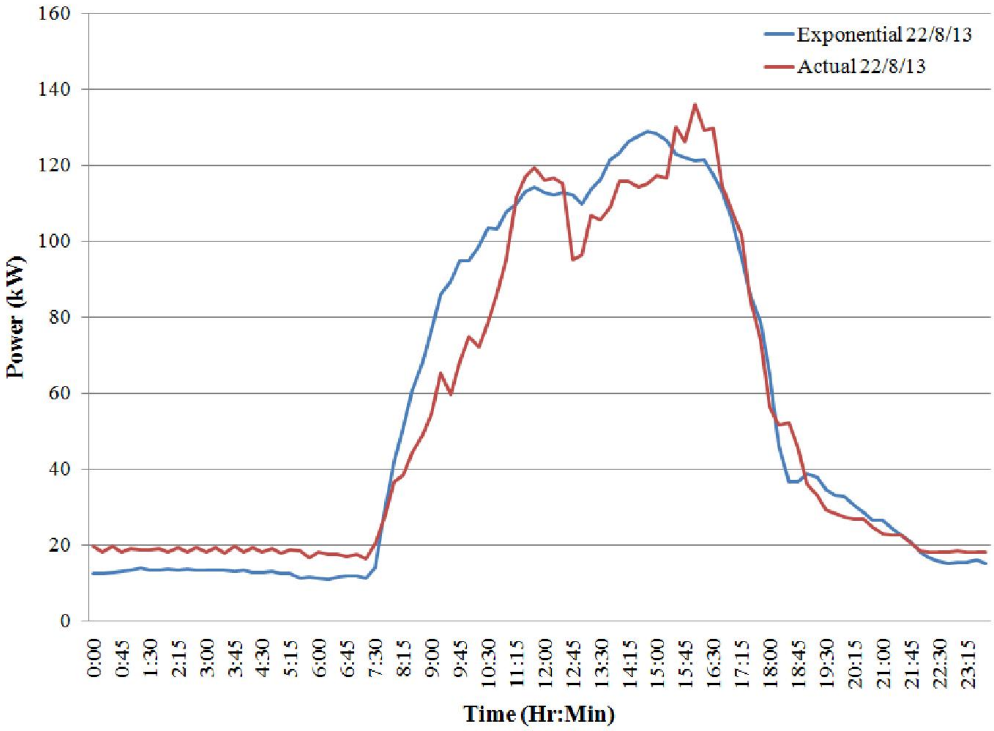


**Figure 4.11: Load Forecasting on Thursday**

### 4.4.5 Load Forecasting on Friday

Figure 4.12 shows the load forecasting on Friday. From the graph, we can see that the actual load is fluctuating a lot throughout the day. The exponential smoothing method estimated the noon load with higher power consumption right before the noon until the end of the day. This is because the load at noon is usually high from the data of previous weeks. The peak difference for the predicted load from actual load is 0.37kW at 1.15pm.

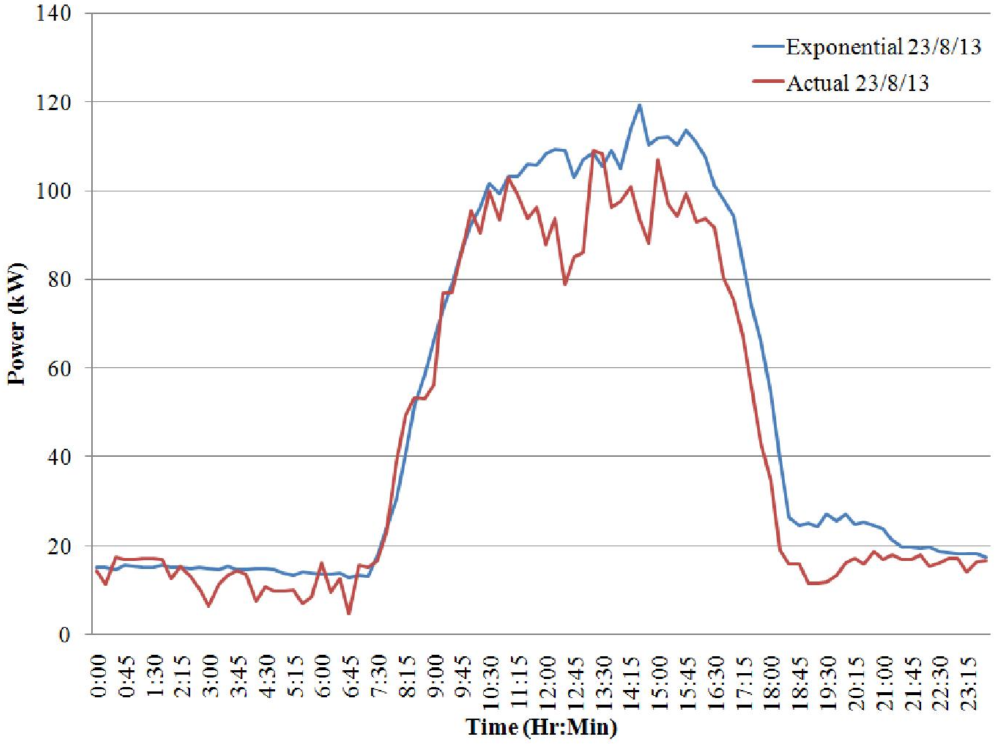


**Figure 4.12: Load Forecasting on Friday**

## 4.5 ARIMA Load Forecasting

With the help of the software R, load forecasting based on ARIMA can be performed by inputting the data and analyzed with proper coding. The real time data collection from the switch room of SE block using power analysers is also used for this forecasting. The data is processed and converted into notepad (.txt) file in order to read by software R. Results of the forecasts are showed at subsections below.

