GDC-UTP ELECTRICITY FORECASTING USING FUZZY SYSTEM

by

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Progress Report submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Universiti Teknologi PETRONAS
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TRONOH, PERAK
MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Farah Tasya Binti Haji Nordin)

ABSTRACT

This report represents the approach for short term load forecasting by using fuzzy logic approach. As depicted in Chapter 1, in order for Gas District Cooling to operate at maximum efficiency and minimum generating costs, it must be able to forecast the load demanded by the sole customer, University Teknologi PETRONAS. Based on the literature review in Chapter 2, there are several factors that affect the forecasting such as weather condition, the type of forecast day and history of the load demand. In Chapter 3 of this report, this project proposes a load forecasting method by using fuzzy logic approach, based on similar days to obtain the next week's forecasted load. The fuzzyTECH software is used to develop a week-week-ahead load forecasting model together with Microsoft Excel as data interface. The test result, as shown in in Chapter 4, show that the proposed forecasting method could provide a considerable improvement of the forecasting accuracy especially as it shows how to reduce forecast error. Several recommendations for future improvements are included in Chapter 5. The suitability of the proposed approach is illustrated through an application to actual load data of the Gas District Cooling of University Teknologi PETRONAS.

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LIST OF ABBREVIATION

DoS	: Degree of Support
GDC	: Gas District Cooling
MAPE	: Mean Absolute Percentage Error
MW	: Megawatt
STLF	: Short Term Load Forecasting
UTP	: Universiti Teknologi PETRONAS

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Universiti Teknolgi PETRONAS (UTP) receives electricity supply provided by the Gas District Cooling-UTP plant since April 2003. It operates on island operation mode during normal condition with utility company supply on hot standby mode. The plant has two generation units rated at 4.2 MW each, with a maximum generation capacity of 8.4 MW. As a sole customer of the plant, the load demand is very much dependent on UTP activities. The generation process must be operated at maximum efficiency and minimum operating cost.

Towards achieving the goal of optimal planning and operation of power system, electricity demand forecasting is essential [1]. Literally, electricity demand forecasting can be interpreted as 'what nature of electrical demand a utility provider can assume from a specific number of users in a specific time interval' [14].

Forecasting activity needs the sources of variation in their load requirements in order to evaluate the production cost. The same information also needed to plans for system's spinning reserve and fuel requirement, plans for maintenance scheduling [14], provide estimation on end user service cost and price retail service [1].

This projects aims to minimize the electricity production costs by minimizing the amount of energy wastage during generation. Therefore, an accurate prediction for the electricity demand is very important to ensure sufficient, continuous and reliable supply to the consumers.

The importance of electricity demand forecasting shall be emphasized at all levels as the consequences of under or over estimation will affect the power service company. If under estimated, the result is serious since the plant installation cannot easily be advanced, thus this will affect the economy, business, loss of time and image [3]. If the demand is over forecasted, it will be a waste of resources and increment in operating cost.

The system accuracy can be determined from the mean absolute percentage error (MAPE) between the forecasted load and the real load consumption. The MAPE is measured based on the error statistic of forecast between the models for one week step. The overall MAPE is calculated by taking into calculation each week's MAPE. The lower overall MAPE shows a better accuracy of the forecasting model.

1.2 Problem Statement

1.2.1 Problem Identification

The reliability and effectiveness of the GDC-UTP plant can be determined by its performance. In power system, many uncertainties could arise due to aging of machine, unforeseen load, fluctuations, losses in transmission line, voltage and frequency instability as well as change of weather condition [2]. Due to these conditions, it is complicated to mathematically formulate the power system problems.

Since the electricity demand is complex, nonlinear and full with uncertainty, it needs a method that can mimics the human thinking and deals with its complexity to forecast the future electricity demands. To emerge this problem, the Fuzzy Set Theory introduced by Prof. Lotfi A. Zadeh in 1965 was applied as a complement tool to the mathematical approach in solving the power system problems.

1.2.2 Significance of Project

Prediction of daily load changes and regulating the operation of generation units can be a great help in maintaining the electricity supply stability. This project employed the Short Term Load Forecasting (STLF) method to predict the future electricity demand in UTP by one week step ahead.

Through this project, the GDC-UTP should be able to predict the future electricity demand in order to determine the total amount of electrical power to be generated. The plant also would be able to manage the electricity generation, set up plant maintenance and prevent energy wastage.

1.3 Objectives and Scope of the Project

1.3.1 Objectives

The following objectives were to be achieves from this project:

- To understand the electricity demand behavior of UTP.
- To do the system modeling and simulation of the load requirement of the plant using the selected software based on the scenarios.
- To be able to forecast the electricity for 7 days ahead and able to revise the forecast based on the load changes.
- To produce a reliable and accurate forecasting model simulation.

1.3.2 Scope of Study

Generally, the scope of study will cover the following areas:

- Short term load demand in Universiti Teknologi PETRONAS.
- Historical data of electricity generated from GDC-UTP.
- Fuzzy Logic as a technique used in the forecasting method.
- fuzzyTECH 5.52 software as the electricity forecasting tool.

1.4 Relevancy of the Project

The study required for this project aims at minimizing electricity production costs by minimizing the amount of energy wastage during generation since short-term load forecasting provides the input for unit commitment. Therefore, having prediction of high accuracy is very important to ensure continuous and reliable supply to the consumers. Based on the trend for UTP load demand and literature reviewed, this project proved to be very beneficial and relevant with current situation.

1.5 Feasibility of the Project

This project will be conducted for two semesters. This includes system research, development and improvement. The required data for electricity demand forecasting was obtained from GDC-UTP. In addition, the fuzzyTECH software should be able to fulfill the requirement in developing the load forecasting model. Therefore, this project is feasible to be carried out within the time and scope.

CHAPTER 2
LITERATURE REVIEW

2.1 Electricity Forecasting

By definition, forecast means the prediction of future events and conditions [4]. The term electricity forecasting referred to the act of making prediction on the future electricity demand using a certain method and taking into account the factors that may affect the forecasting result.

In power system planning and operation, load forecasting plays an important role. The basic operating functions such as economic dispatch, fuel scheduling and generating unit maintenance can be performed efficiently with an accurate forecast [5].

Electricity forecasting can be classified as Short Term Load Forecasting (STLF), Medium Term Load Forecasting (MTLF) and Long Term Load Forecasting (LTLF). Short-term load forecasting is the prediction of the system load over an interval ranging from one hour to one week [6]. Information derived from the STLF is significant to the system management of weekly, daily and hourly operation [2].

Meanwhile, medium-term load forecasting is usually conducted from a week to a year, and long-term load forecasting is normally longer than a year [8], usually covers from one to ten years ahead.

Among these, long-term and medium-term load forecasting is mainly applied in determining the capacity of generation, transmission or distribution system. However, short-term load forecasting can provide accurate prediction for power in week, days and even hours. The short-term forecasting is important for the economic and secure operation of power system as it represents a great saving potential for electric utility company [7].

2.2 Important Factors Affecting Electricity Forecast

Generally, there are several factors that may affect the electricity demand forecasting result such as weather, the condition of the forecast day and previous history of demand. Based on the scope of location whereby this project was conducted, the following factors have been taken into account.

2.2.1 Semester type

The electricity demand rises when semester is on and drops during semester breaks. The graph in Figure 1 shows that the electricity demand for the 28 days during semester on (4 until 31 May 2009) was higher than the demand for the 28 days during semester off (1until 28 June 2009).

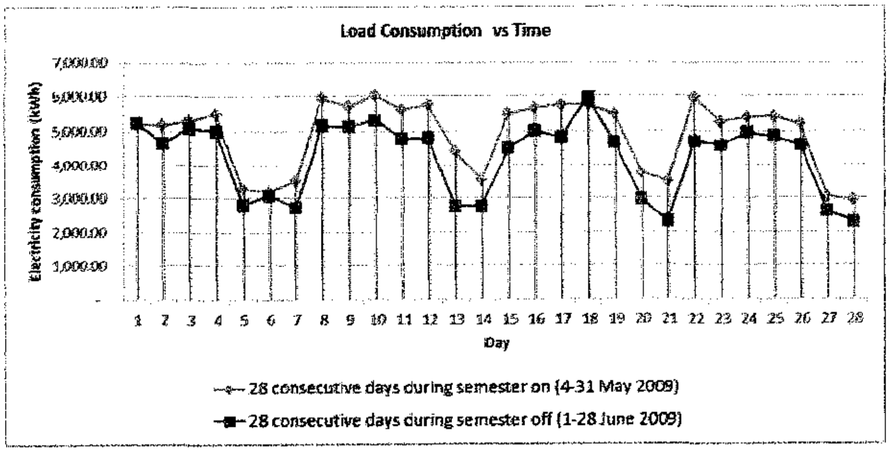

Figure 2.1: Load comparison during semester on and break

2.2.2 Day type

There are significance differences in load consumption between weekdays and weekend. Load on different weekdays in the same may behave differently. The type of the day can be classified into three class; public holiday, normal working day and special occasion. During public holiday, the normal electricity consumption may drop drastically, while during special occasion, the demand may rise.

There are importance difference in load between weekdays and weekends. The load on different weekdays also will behave differently. For example, Monday and Friday are being adjacent to weekends, may have structurally different loads than Tuesday through Thursday. Meanwhile, on weekends, it was day off for most staff and majority of the students are out of campus. This explains why there are significance drop for load demand on weekend.

In addition, lunar festivals, religious events and national holidays are more difficult to forecast than non-holidays because of their infrequent occurrence [8].

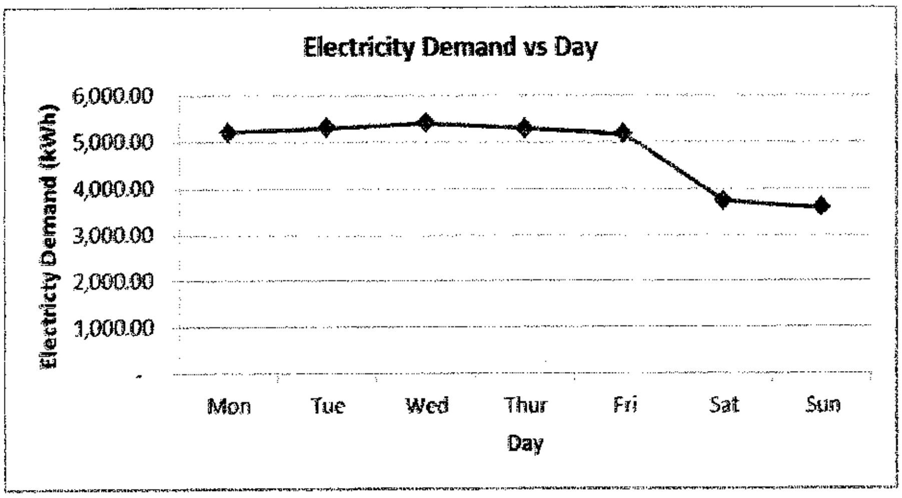

Figure 2.2: Electricity consumption on 23 February – 1 March 2009

2.2.3 *Day temperature*

The influence of weather in energy consumption, particularly electricity demand, has been widely reported in the past [8]. The weather condition will affect the day temperature. In fact, forecasted day temperature is the most important factors in short-term load forecasting. Normally, the peak load of daily demand occurs around the extreme maximum or minimum temperature depending on whether energy is required for space cooling or heating, respectively [15]. The daily load curve normally follows the daily temperature profile.

2.2.4 *Previous week load consumption*

From the study of the load data, it was found that the load demand on a particular day in a week ~~and~~ a week before is not much in difference. It is known that the load at a given hour is dependent not only on the load on the previous hour but also on the load at the same hour of the previous day.

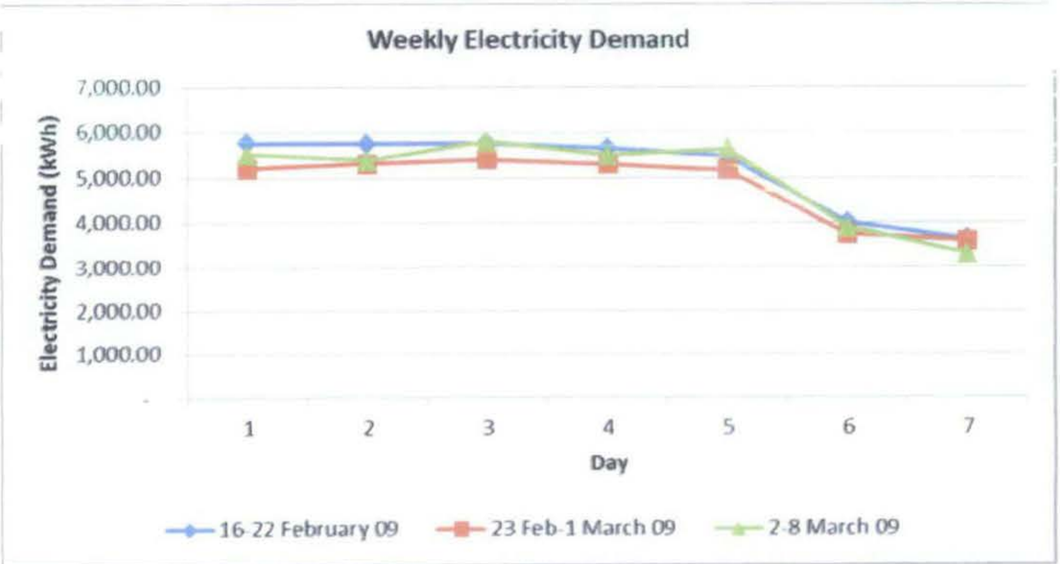

Figure 2.3: Weekly electricity consumption

However, the load on particular day for this week and the last week, or the week before may be almost similar. Hence, it is assumed that the load curve is somewhat similar to the load curve on the previous day. The previous load data could give significant contribution in forecasting the load.