### 4.5.1 ARIMA Forecasting on Monday

Figure 4.13 shows the ARIMA forecasting on Monday. The actual load is fluctuating around 100kW between 10am to 3pm. However, ARIMA forecasting is predicting that the load is increasing until the peak at 3pm and decrease sharply after that. Although there is difference in the noon, but it is reasonable when we look back on the previous data, the loads are always high at the noon time. The peak difference for the predicted load from actual load is 6.1kW at 12.30pm.

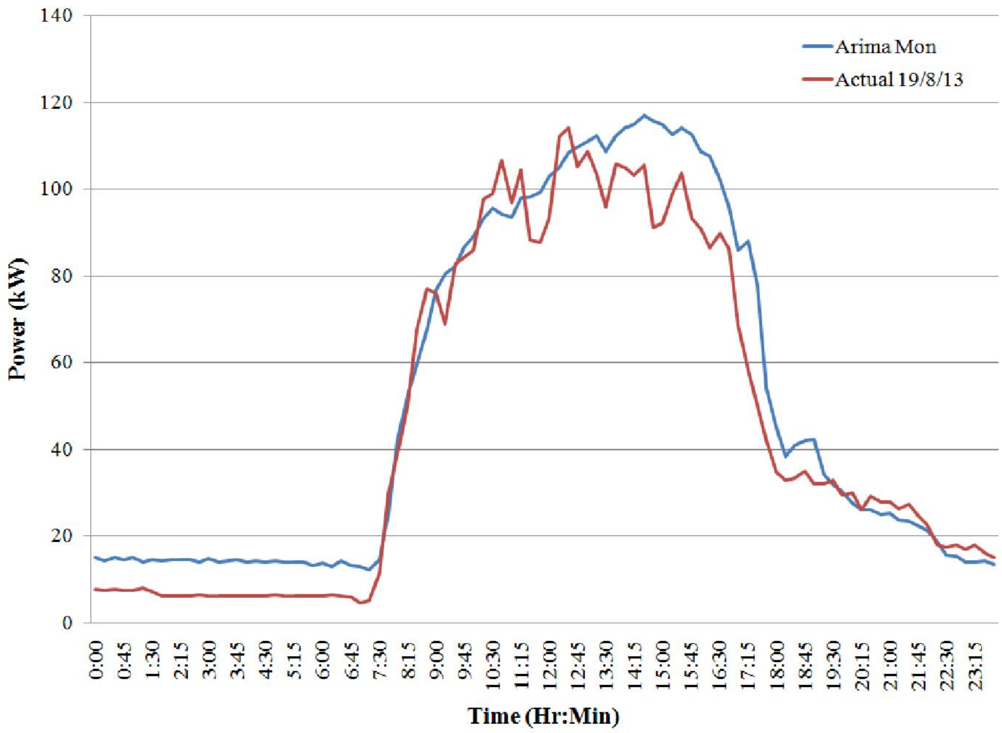


**Figure 4.13: Arima Forecasting on Monday**

### 4.5.2 ARIMA Forecasting on Tuesday

Figure 4.14 shows the ARIMA forecasting on Tuesday. As we can see from the graph, the actual load is having two peak loads at different time between 12pm to 4pm. Meanwhile, the curve for the ARIMA is fluctuating between 9am to 12pm and quite stable from 12pm to 4pm. Although the forecasted result is a bit controversial, by referring to the past weeks load the result is still within the range. The peak difference for the predicted load from actual load is 10.1kW at 3.15pm.