Studies on the load demand are required so that the amount of the electricity to be generated can be assessed. The table below shows the summary of the minimum and maximum load demand along with the average load consumption on Monday until Sunday for the whole 24 weeks (refer Appendix A for details).

Table 2.1: Load Summary

Day	Min (kW)		Max (kW)		Average (kW)
	Sem On	Sem Off	Sem On	Sem Off	
Monday	5120	2368	5,956	5248	4830.1
Tuesday	4080	3992	6,020	5124	5059.4
Wednesday	5304	3832	7,414	5312	5301.0
Thursday	5256	2484	6,024	5000	5086.4
Friday	5124	3676	5,996	5276	4907.0
Saturday	3160	2412	4,460	3348	3465.4
Sunday	2488	2336	4,232	3284	3054.7

2.3 Fuzzy Logic Theory

2.3.1 The Fuzzy Logic Concept

In using our everyday natural language to import knowledge and information, there is a great deal of impression and vagueness. For example; "Jasmin Hani is tall" and "Julia Hani is short". The term tall and short are fuzzy, in the sense that they cannot be sharply defined.

The fuzzy logic provides a mean for representing uncertainties [10]. The basic idea of fuzzy logic is simple: in reality, we cannot define a rule for each possible case.

Exact rules that cover a case perfectly can only be defined for a few distinct cases. These rules are discrete points in the continuum of possible cases and humans approximate between them [9].

The first publication on fuzzy logic, which also coined its name, dates back to 1965. It was written in the U.S. by Lotfi Zadeh, Professor of Systems Theory at the University of California, Berkeley. From there, the history of fuzzy logic follows the pattern of number recent technologies: invented in the U.S., engineered in Europe, and mass-marketed in Japan [9].

2.3.2 Mathematical Modeling

Prof. Zadeh contention is that "meaning in natural language is a matter of degree". If we have a proposition such as "Jasmin Hani is tall", then it is not always possible to assert that it is either true or false. When we know that Jasmin Hani's height is *y,* then the "truth", or more correctly, the "compatibility" of y with "is tall", is a matter of degree.

If the proposition is "Jasmin Hani's is under 160cm height" and we know Jasmine's height, then we can give a yes or no answer to whether the proposition is true or not. In contrast to binary sets that having binary logic (crisp logic), the fuzzy variables may have memberships values of not only 0 or 1. The values can range from 0 to 1. The difference between binary sets and fuzzy logic are as follows:

An ordinary subset A of a set U is determined by its indicator function, or characteristic function X_A defined by:

$$X_A(x) = \begin{Bmatrix} 1, x \in A \\ 0, x \notin A \end{Bmatrix}$$

The indicator function of a subset A of a s et U specifies whether or not It either is or is not. There are only two possible values the indicator function can take. This notion is generalized by allowing images of elements to be in interval [0, 1], rather than being restricted to the two element set {0, 1}. For a fuzzy set $A: U \rightarrow [0, 1]$, the function A is called the membership function and the value $A\ (u)$ is called the degree of membership of u in fuzzy set A.

The degree to which the value of a technical figure satisfies the linguistic concept of the term of a linguistic variable is called degree of membership. For a continuous variable, this degree is expressed by a function called membership function (MBF). The membership functions map each value of the technical figure to the membership degree to the linguistic terms. The technical quantity is called the base variable [12].

The previous example shows the fuzzy logic with a numerical value. The fuzzy logic usually is applied for the non-numeric linguistic variables. It is often used for facilitating the expression of rules and facts. The Fuzzy Logic uses IF-THEN rules which employ the linguistic variables (fuzzy variables) whose values are in the linguistic terms.

The rules are usually expressed in the form [11]:

IF variable IS property, THEN action

For multiple inputs, the following rule applied:

IF x IS a and y IS b, THEN z is c

2.4 FuzzyTech System Modeling Configurations

The structure of the fuzzy logic configurations can be represented as below:

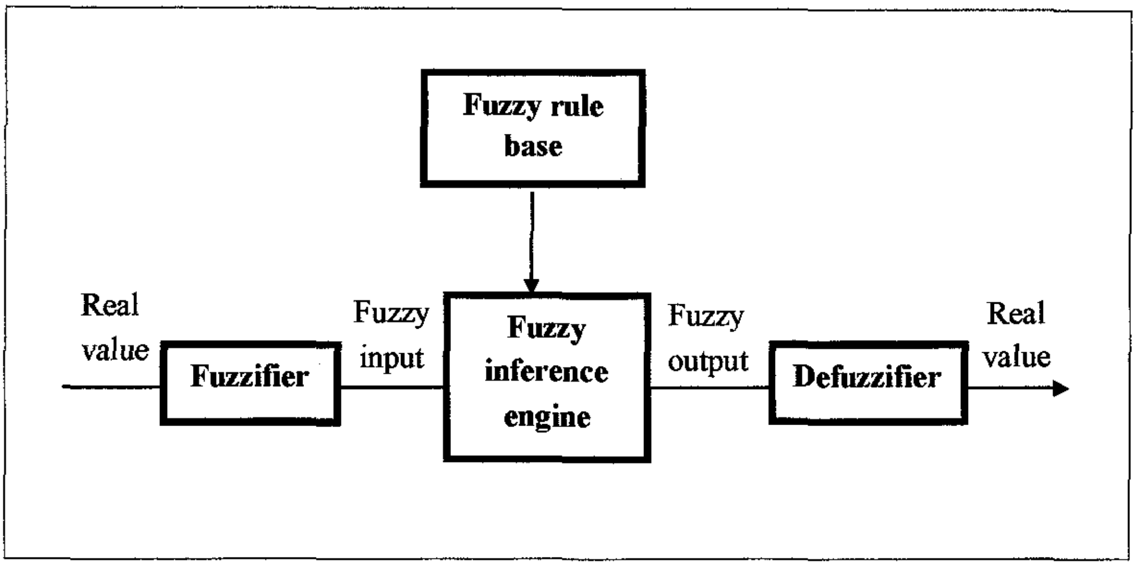

Figure 2.4: Basic Component of Fuzzy System

2.4.1 Fuzzification

The modeling starts with user entering the inputs. The inputs are in terms of the crisp value. Fuzzification is the process of associating crisp input values with the linguistic terms of corresponding input linguistic variables [11]. The Fuzzifier will then transforms the real valued input variables into fuzzy values.

2.4.2 Fuzzy Inference

The Fuzzy Inference engine will map the fuzzy inputs earlier to the fuzzy output based on the Fuzzy Rules. The Fuzzy Rules and Fuzzy Set Database are entered by the user to enable the inference engine to function properly. Now that all input variables have been converted to linguistic variable values, the fuzzy inference step can identify the rules that apply to the current situation and compute the value of the output linguistic variable.

The fuzzy inference system is used to evaluate the similarity between the previous forecast days and previous similar days resulting in correction factors, used to correct the similar days of the forecast day to obtain the load forecast. The computation of the fuzzy inference consists of three components:

- *Aggregation:*

  Computation of the 'IF' part of the rules. This step computes the support of the rule relative to the conditions.

- *Composition:*

  Computation of the 'THEN' part of the rules. This step computes the degree of truth for the rule.

- *Result Aggregation:*

  After the degrees of truth for the rules are computed, this step determines which rules will contribute to the Deffuzzified result

Rule base optimization often consists of arbitrary rule addition/deletion. This method can result in a clumsy trial-and-error approach as the individual importance of a rule can be expressed only as a 0 or 1. For this reason, most fuzzyTECH Editions support an advanced inference method, the Fuzzy Associative Maps inference, or FAM. With FAM, each rule is assigned a degree of support representing the individual importance of the rule. Rules themselves can be "fuzzy" – meaning, with validity between 0 and 1. The validity of a conclusion is calculated by a linking of the validity of the entire condition with the degree of support by a composition operator. When the product operator is used as the composition operator, the degree of support reflects rule "significance" [9].

2.4.3 Rule base

Fuzzy rule base is a set of linguistic rules or conditional statements in the form of "IF a set of conditions IS satisfied, THEN a set of consequences are inferred". These if-then rule statements are used to formulate the conditional statements that comprise fuzzy logic [13].

2.4.4 Defuzzification

The result produced from the evaluation of fuzzy rules is fuzzy. Membership functions are used to retranslate the fuzzy output into a crisp value. This translation is known as *Defuzzification* and can be performed using several methods. Thus, the result of the fuzzy inference is retranslated from a linguistic concept to a crisp output value.

CHAPTER 3
METHODOLOGY

3.1 System Design Approach

This project consists of three main stages. The first stage is the construction phase, followed by expansion and modification on the earlier stage. The final part of the project is to the test the system in stage 1 with electrical load in of the year 2010.

3.2 Tools Required

For this project, two main software are required, the fuzzyTECH and Microsoft Excel. fuzzyTECH is the software for fuzzy logic-based solution. This software provides simple yet powerful user interface for developing the load forecasting model especially for beginners since all the fuzzy logic algorithm are embedded within the program.

However, fuzzyTECH does not provide the interface for data management. Alternatively, fuzzyTECH can be linked together with the software for data interfacing such as the Microsoft Excel. The Dynamic Data Exchange (DDE) Links function, which is embedded inside the fuzzyTECH, can be used to link the system with the worksheet of the Microsoft Excel.

3.3 Procedure Identification Stage 1: Construction

To create the forecasting model, the data for UTP electricity load consumption of 24 weeks, starting from 19 January until 5 July 2010 were obtained (Appendix A). Then, the input linguistic variables (previous week load, semester type, day type and weekly temperature) and output linguistic variables (forecasted load) were identified. From the data obtained, the relationship between the input and output parameters was analyzed.

Using the fuzzyTECH software, the membership functions for all the linguistic variables can be established. Defining a linguistic variables also includes the definition of its possible linguistic values (terms), ranges of values and membership function. The degree of membership, i.e. the degree, to which a crisp value belongs to a linguistic value (term) of the linguistic variables, is computed by means of membership functions.

This membership degree is represented by a value in the range of 0 and 1. A membership degree of 0 means no membership at all, a degree of 1 means absolute membership.

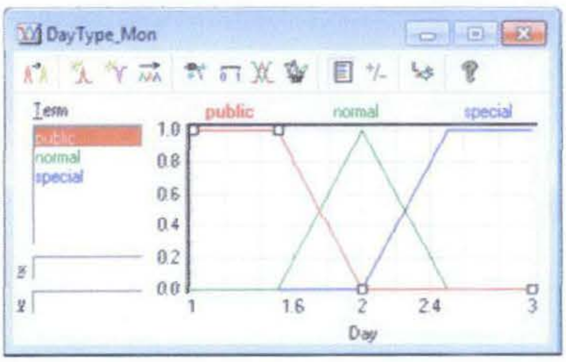

Figure 3.1: Membership function for input variable of the Day Type

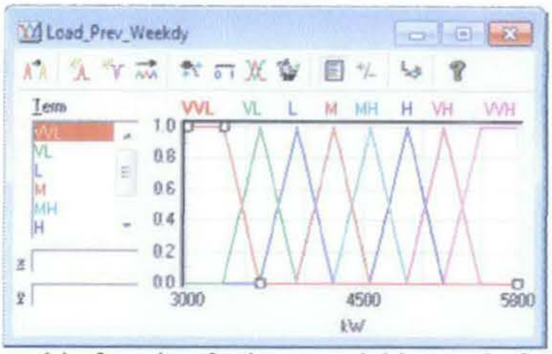

Figure 3.2: Membership function for input variable Load of Previous Weekday

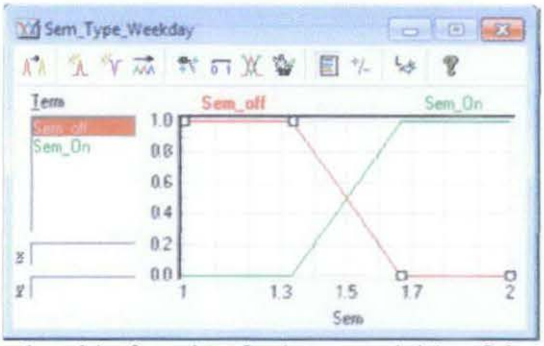

Figure 3.3: Membership function for input variable of the Semester Type

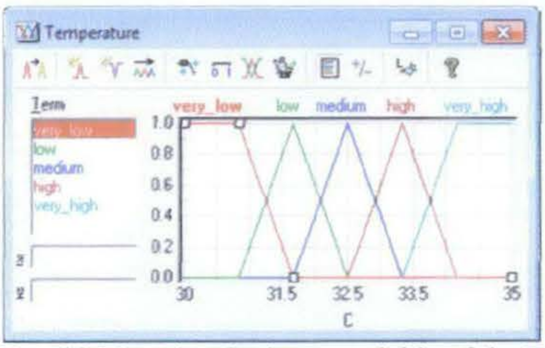

Figure 3.4: Membership function for input variable of the Day Temperature

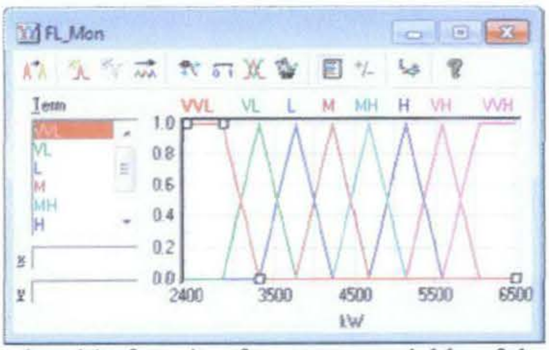

Figure 3.5: Membership function for output variable of the Forecast Load

The next part is the construction of the fuzzy If-Then rule blocks. In fuzzyTECH individual rules are confined into rule blocks to build the system structure. The fuzzy rule block is the medium which connects between the system inputs with the system output based on the If-Then rules. The 'IF' column on the left side shows the variables used in the precondition of fuzzy rules. The 'THEN' column on the right shows the variables used for the conclusion of the condition.