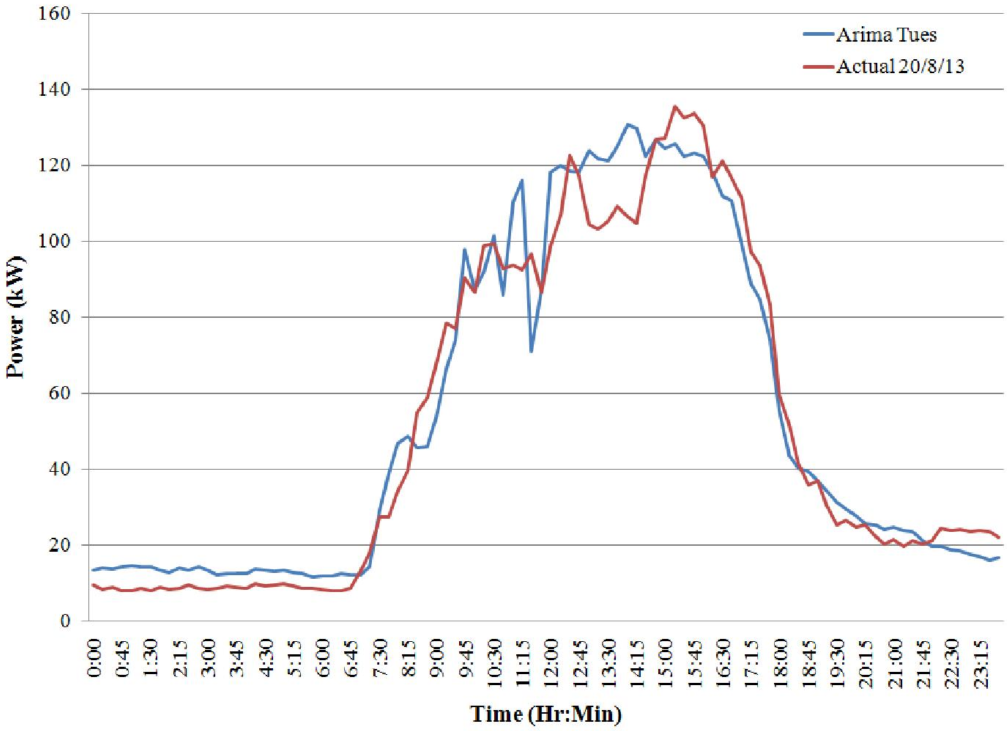


**Figure 4.14: Arima Forecasting on Tuesday**

### 4.5.3 ARIMA Forecasting on Wednesday

Figure 4.15 shows the ARIMA forecasting on Wednesday. It can be seen that the predicted load is lower than the actual load at the centre of the curve between 11am to 4pm. Forecasted load is having huge drop and sudden rise of load between the time as well. This prediction has made the peak difference become huge for the predicted load from the actual load which is 43.3kW at 2.30pm.

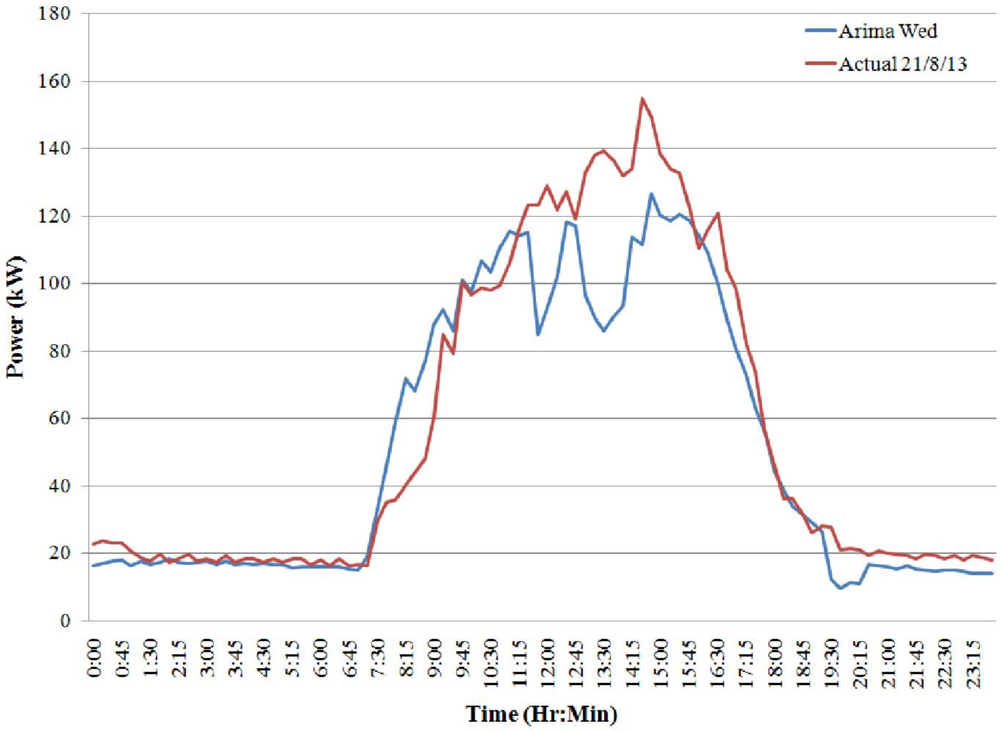


**Figure 4.15: Arima Forecasting on Wednesday**

### 4.5.4 ARIMA Forecasting on Thursday

Figure 4.16 shows the ARIMA forecasting on Thursday. The actual load is having two sudden increases for the peaks at different time. ARIMA forecasting predicted the curve with smoother increment in load at the two peak loads compared to the actual load. The peak difference for the predicted load from actual load is 17.2kW at 4.30pm.

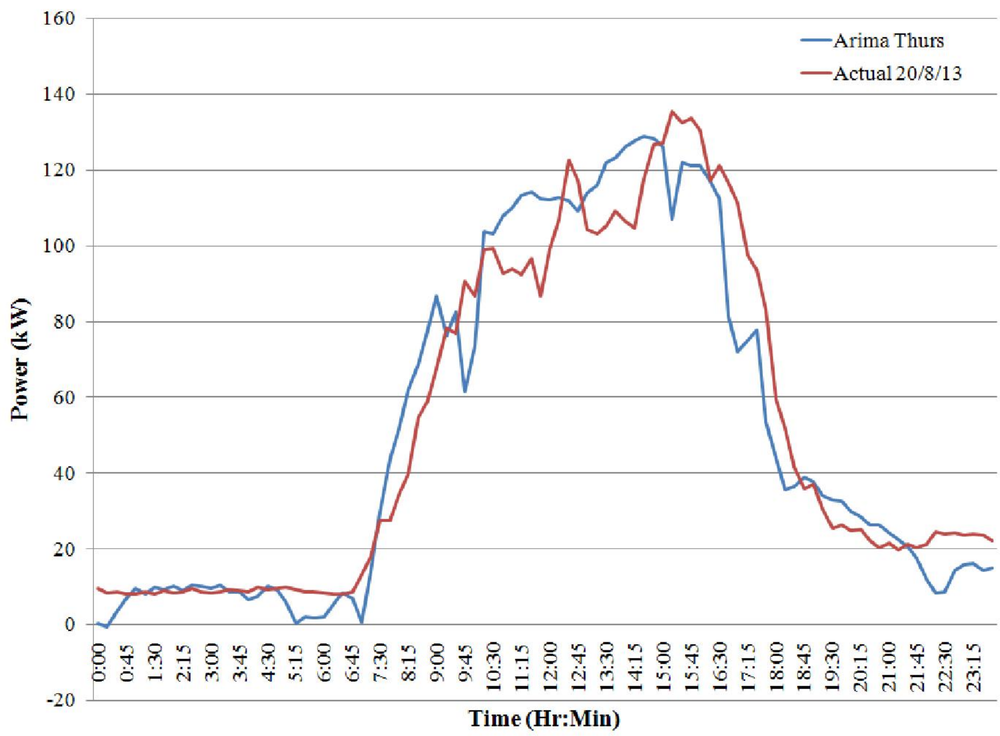


**Figure 4.16: Arima Forecasting on Thursday**

### 4.5.5 ARIMA Forecasting on Friday

Figure 4.17 shows the ARIMA forecasting on Friday. From the graph, we can see that the actual load is fluctuating a lot throughout the day. The ARIMA forecasting followed the trend of the actual load but with a higher level of load. This is acceptable because the loads of the previous weeks are mostly higher than 100kW. The peak difference for the predicted load from actual load is 23.1kW at 1.15pm.

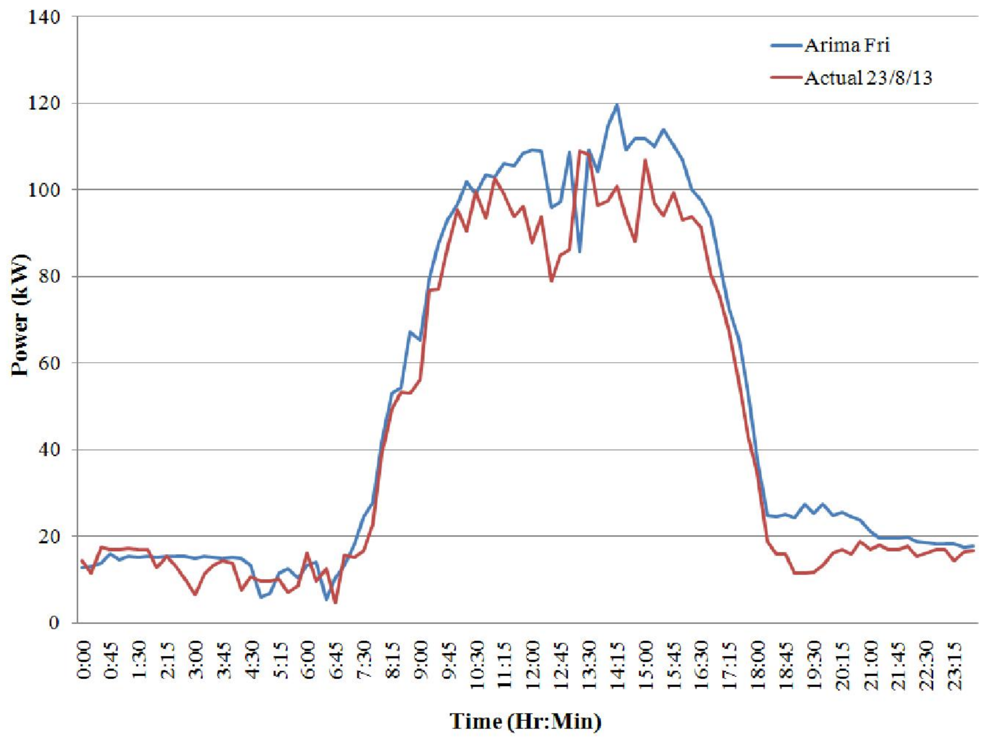


**Figure 4.17: Arima Forecasting on Friday**

## 4.6 Correlation, MAE, and MAPE

It is always important to understand the accuracy of the forecasted results for the comparison of better method to be used. In this case, correlation, mean absolute error (MAE), and mean absolute percentage error (MAPE) are applied to measure the accuracy of the forecasting methods.