Spreadsheet Rule Editor - Rule_Block_Monday

#	IF				THEN	
	DayType_Mon	Load_Prev_Weel	Sem_Type_Weel	Temperature	DoS	FL_Mon
7	public	VH	Sem_On	very_low	1.00	WL
8	public	VH	Sem_On	low	1.00	WL
9	public	VH	Sem_On	medium	0.10	VL
10	public	VH	Sem_On	high	0.10	VL
11	public	WH	Sem_On	very_low	1.00	WL
12	public	WH	Sem_On	low	1.00	WL
13	public	WH	Sem_On	medium	0.80	VL
14	public	WH	Sem_On	high	1.00	VL
15	public	WH	Sem_On	very_high	1.00	VL
16	public	WH	Sem_On	high	0.10	MH
17	normal	WL	Sem_off	low	1.00	M
18	normal	M	Sem_off	very_low	1.00	MH
19	normal	WH	Sem_off	medium	1.00	MH
20	normal	VH	Sem_off	medium	1.00	H
21	normal	MH	Sem_off	very_high	1.00	H
22	normal	VH	Sem_off	high	0.70	M
23	normal	H	Sem_off	medium	1.00	MH
24	normal	MH	Sem_off	medium	0.90	M
25	normal	WH	Sem_off	high	0.80	H
26	normal	VH	Sem_off	medium	0.50	M
27	normal	H	Sem_off	high	0.80	VH
28	normal	VH	Sem_off	medium	0.10	L
29	normal	H	Sem_On	medium	0.10	H
30	normal	M	Sem_On	low	1.00	H
31	normal	WH	Sem_On	low	1.00	H
32	normal	VH	Sem_On	low	1.00	H
33	normal	H	Sem_On	medium	1.00	VH
34	normal	MH	Sem_On	medium	1.00	H

Figure 3.6: Monday Rule Blocks

After the model is completed, simulation can be performed to obtain the forecast load. Performing error analysis will determine the accuracy of the model. Retuning the system will be performed if the MAPE shows a value exceeding 9%. Figure 5 below shows the system design approach of this project.

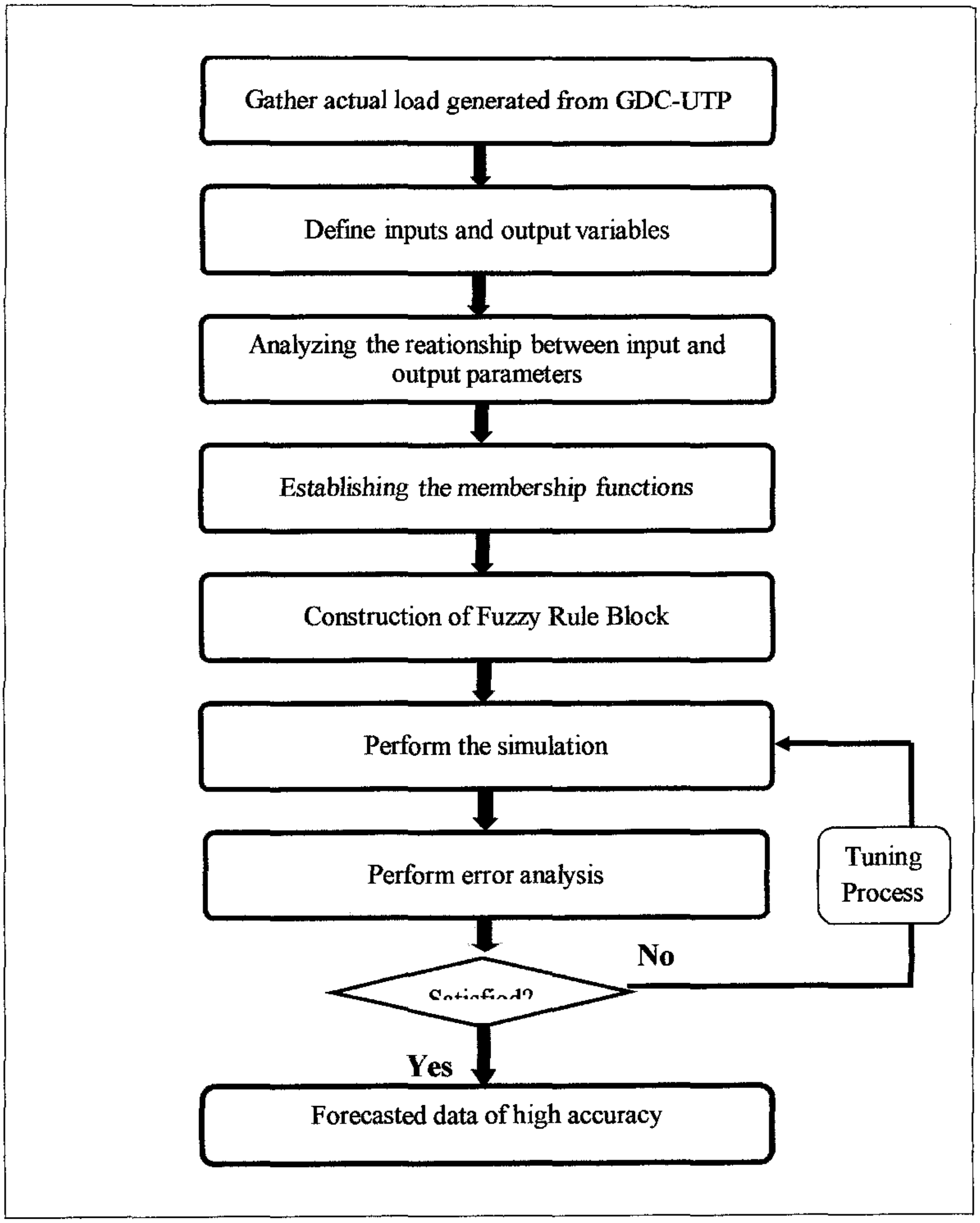

Figure 3.7: Flowchart for system design approach

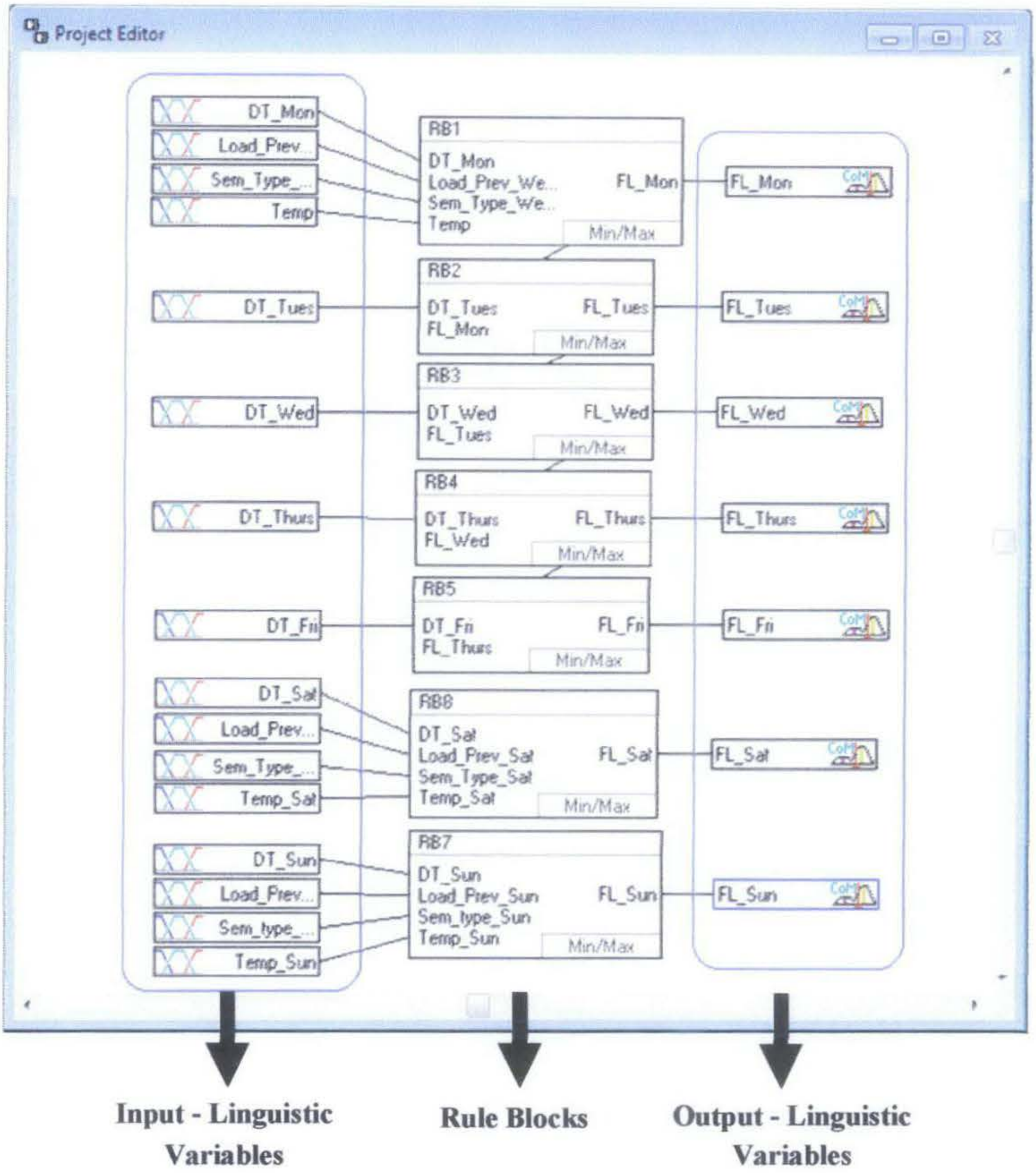

Figure 3.8: Project Editor

3.3.1 Error Calculation

The forecasted load was compared to the actual load data so that error can be calculated. The principal statistic used to evaluate the performance of the model, mean absolute percentage error is defined as

$$MAPE\text{ (weekly)} = \frac{1}{N}\sum_{i=1}^{N}\frac{|P_F^i - P_A^i|}{P_A^i}\text{ x100\%}$$

P_A is actual load, P_F is the forecasted load and N is the number of data points. Overall MAPE represents the overall system performance accuracy.

$$MAPE\text{ (overall)} = \frac{1}{N}\sum_{i=1}^{N}(\text{Weekly MAPE})^i$$

3.3.2 Program Simulation Process

The simulation began by user activating the Debug Interactive Mode button. The process continues by inserting the input in the Data Input column in Microsoft Excel as shown in Table 3. The input which is in term of crisp value will be sent to the fuzzyTECH program through Data Dynamic Exchange (DDE) Link. In fuzzyTECH program, by referring to the membership function values and the rule based, the value of the forecast output will be computed. The input value and the result of the computation are as shown in Table 3.1 and 3.2. For easier data management, the output of the computation can be sent back to the Microsoft Excel. All of these data exchange could be made possible by assigning the Excel column address in the DDE Links Window of fuzzyTECH program.

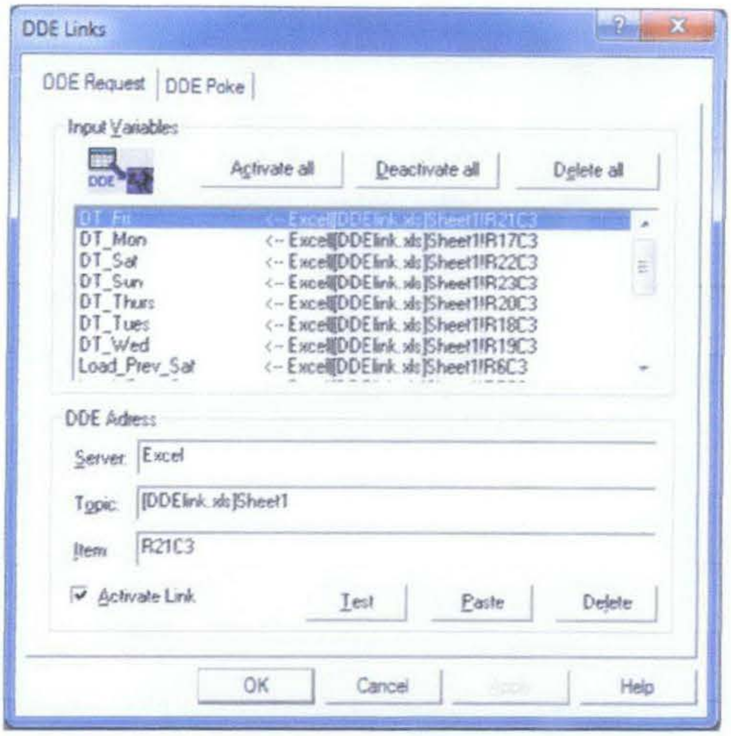

Figure 3.9: DDE Request for assigning Input location

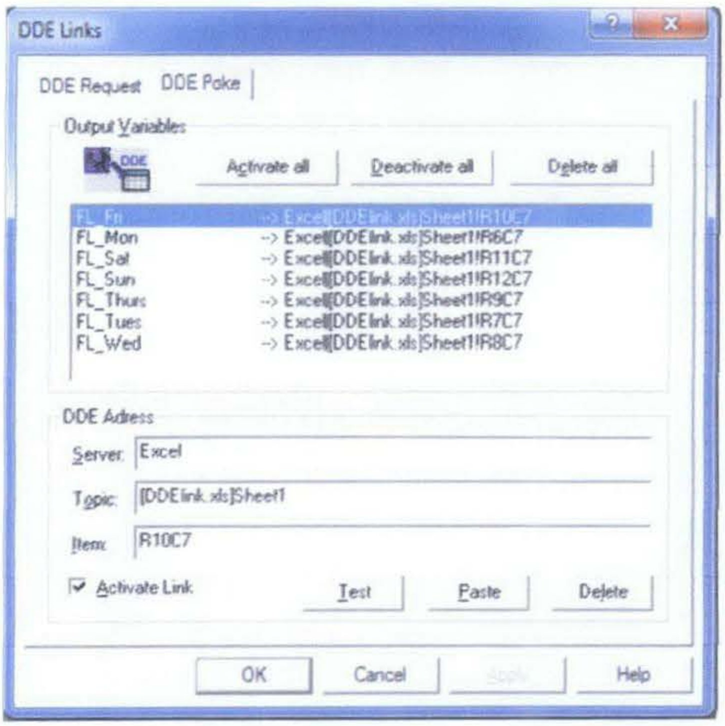

Figure 3.10: DDE Request for assigning Output location

Table 3.1: Example of Input Column in Microsoft Excel

INPUT		
WEEK:		
Insert previous weekday actual average load		kW
Insert previous week actual Saturday load		kW
Insert previous week actual Sunday load		kW
Insert forecast Weekday maximum temperature		C
Insert forecast Saturday Temperature		C
Insert forecast Sunday Temperature		C
Insert forecast Weekday semester type		
Insert forecast Saturday semester type		
Insert forecast Sunday semester type		
Insert forecast Monday Day type		
Insert forecast Tuesday Day type		
Insert forecast Wednesday Day type		
Insert forecast Thursday Day type		
Insert forecast Friday Day type		
Insert forecast Saturday Day type		
Insert forecast Sunday Day type		

Table 3.2: Example of Output Column in Microsoft Excel

OUTPUT					
DAY	**F**	**A**	**F-A**	**ABS F-A**	**ERROR**
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					
				MAPE:	

3.3.3 Fine Tuning Process

During the first stage, the rules in each rule block were tested and modified as well as the DoS for each rules repeatedly. It is an error analysis process called fine-tuning process. The process was performed to obtain the lowest possible MAPE on every week. The flow of the process is shown in the figure below.