### 4.6.1 Comparison of Mondays Data

For Monday, the accuracy of forecasted value and the actual value using correlation is 0.969 for Exponential method and 0.981 for ARIMA method. From the results obtained, the correlation for ARIMA is slightly higher as we can see from the graph below as well. The curve line is somehow closer to the actual load curve. However, for MAE and MAPE of Exponential method is lower which is 3.944 and 8.36% respectively. Meanwhile, ARIMA has the MAE and MAPE of 7.65 and 46.04%.

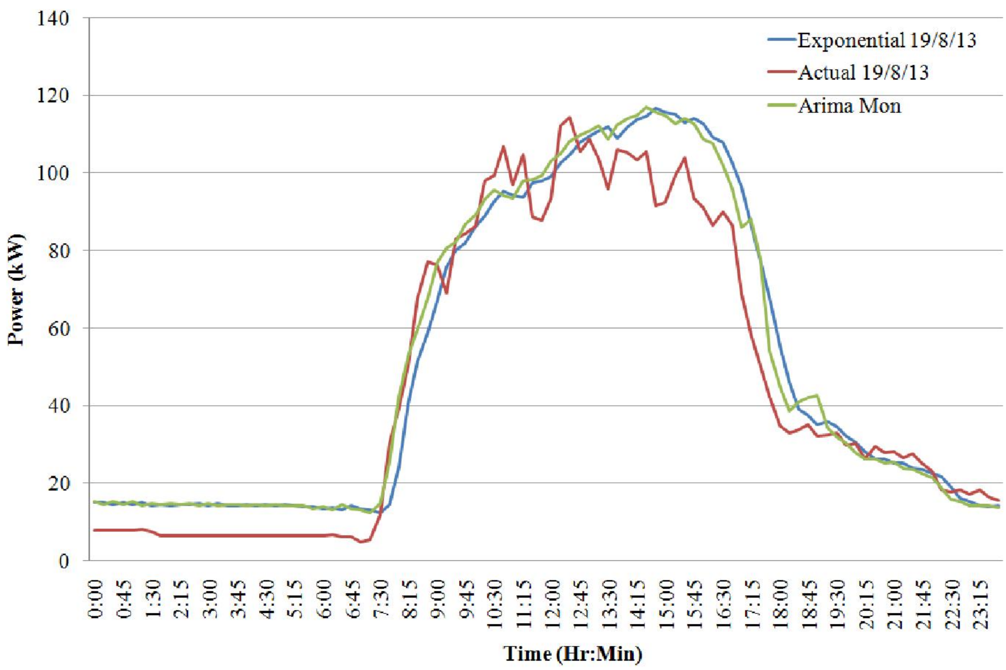


**Figure 4.18: Monday Comparison**

### 4.6.2 Comparison of Tuesdays Data

For Tuesday, the accuracy of forecasted value and the actual value using correlation is 0.987 for Exponential method and 0.980 for ARIMA method. From the results obtained, the correlation for Exponential is slightly higher as we can see from the graph below as well. Even the Exponential curve is not closely related to the actual curve, but the curve of ARIMA has some fluctuation which makes the accuracy slightly lower. So, for MAE and MAPE of Exponential method is definitely lower which is 4.067 and 8.4% respectively. Meanwhile, ARIMA has the MAE and MAPE of 6.834 and 24.49%.

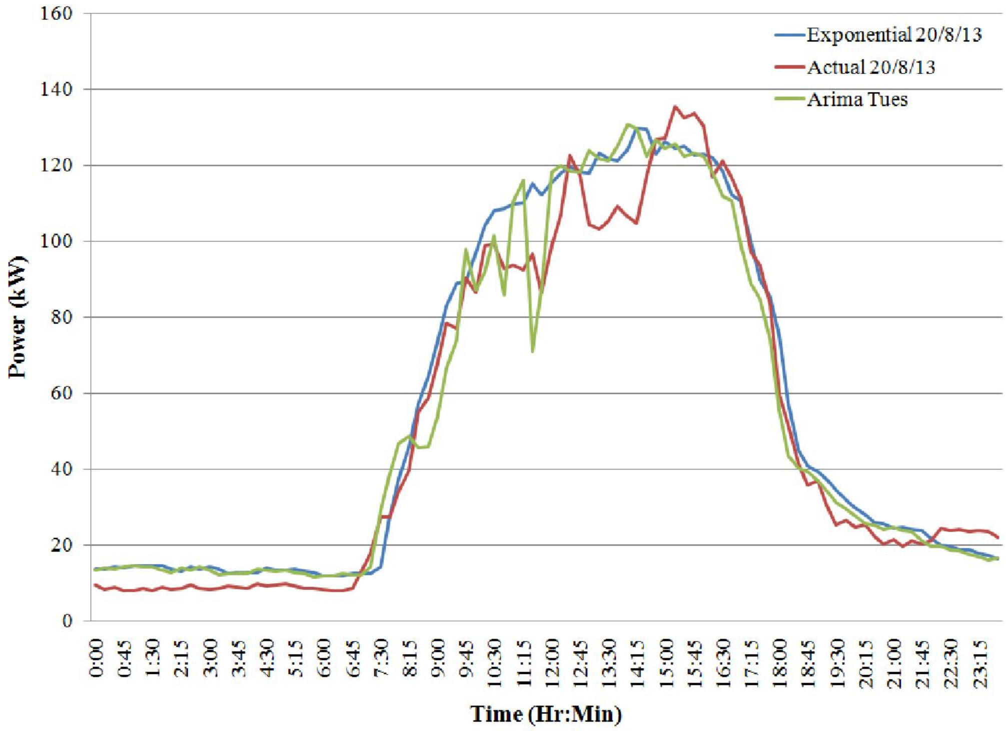


**Figure 4.19: Tuesday Comparison**

### 4.6.3 Comparison of Wednesdays Data

For Wednesday, the accuracy of forecasted value and the actual value using correlation is 0.984 for Exponential method and 0.952 for ARIMA method. From the results obtained, the correlation for Exponential is higher which we can see from the graph below as well. Both the Exponential and ARIMA curve are away from the actual curve in different direction at the mid section of the curve. Although both curves are a bit out of range, ARIMA seems to have a little more out of range components. Not surprisingly, MAE and MAPE of Exponential method is definitely lower which is 4.366 and 8.15% respectively. Meanwhile, ARIMA has the MAE and MAPE of 9.738 and 17.52%.

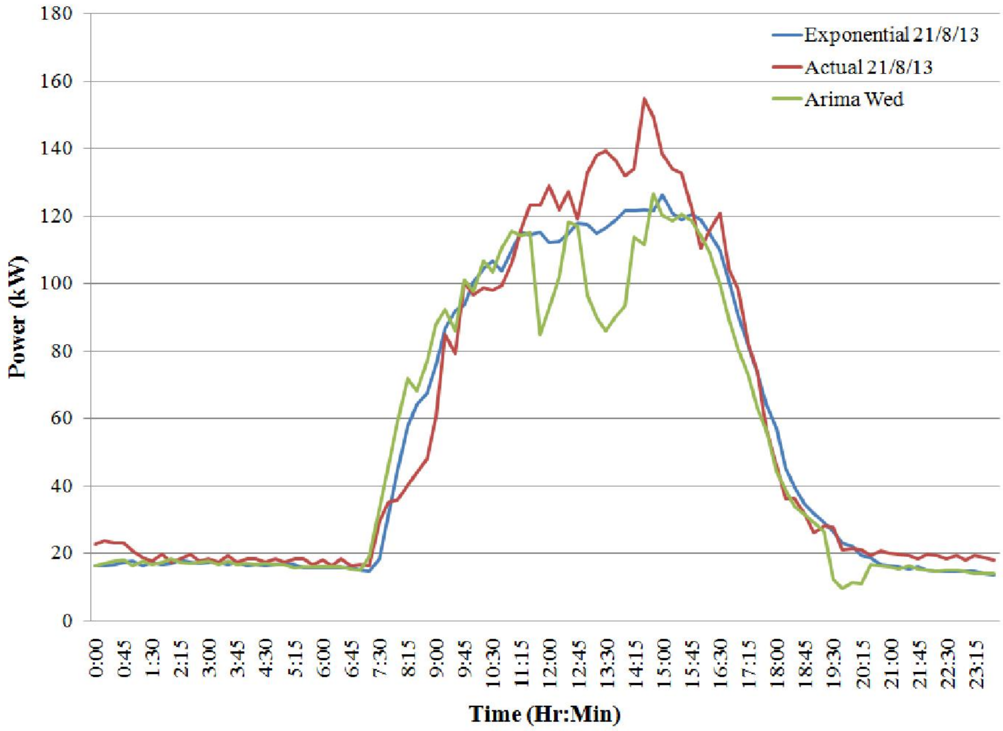


**Figure 4.20: Wednesday Comparison**

### 4.6.4 Comparison of Thursdays Data

For Thursday, the accuracy of forecasted value and the actual value using correlation is 0.978 for Exponential method and 0.955 for ARIMA method. From the results obtained, the correlation for Exponential is a bit higher than ARIMA as we can see from the graph below. At the beginning of the curve, ARIMA is somehow further away from actual curve more than the exponential curve, and the fluctuation at the rest of the curve makes the ARIMA loses more accuracy. So, for MAE and MAPE of Exponential method will be lower which is 3.769 and 7.13% respectively. Meanwhile, ARIMA has the MAE and MAPE of 11.322 and 33.06%.