If the forecasted result shows high MAPE, then a process called fine tuning needed to be done. The fine tuning process is a trial and error process, that is repeated during simulation until an optimal result or an accurate model is obtained. The fine tuning involves the process of specifying and editing the IF-THEN rules as well as the DoS for the rules.

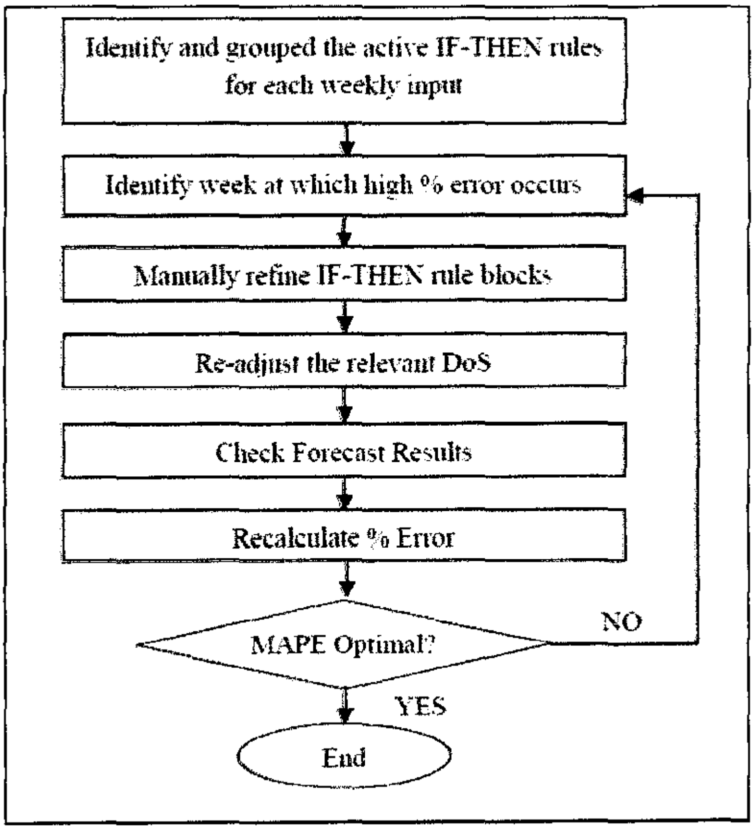

Figure 3.11: Fine tuning process

First of all, the number of rules in each block, and the configuration the rule were maintained. The manual adjustment will be started from the first rule block, which is the rule block for forecast Monday. In this process, all 24 weeks will be run one by one. In every week that was run, to which rules (in rule block Monday) it was related to will be noted and recorded.

After all the 24 weeks data has been gathered, weeks that may be sharing the same rules are grouped. By doing this, we now know which rules are affected the particular week's output. Then, adjustment can be made to the Degree of Support of the respective rules, so that the percentage error between forecast value and actual load value on Monday will be minimized and balanced.

The same action was repeated for Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday rule blocks. The rule blocks and membership function were attached in Appendix B.

3.4 Procedure Identification Stage 2: Expansion

The second part of this project is to expand the membership function for the linguistic variables 'Temperature', 'Load_Previous' and 'Forecast Load' in the system. The purpose of this expansion is a trial in designing a model with higher interpretability and accuracy.

For a variable with multiple terms, the membership functions of all terms are displayed. Membership functions are numerical functions corresponding to linguistic terms. Membership functions are defined using a point-oriented method. An L-Shape shape type was chosen for connecting the definition points. A term's definition points are drawn as squares – a cross in a square indicates a selected point and an empty square shows that the point has not been selected. An example of membership function expansion is shown below. Refer to Appendix C for details.