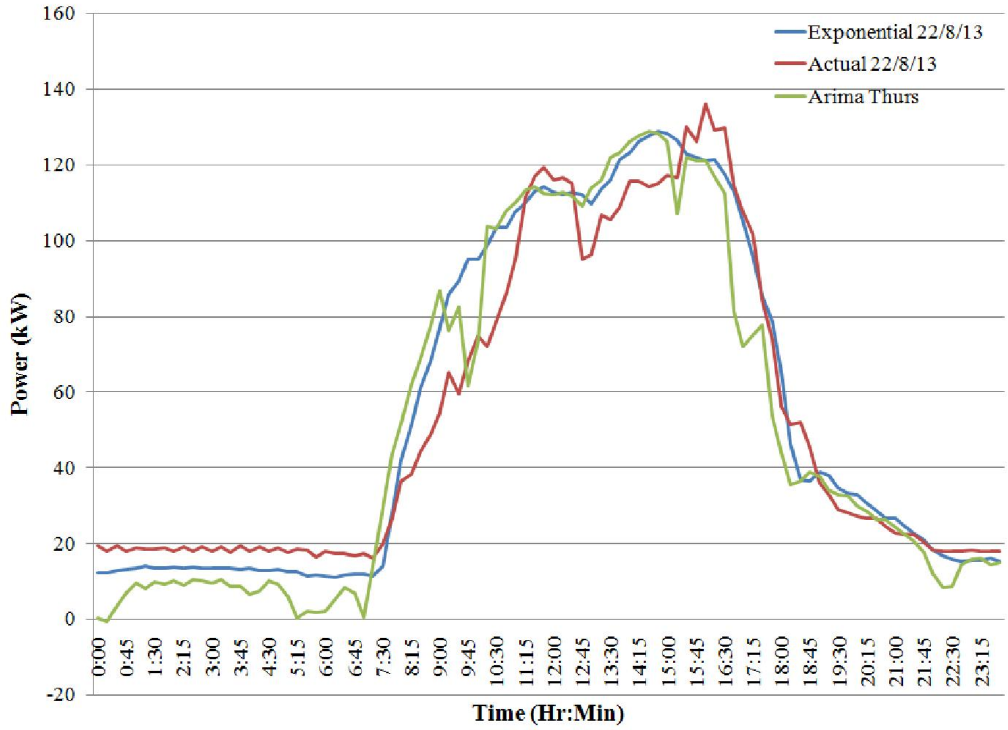


**Figure 4.21: Thursday Comparison**

### 4.6.5 Comparison of Fridays Data

For Friday, the accuracy of forecasted value and the actual value using correlation is 0.983 for Exponential method and 0.987 for ARIMA method. From the results obtained, the correlation for ARIMA is a bit higher than Exponential. The actual load of Friday is fluctuating a lot throughout the day which makes the forecast difficult. Exponential is forming the smooth curve as usual and for ARIMA, it is somehow follow some of the fluctuation pattern of the actual load and this makes the forecast result slightly higher. However, for MAE and MAPE of Exponential method is still lower which is 4.692 and 16.88% respectively. Meanwhile, ARIMA has the MAE and MAPE of 7.041 and 26.81%. The MAPE for Exponential method is the highest on Friday as the load on this day is always unexpected.