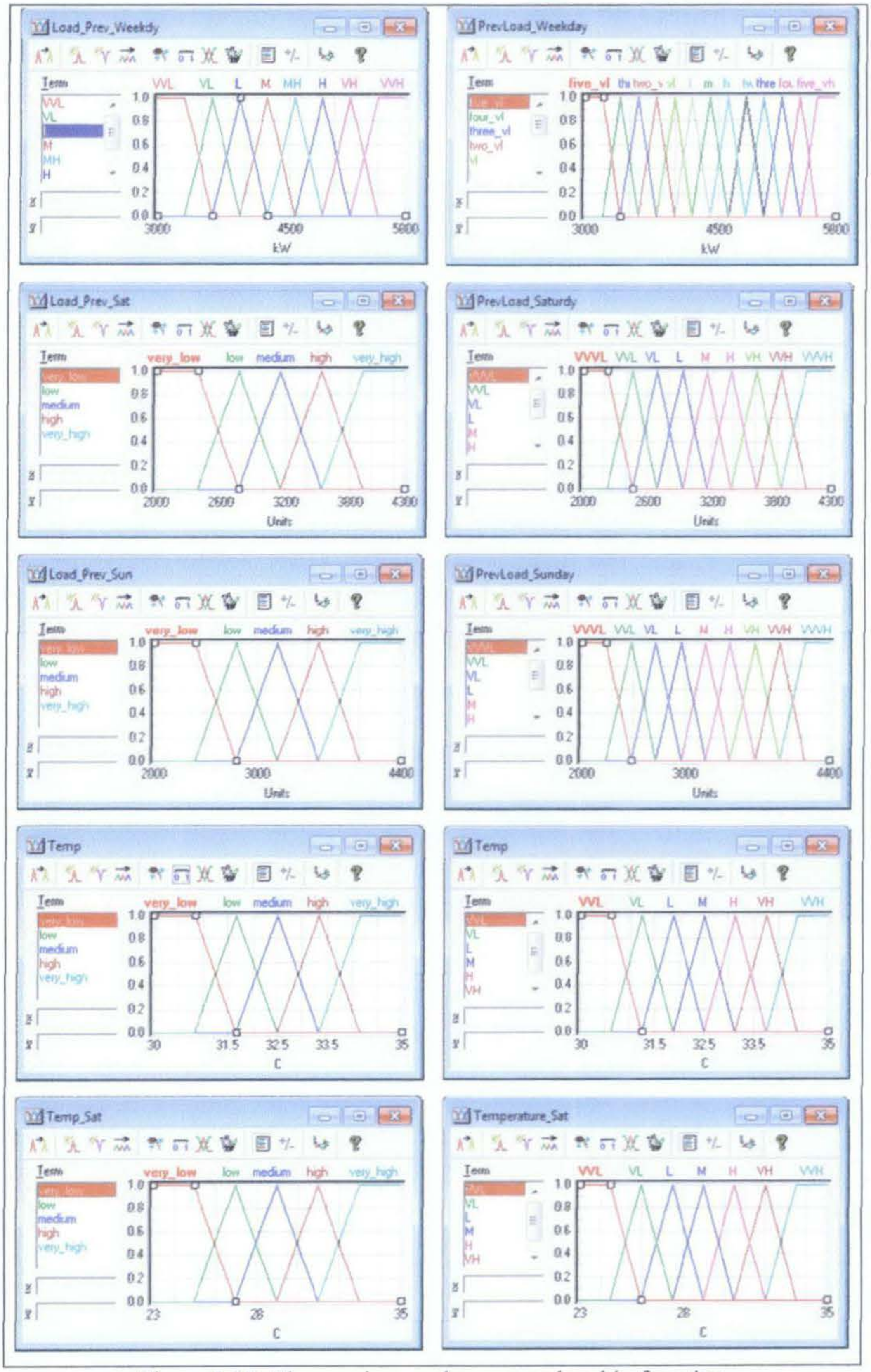

Figure 3.12: The previous and new membership function

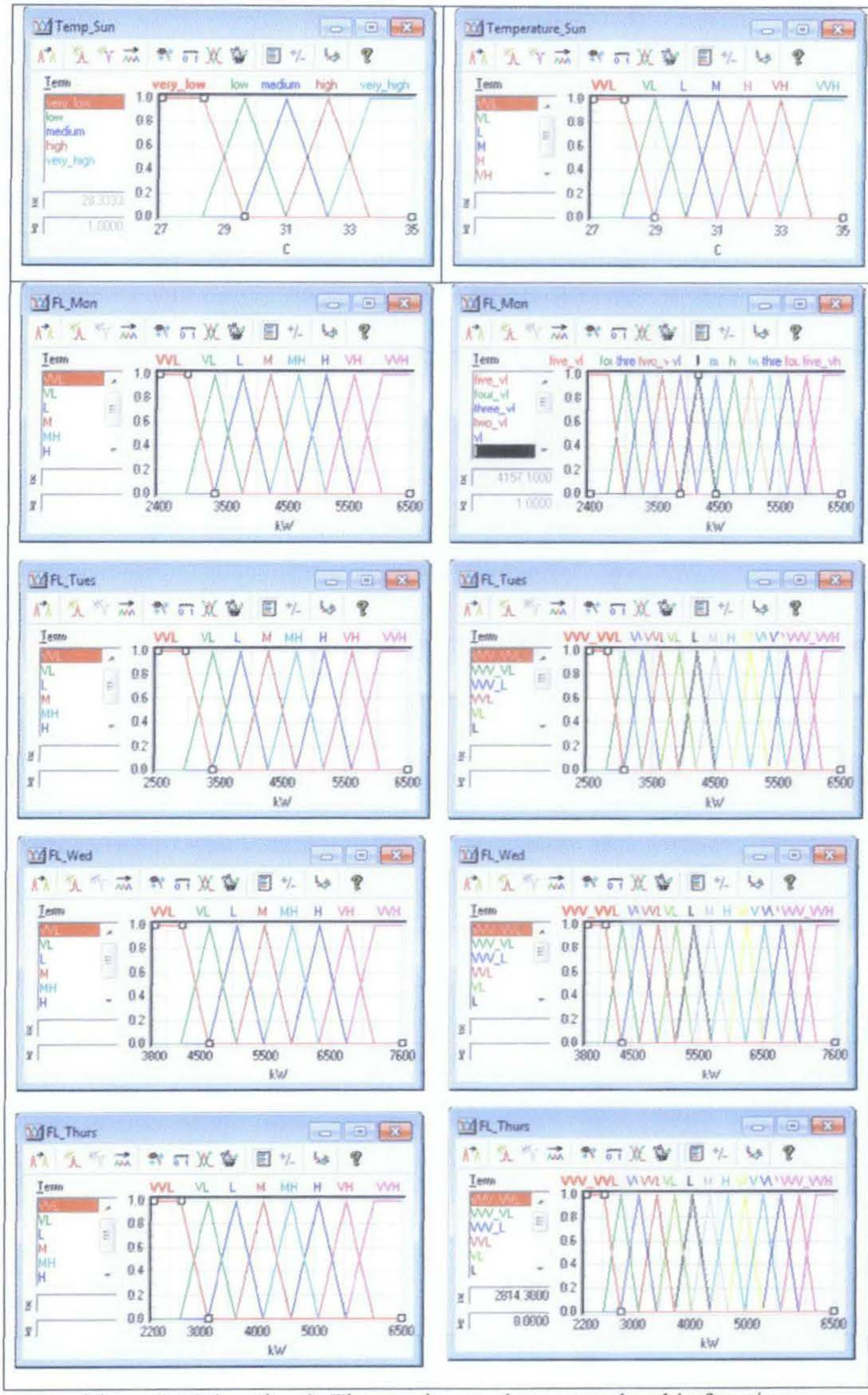

Figure 3.12 (continue): The previous and new membership function

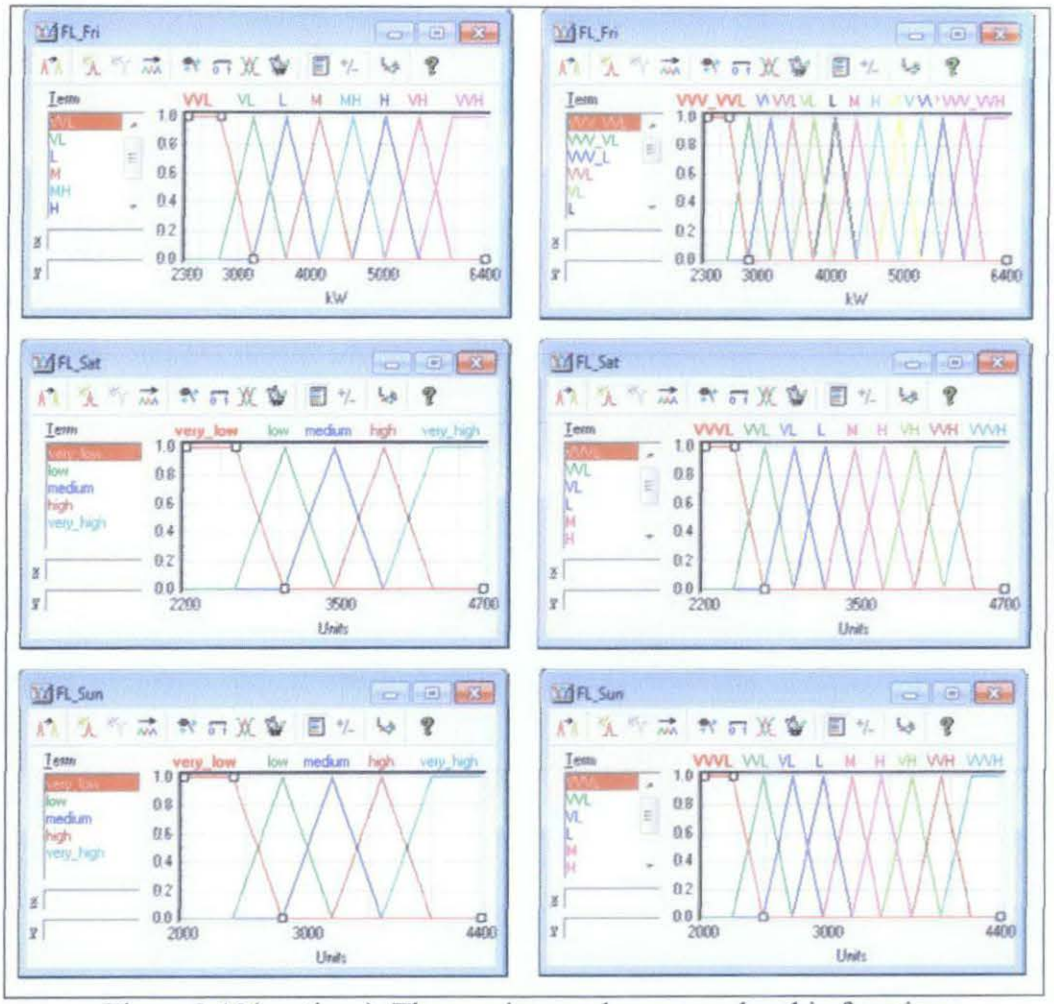

Figure 3.12(continue): The previous and new membership function

As new terms has been added, all seven rule bases were recreated based on the situation of the load demand. The fine tuning process was performed repeatedly until a smaller MAPE was obtained in the forecasting model. The new rule bases were shown in Appendix C.

3.5 Procedure Identification Stage 3: Testing

The final part of this project is to test the system that was build based on year 2009 load demand in Stage 1. This program was tested with the 2010 real time data. During the testing stage, no further modification or changes were applied. The system was solely tested and checked for accuracy. The datasheet for the electrical demand and maximum daily temperature for the whole year 2010 were available in Appendix D.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Simulation Result

4.1.1 Program tested using load demand data of year 2009

Table 4.1: Error analysis (MAPE) during semester on

Week	MAPE	
	Stage 1	**Stage 2**
1	5.13	1.81
2	5.55	2.66
3	7.17	4.07
4	4.86	4.04
5	2.39	4.93
6	4.32	3.01
7	4.51	3.28
8	3.95	3.64
9	2.77	2.22
11	3.27	3.21
12	2.57	4.53
13	4.86	5.79
14	4.92	9.97
15	3.43	2.43
16	6.05	3.59
17	4.05	4.92
18	2.07	4.71
19	5.81	1.31
AVERAGE	**4.31**	**3.89**

Table 4.2: Error analysis (MAPE) during semester off

Week	**MAPE**	
	Stage 1	**Stage 2**
10	6.78	9.03
20	4.23	6.64
21	4.29	5.22
22	6.37	6.90
23	4.44	4.88
24	6.68	6.67
AVERAGE	**5.46**	**6.56**

Table 4.3: Overall error analysis (MAPE)

Week	**MAPE**	
	Stage 1	**Stage 2**
1	5.13	1.81
2	5.55	2.66
3	7.17	4.07
4	4.86	4.04
5	2.39	4.93
6	4.32	3.01
7	4.51	3.28
8	3.95	3.64
9	2.77	2.22
10	6.78	9.03
11	3.27	3.21
12	2.57	4.53
13	4.86	5.79
14	4.92	9.97
15	3.43	2.43
16	6.05	3.59
17	4.05	4.92
18	2.07	4.71
19	5.81	1.31
20	4.23	6.64
21	4.29	5.22
22	6.37	6.90
23	4.44	4.88
24	6.68	6.67
AVERAGE	**4.60**	**4.56**

4.1.2 Program tested using load demand data of the year 2010

Table 4.4: Error analysis (MAPE) during semester on

Week	MAPE (Stage 3)
4	9.12
5	7.23
6	3.69
7	3.45
8	4.28
9	6.44
10	12.01
12	10.54
13	12.82
14	9.64
15	18.69
16	7.69
17	5.21
18	4.25
19	7.60
20	6.10
21	4.39
22	6.50
30	13.63
31	6.45
32	6.43
33	11.92
34	7.74
35	10.00
38	3.46
39	6.57
40	5.11
41	3.21
42	8.29
43	6.40
44	18.61
45	15.84
46	16.64
47	4.83
48	5.86
AVERAGE	**8.30**

Table 4.5: Error analysis (MAPE) during semester off

Week	MAPE (Stage 3)
1	11.93
2	6.48
3	4.26
11	11.39
23	12.08
24	16.82
25	8.94
26	9.87
27	4.70
28	20.30
29	4.79
36	36.20
37	28.56
49	25.63
50	11.42
51	8.60
AVERAGE	**13.87**

Table 4.6: Overall error analysis (MAPE)

Week	MAPE (Stage 3)
1	11.93
2	6.48
3	4.26
4	9.12
5	7.23
6	3.69
7	3.45
8	4.28
9	6.44
10	12.01
11	11.39
12	10.54
13	12.82
14	9.64
15	18.69
16	7.69
17	5.21

Table 4.6 (continue): Overall error analysis (MAPE)

Week	MAPE (Stage 3)
18	4.25
19	7.60
20	6.10
21	4.39
22	6.50
23	12.08
24	16.82
25	8.94
26	9.87
27	4.70
28	20.30
29	4.79
30	13.63
31	6.45
32	6.43
33	11.92
34	7.74
35	10.00
36	36.20
37	28.56
38	3.46
39	6.57
40	5.11
41	3.21
42	8.29
43	6.40
44	18.61
45	15.84
46	16.64
47	4.83
48	5.86
49	25.63
50	11.42
51	8.60
AVERAGE	**10.05**

4.2 Discussion

4.2.1 Output computation in FuzzyTECH

In the fuzzyTECH program, the result of the output computation will be shown in the *Watch: Interactive Debug Mode* window.

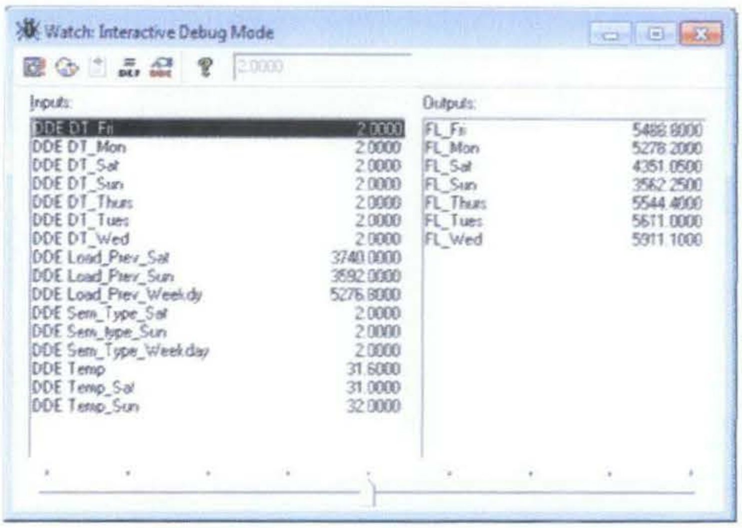

Figure 4.1: Watch: Interactive Debug Mode window

In the Center of Maximum (CoM) defuzzification method, the fuzzy logic controller first determines the typical numerical value for each scaled membership function. The typical numerical value is the mean of the numerical values corresponding to the degree of membership at which the membership function was scaled. The fuzzy logic controller then uses the following equation to calculate a weighted average of the typical values.

$$x_{final} = \frac{(x_1\mu_1 + x_2\mu_2 + \cdots + x_n\mu_n)}{(\mu_1 + \mu_2 + \cdots + \mu_n)}$$

where x_n is the typical numerical value for the scaled membership function n, and μ_n is the degree of membership at which membership function n was scaled. Figure 4.7 illustrates how to use the CoM defuzzification method.

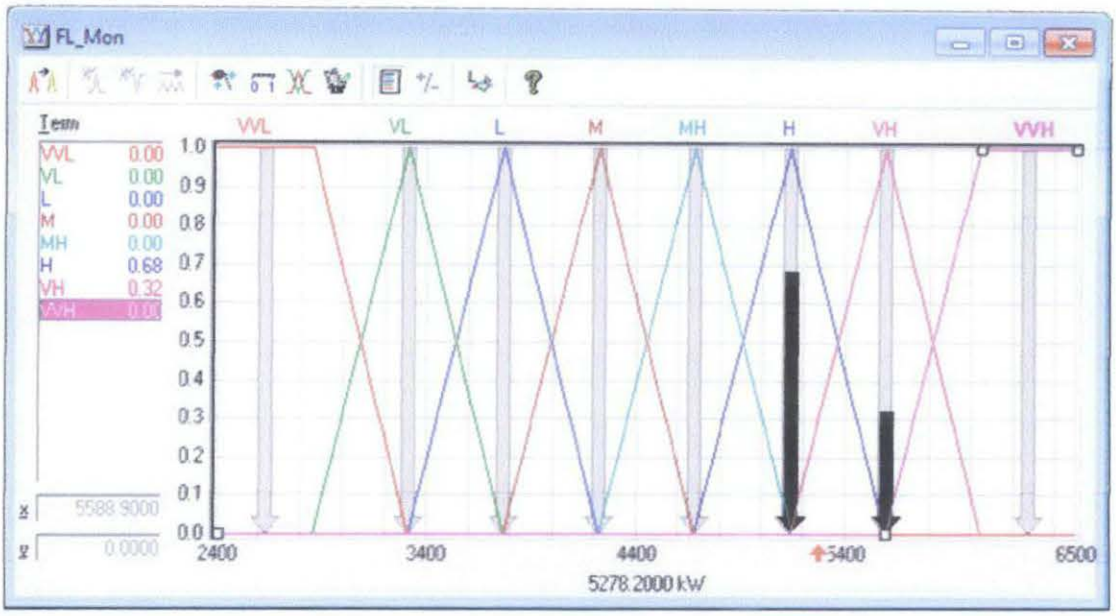

Figure 4.2: Output variable for Forecast load on Monday (FL_Monday)

The values 5132.0 kW and 5588.9 kW are the typical values of the linguistic terms *H* and *VH*. The degrees of truth for these linguistic terms are 0.68 and 0.32, respectively. Therefore, the defuzzified crisp output value is calculated by the following equation:

$$x_{final} = \frac{((5132.0)(0.68) + (5588.9)(0.32))}{(0.68 + 0.32)} = 5278.2$$

4.2.2 Result

In stage 1, the system was created based on 2009 load demand data. The rule base was designated based on the past history of load demand. The system has an overall accuracy of 4.60%. However, the system performance during specific time such as semester break or semester on is slightly different. For such case, during semester on, the MAPE is 4.31%, lower if compared to 5.46% during semester off. This condition is probably due to unstable load demand pattern during semester break.

Meanwhile in stage 2, it was a completely new system. Even though using the same data system, the membership functions of all input linguistic variables and output linguistic variables were expanding. Due to these changes, the MAPE for semester on was decreased from 4.31% to 3.89%. Meanwhile, the MAPE during semester OFF is 6.56%. This gives the overall result for the average MAPE as 4.56%. As the membership functions of the linguistic terms were expands, there are more terms to represent the variety of the load demand condition. When the membership functions were expanding, the rule becomes more complex as there are possibilities of 546 rules. However, the system in Stage 2 can be further improved by the fine tuning process.

In stage 3, the system was once again tested using real time 2010 electricity demand data. It is found that the forecast result is slightly higher. This condition may happen because of the changes in the electricity demand pattern. Besides, the minimum and maximum electricity demand value recorded for the year 2010 are both smaller and higher respectively if compared to year 2009.

The variation between each absolute error show that the forecast result depends on variation of the historical data since the range between the minimum and maximum for each membership function is determined based on the data from the year 2009. Therefore, each prediction is based on the behavior of the historical data.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Maintaining a balanced load distribution to all sections in UTP throughout the year is important to avoid power shortage, overload, and also power disruption. Many times, incidence like this would cause lost in time and generation cost. Therefore, it is important to be able to forecast the future load in UTP.

The importance of electricity demand forecasting shall be emphasized at all levels as the consequences of under or over estimation will affect the power service company. Through this project, the GDC-UTP should be able to predict the future electricity demand in order to determine the total amount of electrical power to be generated. The plant also would be able to manage the electricity generation, set up plant maintenance and prevent energy wastage.