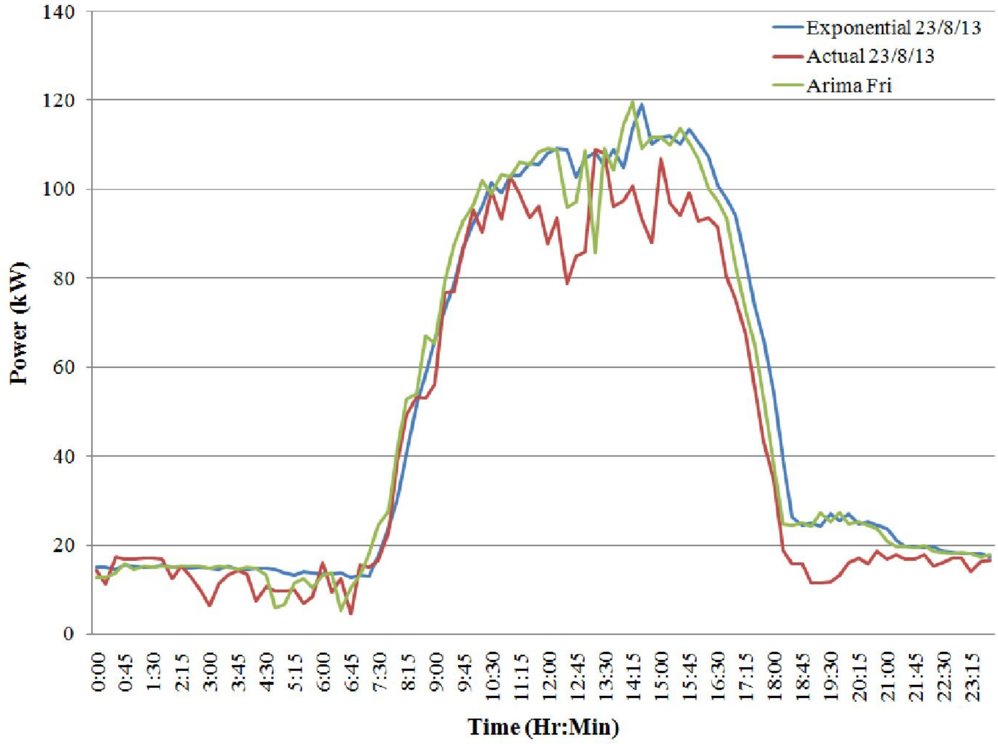


**Figure 4.22: Friday Comparison**

### 4.6.6 Summary

Table 4.6 below shows the summary of the overall correlation, MAE, and MAPE for everyday. It can be seen clearly that for correlation, the accuracy between the Exponential and ARIMA is always very close to each other. While for the MAE, Exponential is having a mean around 4 and ARIMA is not having constant MAE for the five days. The different become quite large when it comes to MAPE. For Exponential, the percentage error is always around 8% while Friday is the only case of having 16.88%. For ARIMA, the MAPE is having a large different from Exponential which range from 17.52% to 46.04%. Hence, it can be concluded that the exponential smoothing method has higher accuracy than ARIMA method in load forecast.

**Table 4.11: Summary of Everyday's Comparison**

| | Exponential | | | ARIMA | | |
|---|---|---|---|---|---|---|
| | Correlation | MAE | MAPE | Correlation | MAE | MAPE |
| Monday | 0.969 | 3.944 | 8.36 | 0.981 | 7.650 | 46.04 |
| Tuesday | 0.987 | 4.067 | 8.40 | 0.980 | 6.834 | 24.49 |
| Wednesday | 0.984 | 4.366 | 8.15 | 0.952 | 9.738 | 17.52 |
| Thursday | 0.978 | 3.769 | 7.13 | 0.955 | 11.322 | 33.06 |
| Friday | 0.983 | 4.692 | 16.88 | 0.987 | 7.041 | 26.81 |

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

The overall idea of this project is to analyze the load of the building and forecast the future load. Building load demand data has been collected successfully for the load prediction. The load data collected from the switch room and the timetable of the whole building combined with the estimated load of each equipments in the building make the load analysis even more precise. Every equipment in the building are identified for their respective energy consumption. The air conditioning is subjected to be most power consuming units after the analysis and the machinery in the labs is ranked after that. From the data analysis, it is crucial to reduce the usage of air conditioning in order to bring down the overall peak load so as to reduce the maximum demand charges. The load profile for every day is different and analyzed using same weekdays as well as different weekdays for weeks. Analyzing data for the same weekdays given the higher correlation and it makes the load forecasting results better.

From the results obtained, it shows that the correlation analysis for the same weekdays is higher which means it is a better way to use for load forecasting. As for the load forecasting methods, exponential smoothing method has slightly higher average of the correlation than the ARIMA method and the MAPE of exponential smoothing method is far less than the ARIMA method. hence, the exponential smoothing method is a better way to forecast load.

## 5.2 Recommendation

For the current stage of exponential smoothing method, the biggest issue is how to accurately adjust the weight in the formula, as the weight is the main factor that influences the accuracy of the total load forecasting. If the weight of the exponential smoothing method can be find out using statistical tools, then the optimization of weight will highly increase the load forecasting accuracy as well.

Other than that, the accuracy of the forecasting results can be further improved. With only two methods, it is still insufficient to guarantee the forecasted results. As we can see from the forecasted results, there are some differences in between those two methods. So to improve the accuracy and reliability, it can be done by using other types of forecasting methods while more methods provide more references to make the results even more accurate.

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# APPENDICE

## APPENDIX A: Timetables of First Floor at SE Block

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-Mar-2013 | Mon | | | | | | | | | | | | | | 7h |
| 19-Mar-2013 | Tue | | | | | | | | | | | | | | 5h |
| 20-Mar-2013 | Wed | | | | | | | | | | | | | | 8h |
| 21-Mar-2013 | Thu | | | | | | | | | | | | | | 7h |
| 22-Mar-2013 | Fri | | | | | | | | | | | | | | 11h |
| 23-Mar-2013 | Sat | | | | | | | | | | | | | | |
| 24-Mar-2013 | Sun | | | | | | | | | | | | | | |
| 25-Mar-2013 | Mon | | | | | | | | | | | | | | 7h |
| 26-Mar-2013 | Tue | | | | | | | | | | | | | | 5h |
| 27-Mar-2013 | Wed | | | | | | | | | | | | | | 8h |
| 28-Mar-2013 | Thu | | | | | | | | | | | | | | 7h |
| 29-Mar-2013 | Fri | | | | | | | | | | | | | | 11h |
| 30-Mar-2013 | Sat | | | | | | | | | | | | | | |

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