The fuzzyTECH software simplifies the implementation of fuzzy logic for the load forecasting model since fuzzy logic requires advanced in mathematical modeling. Several steps are required in building the model which include establishing membership function of every input and output as well as the rule block that holds the control strategy for the whole system based on the If-Then rules.

5.2 Recommendation

For further improvement, it is recommended add linguistic variables 'Temperature' to the rule block Tuesday, Wednesday, Thursday and Friday. In the current system, the variable 'Temperature' is only applied on Rule Block Monday, Saturday and Sunday. On Monday, the average forecasted temperature of the weekday (Monday until Friday) was used in the respective week. Meanwhile, daily forecasted temperature was used for rule block Saturday and Sunday. However, the next modification will use the data of daily forecasted temperature. The figure below shows the recommended system with the linguistic variable 'Temperature' added to the respective rule block.

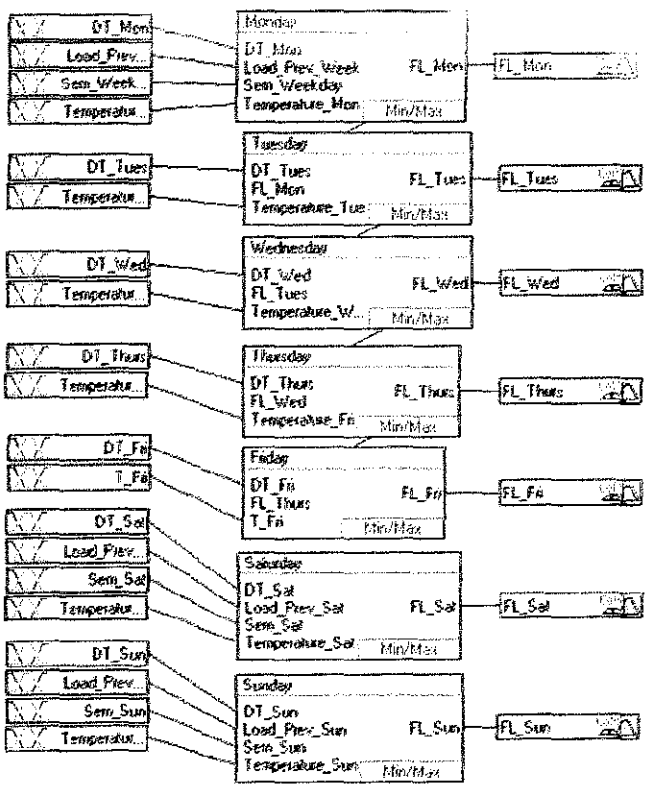

Figure 5.1: Suggested Project Editor

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APPENDICES

APPENDIX A

UTP Electricity Load Demand for January 2009 Semester

Max. Daily Temperature/Load	0	°C	1	°C	2	°C	3	°C	4
Monday	4,882.00	31	5,120.00	33	2,932.00	32	5,204.00	33	3756
Tuesday	5,036.00	33	5,396.00	33	2,752.00	32	4,080.00	33	5524
Wednesday	5,092.00	33	5,414.00	32	5,348.00	33	5,376.00	32	5548
Thursday	4,548.00	32	5,382.00	31	5,662.00	33	5,256.00	33	5584
Friday	5,276.00	35	5,140.00	32	5,156.00	30	5,124.00	33	5900
Saturday	2,956.00	33	3,638.00	31	4,386.00	32	3,676.00	35	4460
Sunday	3,236.00	27	2,488.00	31	3,068.00	33	3,256.00	33	3088
Average Weekday Load (kW)	4966.8		5290.4		4370		5008		5262.4
Average Weekday Temperature		32.8		32.2		32		32.8	
Saturday's Temperature (°C)		33		31		32		35	
Sunday's Temperature (°C)		27		31		33		33	

Max. Daily Temperature/Load		5	°C	6	°C	7	°C	8
Monday	32	5,764.00	32	5,208.00	30	5,520.00	27	2,692.00
Tuesday	31	5,748.00	31	5,308.00	32	5,392.00	32	5,524.00
Wednesday	31	5,760.00	31	5,404.00	33	5,804.00	31	5,820.00
Thursday	32	5,652.00	32	5,292.00	30	5,496.00	32	5,364.00
Friday	32	5,464.00	32	5,172.00	33	5,636.00	31	5,288.00
Saturday	33	4,004.00	33	3,740.00	31	3,908.00	32	4,052.00
Sunday	32	3,628.00	32	3,592.00	32	3,300.00	32	3,232.00
Average Weekday Load (kW)		5677.6		5276.8		5569.6		4937.6
Average Weekday	31.6		31.6		31.6		30.6	
Saturday's Temperature (°C)	33		33		31		32	
Sunday's Temperature (°C)	32		32		32		32	

Max. Daily Temperature/Load	°C	9	°C	10	°C	11	°C	12
Monday	32	5,712.00	35	4,912.00	32	5,448.00	31	5,572.00
Tuesday	31	5,680.00	31	4,928.00	32	5,524.00	30	5,848.00
Wednesday	32	5,412.00	35	4,772.00	35	5,448.00	32	5,824.00
Thursday	33	5,372.00	31	4,700.00	33	5,412.00	33	5,560.00
Friday	33	5,484.00	31	4,364.00	32	5,828.00	31	5,456.00
Saturday	33	3,220.00	33	3,104.00	32	4,192.00	32	4,068.00
Sunday	32	2,420.00	33	2,996.00	33	3,336.00	33	4,232.00
Average Weekday Load (kW)		5532		4735.2		5532		5652
Average Weekday	32.2		32.6		32.8		31.4	
Saturday's Temperature (°C)	33		33		32		32	
Sunday's Temperature (°C)	32		33		33		33	

Max. Daily Temperature/Load	°C	13	°C	14	°C	15	°C	16
Monday	32	5,932.00	35	3440	35	5632	32	5,204.00
Tuesday	33	6,020.00	30	5392	35	5568	32	5,164.00
Wednesday	28	5,516.00	35	5772	33	7414	33	5,304.00
Thursday	31	5,516.00	35	6024	33	5416	32	5,496.00
Friday	35	5,872.00	32	5996	35	3496	33	3,272.00
Saturday	35	3,780.00	33	3816	31	3160	33	3,200.00
Sunday	30	2,944.00	33	3496	30	2988	33	3,528.00
Average Weekday Load (kW)		5771.2		5324.8		5505.2		4888
Average Weekday	31.8		33.4		34.2		32.4	
Saturday's Temperature (°C)	35		33		31		33	
Sunday's Temperature (°C)	30		33		30		33	

Max. Daily Temperature/Load	°C°C	17	°C	18	°C	19	°C	20
Monday	32	5,932.00	31	5,480.00	35	5,956.00	32	5248
Tuesday	35	5,712.00	33	5,652.00	30	5,244.00	32	4644
Wednesday	33	6,020.00	33	5,744.00	32	5,376.00	32	5088
Thursday	30	5,608.00	32	5,748.00	32	5,400.00	31	5000
Friday	32	5,748.00	32	5,480.00	32	5,192.00	33	2800
Saturday	32	4,388.00	33	3,756.00	31	3,036.00	35	3088
Sunday	32	3,552.00	35	3,512.00	33	2,936.00	33	2720
Average Weekday Load (kW)		5804		5620.8		5433.6		4556
Average Weekday	32.4		32.2		32.2		32	
Saturday's Temperature (°C)	32		33		31		35	
Sunday's Temperature (°C)	32		35		33		33	

Max. Daily Temperature/Load	°C	21	°C	22	°C	23	°C	24
Monday	33	5144	33	4488	32	4680	32	4468
Tuesday	35	5124	32	4992	33	4568	33	4144
Wednesday	33	5312	35	4796	31	4936	32	4072
Thursday	35	4776	32	5942	33	4834	30	4116
Friday	35	4780	35	4646	31	4576	32	4440
Saturday	33	2772	33	2964	32	2600	33	3348
Sunday	32	2772	32	2308	31	2296	32	2516
Average Weekday Load (kW)		5027.2		4972.8		4718.8		4248
Average Weekday	34.2		33.4		32		31.8	
Saturday's Temperature (°C)	33		33		32		33	

APPENDIX B

Membership Function and Rule Blocks of Stage 1

(1) Membership Functions

Condition	*Linguistic Terms in fuzzyTECH*	*Membership Function Definition*

Input variables

Day Type

Public Holiday	public	1
Normal Day	normal	2
Special Occasion	special	3

Semester Type

Semester Break	Sem_off	1
Semester On	Sem_On	2

Previous Weekday Average Load

Very-Very Low	VVL	3000.00-3622.20 kW
Very Low	VL	3622.20- 3931.85 kW
Low	L	3931.85-4245.45 kW
Medium	M	4245.45-4559.45 kW
Medium-High	MH	4559.45-4868.15 kW
High	H	4868.15-5177.30 kW
Very High	VH	5177.30-5409.25 kW
Very-Very High	VVH	5409.25-5800.99 kW

Average Maximum Temperature For Next Weekdays

Rainy	very_low	30.00-31.67°C
Cool	low	31.67-32.50°C
Average	medium	32.50-33.33°C
Warm	high	33.33-34.18°C
Hot	very_high	34.18-35.00°C

Previous Saturday Load

Very Low	very_low	2000-2766.65 kW
Low	low	2766.5-3150 kW
Medium	medium	3150-3530.15 kW
High	high	3530.15-3929.35KW
Very High	very_high	3929.35-4300 kW

Maximum Temperature For Next Saturday

Rainy	very_low	23-27°C
Cool	low	27-29°C
Average	medium	29-31°C
Warm	high	31-33°C
Hot	very_high	33-35°C

Previous Sunday Averge Load

Very Low	very_low	2000-2800 kW
Low	low	2800-3140 kW
Medium	medium	3140-3600 kW
High	high	3600-4000 kW
Very High	very_high	4000-4400 kW

Maximum Temperature For Next Sunday

Rainy	very_low	27.00-29.67°C
Cool	low	29.67-31.00°C
Average	medium	31.00-32.33°C
Warm	high	32.33-33.70°C
Hot	very_high	33.70-35.00°C

Output Variables

Forecasted Load Demand- Monday

Very-Very Low	VVL	2400.0-3311.1 kW
Very Low	VL	3311.1-3768.2 kW
Low	L	3768.2-4224.3 kW
Medium	M	4224.3-4675.2 kW
Medium-High	MH	4675.2-5131.8 kW
High	H	5131.8-5587.9 kW
Very High	VH	5587.9-6043.9 kW
Very-Very High	VVH	6043.9-6500.0 kW

Forecasted Load Demand -Tuesday

Very-Very Low	VVL	2500.0-3388.9 kW
Very Low	VL	3388.9-3843.4 kW
Low	L	3843.4-4275.3 kW
Medium	M	4275.3-4720.2 kW
Medium-High	MH	4720.2-5169.7 kW
High	H	5169.7-5614.6 kW
Very High	VH	5614.6-6058.3 kW
Very-Very High	VVH	6058.3-6500.0 kW

Forecasted Load Demand -Wednesday

Very-Very Low	VVL	3800.0-4644.4 kW
Very Low	VL	4644.4-5063.8 kW
Low	L	5063.8-5490.8 kW
Medium	M	5490.8-5909.2 kW
Medium-High	MH	5909.2-6331.9 kW
High	H	6331.9-6750.3 kW
Very High	VH	6750.3-7181.6 kW
Very-Very High	VVH	7181.6-7600.0 kW

Forecasted Load Demand -Thursday

Very-Very Low	VVL	2200.0-3155.5 kW
Very Low	VL	3155.5-3634.9 kW
Low	L	3634.9-4113.3 kW
Medium	M	4113.3-4586.7 kW
Medium-High	MH	4586.7-5065.1 kW
High	H	5065.1-5548.2 kW
Very High	VH	5548.2-6031.3 kW
Very-Very High	VVH	6031.3-6500.0 kW

Forecasted Load Demand -Friday

Very-Very Low	VVL	2300.0-3211.1 kW
Very Low	VL	3211.1-3668.2 kW
Low	L	3668.2-4124.3 kW
Medium	M	4124.3-4575.7 kW
Medium-High	MH	4575.7-5031.8 kW
High	H	5031.8-5492.5 kW
Very High	VH	5492.5-5943.5 kW
Very-Very High	VVH	5943.5-6400.0 kW

Forecasted Load Demand -Saturday

Very Low	very_low	22000.0-3033.3 kW
Low	low	3033.3-3450.0 kW
Medium	medium	3450.0-3868.0 kW
High	high	3868.8-4297.1 kW
Very High	very_high	4297.1-4700.0 kW

Forecasted Load Demand -Sunday

Very Low	very_low	2000-2800 kW
Low	low	2800-3140 kW
Medium	medium	3140-3600 kW
High	high	3600-4000 kW
Very High	very_high	4000-4400 kW

(2) Rule Blocks

Spreadsheet Rule Editor - RB1

#	IF DT_Mon	Load_Prev_Weekdy	Sem_Type_Weekday	Temp	THEN DoS	FL_Mon
1	public	VL	Sem_off	very_low	1.00	VVL
2	public	H	Sem_On	very_low	1.00	VL
3	public	H	Sem_On	low	1.00	VL
4	public	H	Sem_On	medium	1.00	L
5	public	H	Sem_On	high	1.00	L
6	public	H	Sem_On	very_high	1.00	L
7	public	VH	Sem_On	very_low	1.00	VVL
8	public	VH	Sem_On	low	1.00	VVL
9	public	VH	Sem_On	medium	0.10	VL
10	public	VH	Sem_On	high	0.00	VL
11	public	VVH	Sem_On	very_low	1.00	VVL
12	public	VVH	Sem_On	low	0.90	VVL
13	public	VVH	Sem_On	medium	0.80	VL
14	public	VVH	Sem_On	high	1.00	VVL
15	public	VVH	Sem_On	very_high	1.00	VVL
16	public	VVH	Sem_On	high	0.70	MH
17	normal	VVL	Sem_off	low	1.00	M
18	normal	M	Sem_off	very_low	1.00	MH
19	normal	VVH	Sem_off	medium	1.00	MH
20	normal	VH	Sem_off	medium	1.00	H
21	normal	MH	Sem_off	very_high	1.00	H
22	normal	VH	Sem_off	high	1.00	M
23	normal	H	Sem_off	medium	1.00	MH
24	normal	MH	Sem_off	medium	0.90	M
25	normal	VVH	Sem_off	high	1.00	H
26	normal	VH	Sem_off	medium	0.10	M

Figure B1: Rule Block on Monday

Spreadsheet Rule Editor - RB1

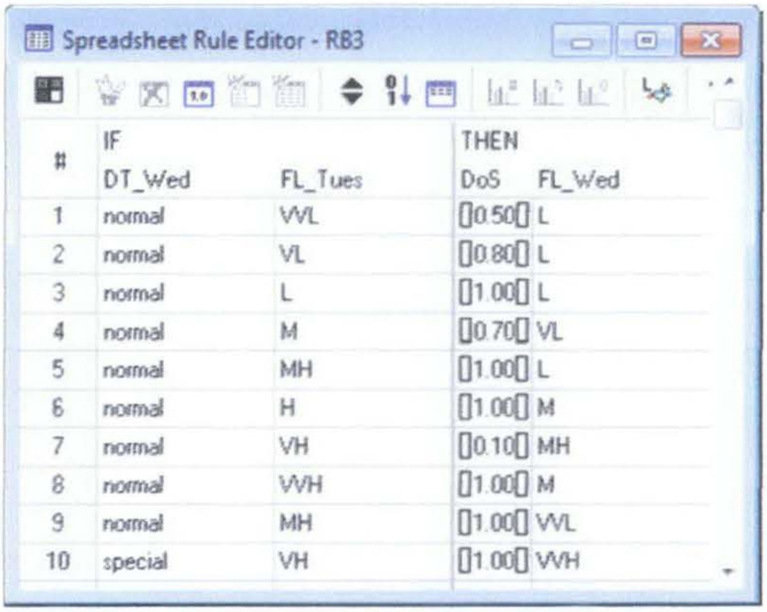
#	IF DT_Mon	Load_Prev_Weekdy	Sem_Type_Weekday	Temp	THEN DoS	FL_Mon
27	normal	H	Sem_off	high	1.00	VH
28	normal	VH	Sem_off	medium	0.30	L
29	normal	H	Sem_On	medium	0.50	H
30	normal	M	Sem_On	low	1.00	H
31	normal	VVH	Sem_On	low	1.00	H
32	normal	VH	Sem_On	low	0.10	H
33	normal	H	Sem_On	medium	1.00	VH
34	normal	MH	Sem_On	medium	0.60	H
35	normal	VVH	Sem_On	low	1.00	VH
36	normal	VH	Sem_On	very_high	1.00	VH
37	normal	MH	Sem_On	very_high	1.00	VH
38	normal	VVH	Sem_On	medium	1.00	VH
39	normal	VVH	Sem_On	medium	0.10	VVH

Figure B.1 (continue): Rule Block on Monday

Spreadsheet Rule Editor - RB2

#	IF DT_Tues	FL_Mon	THEN DoS	FL_Tues
1	public	VVL	1.00	VVL
2	normal	VVL	1.00	H
3	normal	VL	1.00	H
4	normal	L	0.20	H
5	normal	M	1.00	M
6	normal	VH	1.00	VH
7	normal	VVH	1.00	VVH
8	public	VL	1.00	VL
9	public	VVL	1.00	L
10				

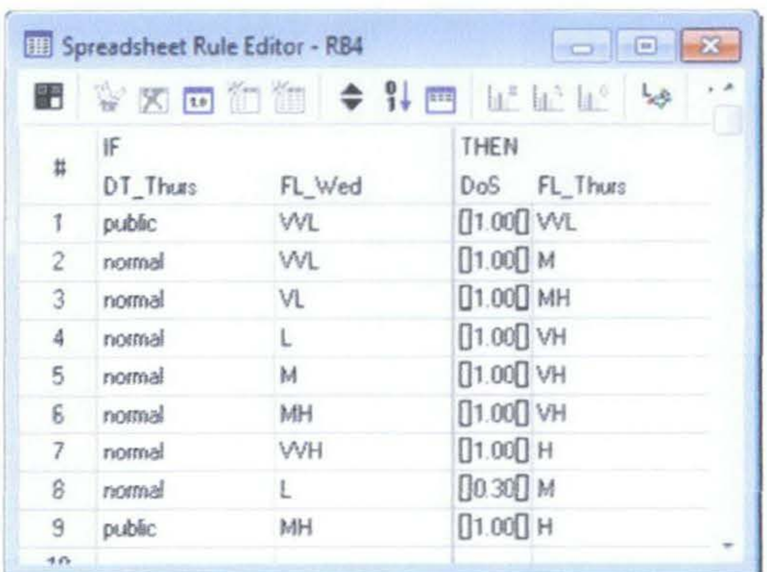
Figure B.2: Rule Block on Tuesday



Spreadsheet Rule Editor - RB3

#	IF DT_Wed	FL_Tues	THEN DoS	FL_Wed
1	normal	VVL	0.50	L
2	normal	VL	0.80	L
3	normal	L	1.00	L
4	normal	M	0.70	VL
5	normal	MH	1.00	L
6	normal	H	1.00	M
7	normal	VH	0.10	MH
8	normal	VVH	1.00	M
9	normal	MH	1.00	VVL
10	special	VH	1.00	VVH

Figure B.3: Rule Block on Wednesday



Spreadsheet Rule Editor - RB4

#	IF DT_Thurs	FL_Wed	THEN DoS	FL_Thurs
1	public	VVL	1.00	VVL
2	normal	VVL	1.00	M
3	normal	VL	1.00	MH
4	normal	L	1.00	VH
5	normal	M	1.00	VH
6	normal	MH	1.00	VH
7	normal	VVH	1.00	H
8	normal	L	0.30	M
9	public	MH	1.00	H

Figure B.4: Rule Block on Thursday

Spreadsheet Rule Editor - RB5

#	IF DT_Fri	FL_Thurs	THEN DoS	FL_Fri
1	public	MH	1.00	VVL
2	public	H	1.00	VL
3	public	VH	1.00	VL
4	normal	L	1.00	M
5	normal	M	1.00	M
6	normal	MH	1.00	MH
7	normal	H	0.80	H
8	normal	VH	1.00	VH
9	normal	VVL	1.00	L
10	normal	H	0.80	VH
11	public	VVH	1.00	VVL

Figure B.5: Rule Block on Friday

Spreadsheet Rule Editor - RB8

#	IF DT_Sat	Load_Prev_Sat	Sem_Type_Sat	Temp_Sat	THEN DoS	FL_Sat
1	normal	low	sem_off	very_high	1.00	low
2	normal	high	sem_off	high	1.00	low
3	normal	very_low	sem_off	very_high	1.00	low
4	normal	very_low	sem_off	high	1.00	low
5	normal	low	sem_off	very_high	0.40	very_low
6	normal	very_low	sem_on	very_high	1.00	medium
7	normal	medium	sem_on	high	1.00	very_high
8	normal	very_high	sem_on	very_high	0.20	medium
9	normal	medium	sem_on	very_high	1.00	high
10	normal	very_high	sem_on	very_high	0.80	high
11	normal	high	sem_on	very_high	1.00	medium
12	normal	high	sem_on	high	0.10	high
13	normal	high	sem_on	very_high	1.00	high
14	normal	low	sem_on	very_high	1.00	high
15	normal	high	sem_on	very_high	0.40	very_high
16	normal	high	sem_on	high	1.00	very_high
17	normal	high	sem_on	high	0.10	medium
18	normal	low	sem_off	medium	1.00	very_low
19	public	low	sem_off	very_high	1.00	very_low

Figure B.6: Rule Block on Saturday

Spreadsheet Rule Editor - RB7

#	IF DT_Sun	Load_Prev_Si	Sem_type_Su	Temp_Sun	THEN DoS	FL_Sun
1	public	medium	sem_on	very_low	1.00	very_low
2	public	low	sem_on	high	1.00	medium
3	public	very_high	sem_on	low	1.00	low
4	public	medium	sem_on	low	0.90	low
5	public	low	sem_on	very_high	1.00	medium
6	public	medium	sem_on	very_low	1.00	low
7	normal	medium	sem_off	high	1.00	very_low
8	normal	very_low	sem_off	very_high	1.00	low
9	normal	medium	sem_off	very_high	1.00	low
10	normal	very_low	sem_off	very_high	1.00	very_low
11	normal	low	sem_off	very_high	0.60	very_low
12	normal	very_low	sem_off	high	1.00	very_low
13	normal	very_low	sem_off	medium	1.00	very_low
14	normal	very_low	sem_off	high	0.30	medium
15	normal	very_low	sem_off	high	0.40	low
16	normal	medium	sem_off	high	0.60	low
17	normal	very_low	sem_on	medium	1.00	medium
18	normal	medium	sem_on	very_high	1.00	low
19	normal	low	sem_on	low	1.00	high
20	normal	high	sem_on	high	0.20	high
21	normal	medium	sem_on	high	0.80	medium
22	normal	low	sem_on	very_high	1.00	medium
23	normal	medium	sem_on	very_high	1.00	very_high
24	normal	low	sem_on	very_high	1.00	high
25	normal	medium	sem_on	very_high	1.00	medium
26	normal	medium	sem_on	very_high	1.00	very_low
27	normal	medium	sem_on	very_high	1.00	high
28	special	medium	sem_on	very_high	1.00	very_high
29	public	medium	sem_on	very_high	1.00	low

Figure B.7: Rule Block on Sunday

APPENDIX C

Membership Function and Rule Blocks of Stage 2

(1) Membership Function

Condition	*Linguistic Terms fuzzyTECH*	*Membership Function Definition*

Input Variables

Day Type

public	Public Holiday	1
normal	Normal Day	2
special	Special Occasion	3

Semester Type

Sem_off	Semester Break	1
Sem_On	Semester On	2

Previous Weekday Average Load

Extremely_Low	five_vl	3000.00 – 3400.00 kW
VeryVery_Low	four_vl	3400.00 – 3600.00 kW
Very _Low	three_vl	3600.00 – 3800.00 kW
Low	two_vl	3800.00 – 4000.00 kW
Quite_Low	vl	4000.00 – 4200.00 kW
Med_Low	l	4200.00 – 4400.00 kW
Medium	m	4400.00 – 4600.00 kW
Med_High	h	4600.00 – 4800.00 kW
Quite_High	vh	4800.00 – 5000.00 kW
High	two_vh	5000.00 – 5200.00 kW
Very_High	three_vh	5200.00 – 5400.00 kW
VeryVery_High	four_vh	5400.00 – 5600.00 kW
Extremely_High	five_vh	5600.00 – 5800.00 kW

Previous Saturday Load

VeryVery_Low	VVVL	2000.00 – 2460.00 kW
Very_Low	VVL	2460.00 – 2690.00 kW
Low	VL	2690.00 – 2920.00 kW
Med_Low	L	2920.00 – 3150.00 kW
Medium	M	3150.00 – 3380.00 kW
Med_High	H	3380.00 – 3610.00 kW
High	VH	3610.00 – 3840.00 kW
Very_High	VVH	3840.00 – 4070.00 kW
VeryVery_High	VVVH	4070.00 – 4300.00 kW

Previous Sunday Load

VeryVery_Low	VVVL	2000.00 – 2480.00 kW
Very_Low	VVL	2480.00 – 2720.00 kW
Low	VL	2720.00 – 2960.00 kW
Med_Low	L	2960.00 – 3200.00 kW
Medium	M	3200.00 – 3440.00 kW
Med_High	H	3440.00 – 3680.00 kW
High	VH	3680.00 – 3920.00 kW
Very_High	VVH	3920.00 – 4160.00 kW
VeryVery_High	VVVH	4160.00 – 4400.00 kW

Average Temperature for the Forecasted Weekdays

Rainy	VVL	30.00 – 31.25 °C
Cold	VL	31.25 – 31.88 °C
Chilly	L	31.88 – 32.50 °C
Average	M	32.50 – 33.13 °C
Warm	H	33.13 – 33.75 °C
Sunny	VH	33.75 – 34.38 °C
Hot	VVH	34.38 – 35.00 °C

Maximum Temperature for the Forecasted Saturday

Rainy	VVL	23.00 – 26.00 °C
Cold	VL	26.00 – 27.50 °C
Chilly	L	27.50 – 29.00 °C
Average	M	29.00 – 30.50 °C
Warm	H	30.50 – 32.00 °C
Sunny	VH	32.00 – 33.50 °C
Hot	VVH	33.50 – 35.00 °C

Maximum Temperature for Sunday

Rainy	VVL	27.00 – 29.00 °C
Cold	VL	29.00 – 30.00 °C
Chilly	L	30.00 – 31.00 °C
Average	M	31.00 – 32.00 °C
Warm	H	32.00 – 33.00 °C
Sunny	VH	33.00 – 34.00 °C
Hot	VVH	34.00 – 35.00 °C

<u>Output Variables</u>

Forecasted Load Demand: Monday

Extremely_Low	five_vl	2400.00 – 2894.30 kW
VeryVery_Low	four_vl	2894.30 – 3278.90 kW
Very _Low	three_vl	3278.9 – 3571.40 kW
Low	two_vl	3471.40 – 3864.30 kW
Quite_Low	vl	3864.30 – 4157.10 kW
Med_Low	l	4157.10 – 4450.00 kW
Medium	m	4450.00 – 4742.10 kW
Med_High	h	4742.10 – 5036.80 kW
Quite_High	vh	5036.80 – 5326.40 kW
High	two_vh	5326.40 – 5621.10 kW
Very_High	three_vh	5621.10 – 5914.20 kW
VeryVery_High	four_vh	5914.20 – 6207.10 kW
Extremely_High	five_vh	6207.10 – 6500.00 kW

Forecasted Load Demand: Tuesday

Extremely_Low	VVV_VVL	3000.00 – 3069.40 kW
VeryVery_Low	VVV_VL	3069.40 – 3356.50 kW
Very _Low	VVV_L	3356.50 – 3643.50 kW
Low	VVL	3643.50 – 3928.50 kW
Quite_Low	VL	3928.50 – 4212.90 kW
Med_Low	L	4212.90 – 4500.00 kW
Medium	M	4500.00 – 4787.10 kW
Med_High	H	4787.10 – 5070.90 kW
Quite_High	VH	5070.90 – 5358.30 kW
High	VVH	5358.30 – 5641.70 kW
Very_High	VVV_H	5641.70 – 5929.10 kW

VeryVery_High	VVV_VH	5929.10 – 6214.20 kW
Extremely_High	VVV_VVH	6214.20 – 6500.00 kW

Forecasted Load Demand: Wednesday

Extremely_Low	VVV_VVL	3800.00 – 4341.10 kW
VeryVery_Low	VVV_VL	4341.10 – 4615.70 kW
Very _Low	VVV_L	4615.70 – 4886.30 kW
Low	VVL	4886.30 – 5157.10 kW
Quite_Low	VL	5157.10 – 5427.30 kW
Med_Low	L	5427.30 – 5700.00 kW
Medium	M	5700.00 – 5972.70 kW
Med_High	H	5972.70 – 6242.80 kW
Quite_High	VH	6242.80 – 6513.60 kW
High	VVH	6513.60 – 6786.40 kW
Very_High	VVV_H	6786.40 – 7057.10 kW
VeryVery_High	VVV_VH	7057.10 – 7327.30 kW
Extremely_High	VVV_VVH	7327.30 – 7600.00 kW

Forecasted Load Demand: Thursday

Extremely_Low	VVV_VVL	2200.00 – 2814.30 kW
VeryVery_Low	VVV_VL	2814.30 – 3118.90 kW
Very _Low	VVV_L	3118.90 – 3428.60 kW
Low	VVL	3428.60 – 3735.70 kW
Quite_Low	VL	3735.70 – 4042.80 kW
Med_Low	L	4042.80 – 4352.50 kW
Medium	M	4352.50 – 4657.10 kW
Med_High	H	4657.10 – 4964.20 kW
Quite_High	VH	4964.20 – 5271.40 kW
High	VVH	5271.40 – 5578.50 kW
Very_High	VVV_H	5578.50 – 5885.70 kW
VeryVery_High	VVV_VH	5885.70 – 6190.30 kW
Extremely_High	VVV_VVH	6190.30 – 6500.00 kW

Forecasted Load Demand: Friday

Extremely_Low	VVV_VVL	2300.00 – 2885.70 kW
VeryVery_Low	VVV_VL	2885.70 – 3170.60 kW
Very _Low	VVV_L	3170.60 – 3471.40 kW
Low	VVL	3471.40 – 3764.30 kW
Quite_Low	VL	3764.30 – 4057.10 kW
Med_Low	L	4057.1 – 4350.00 kW
Medium	M	4350.00 – 4642.80 kW
Med_High	H	4642.80 – 4935.70 kW
Quite_High	VH	4935.70 – 5228.50 kW
High	VVH	5228.50 – 5521.40 kW
Very_High	VVV_H	5521.40 – 5814.20 kW
VeryVery_High	VVV_VH	5814.20 – 6107.10 kW
Extremely_High	VVV_VVH	6107.10 – 6400.00 kW

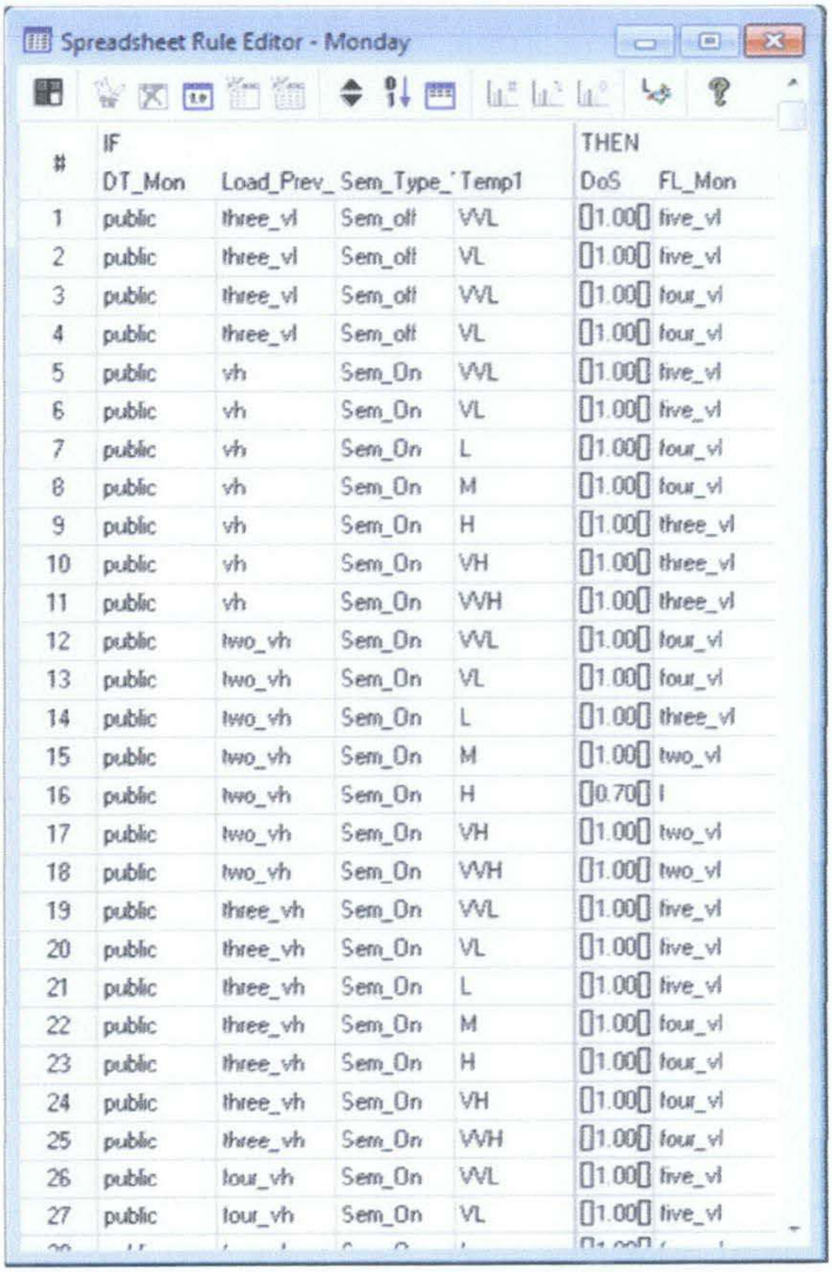
Forecasted Load Demand: Saturday

VeryVery_Low	VVVL	2200.00 – 2700.00 kW
Very_Low	VVL	2700.00 – 2950.00 kW
Low	VL	2950.00 – 3200.00 kW
Med_Low	L	3200.00 – 3450.00 kW
Medium	M	3450.00 – 3700.00 kW
Med_High	H	3700.00 – 3950.00 kW
High	VH	3950.00 – 4200.00 kW
Very_High	VVH	4200.00 – 4450.00 kW
VeryVery_High	VVVH	4450.00 – 4700.00 kW

Forecasted Load Demand: Sunday

VeryVery_Low	VVVL	2000.00 – 2480.00 kW
Very_Low	VVL	2480.00 – 2720.00 kW
Low	VL	2720.00 – 2960.00 kW
Med_Low	L	2960.00 – 3200.00 kW
Medium	M	3200.00 – 3440.00 kW
Med_High	H	3440.00 – 3680.00 kW
High	VH	3680.00 – 3920.00 kW
Very_High	VVH	3920.00 – 4160.00 kW
VeryVery_High	VVVH	4160.00 – 4400.00 kW

(2) Rule Blocks



Spreadsheet Rule Editor - Monday

#	IF DT_Mon	Load_Prev_	Sem_Type_'	Temp1	THEN DoS	FL_Mon
1	public	three_vl	Sem_off	VVL	1.00	five_vl
2	public	three_vl	Sem_off	VL	1.00	five_vl
3	public	three_vl	Sem_off	VVL	1.00	four_vl
4	public	three_vl	Sem_off	VL	1.00	four_vl
5	public	vh	Sem_On	VVL	1.00	five_vl
6	public	vh	Sem_On	VL	1.00	five_vl
7	public	vh	Sem_On	L	1.00	four_vl
8	public	vh	Sem_On	M	1.00	four_vl
9	public	vh	Sem_On	H	1.00	three_vl
10	public	vh	Sem_On	VH	1.00	three_vl
11	public	vh	Sem_On	VVH	1.00	three_vl
12	public	two_vh	Sem_On	VVL	1.00	four_vl
13	public	two_vh	Sem_On	VL	1.00	four_vl
14	public	two_vh	Sem_On	L	1.00	three_vl
15	public	two_vh	Sem_On	M	1.00	two_vl
16	public	two_vh	Sem_On	H	0.70	l
17	public	two_vh	Sem_On	VH	1.00	two_vl
18	public	two_vh	Sem_On	VVH	1.00	two_vl
19	public	three_vh	Sem_On	VVL	1.00	five_vl
20	public	three_vh	Sem_On	VL	1.00	five_vl
21	public	three_vh	Sem_On	L	1.00	five_vl
22	public	three_vh	Sem_On	M	1.00	four_vl
23	public	three_vh	Sem_On	H	1.00	four_vl
24	public	three_vh	Sem_On	VH	1.00	four_vl
25	public	three_vh	Sem_On	VVH	1.00	four_vl
26	public	four_vh	Sem_On	VVL	1.00	five_vl
27	public	four_vh	Sem_On	VL	1.00	five_vl

Figure C1: Modified Rule Block Monday

Spreadsheet Rule Editor - Monday

#	IF DT_Mon	Load_Prev_	Sem_Type_	Temp1	THEN DoS	FL_Mon
27	public	four_vh	Sem_On	VL	1.00	five_vl
28	public	four_vh	Sem_On	L	1.00	four_vl
29	public	four_vh	Sem_On	M	1.00	three_vl
30	public	four_vh	Sem_On	H	1.00	four_vl
31	public	four_vh	Sem_On	VH	1.00	four_vl
32	public	four_vh	Sem_On	VVH	1.00	four_vl
33	public	five_vh	Sem_On	VVL	0.10	four_vl
34	public	five_vh	Sem_On	VL	1.00	five_vl
35	public	five_vh	Sem_On	L	1.00	five_vl
36	public	five_vh	Sem_On	M	1.00	four_vl
37	public	five_vh	Sem_On	H	0.80	vl
38	public	five_vh	Sem_On	VH	0.90	four_vl
39	public	five_vh	Sem_On	VVH	1.00	three_vl
40	normal	l	Sem_On	VVL	1.00	vh
41	normal	l	Sem_On	VL	1.00	vh
42	normal	l	Sem_On	L	1.00	h
43	normal	l	Sem_On	M	1.00	three_vl
44	normal	l	Sem_On	H	1.00	three_vh
45	normal	l	Sem_On	VH	1.00	three_vh
46	normal	l	Sem_On	VVH	1.00	three_vh
47	normal	m	Sem_On	VVL	1.00	vh
48	normal	m	Sem_On	VL	1.00	three_vh
49	normal	m	Sem_On	L	1.00	three_vh
50	normal	m	Sem_On	M	1.00	two_vh
51	normal	m	Sem_off	VVL	1.00	three_vh
52	normal	m	Sem_off	VL	1.00	four_vh
53	normal	m	Sem_off	L	1.00	three_vh
54	normal	m	Sem_off	M	1.00	two_vh
55	normal	m	Sem_off	H	1.00	three_vh
56	normal	m	Sem_off	VH	1.00	l
57	normal	m	Sem_off	VVH	1.00	three_vh
58	normal	h	Sem_off	VVL	1.00	vh
59	normal	h	Sem_off	VL	1.00	three_vh
60	normal	h	Sem_off	VL	1.00	four_vh
61	normal	h	Sem_off	M	1.00	two_vh
62	normal	h	Sem_off	H	1.00	two_vh
63	normal	h	Sem_off	VH	1.00	two_vl

Figure C2: Modified Rule Block Monday

Spreadsheet Rule Editor - Monday

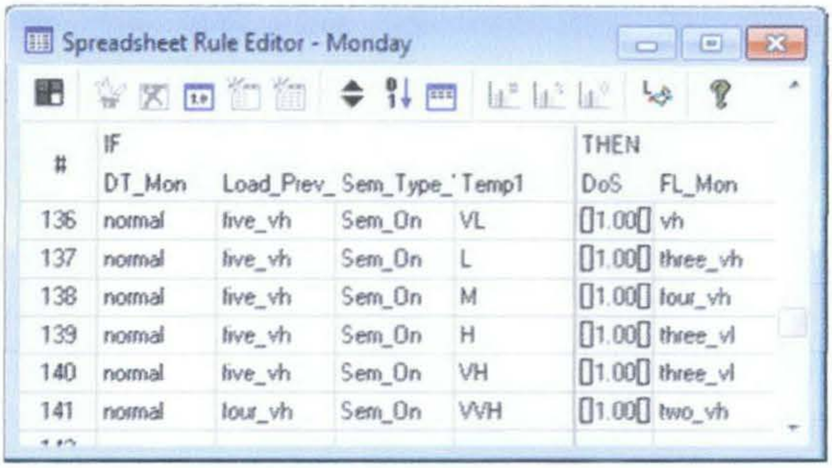
#	IF				THEN	
	DT_Mon	Load_Prev_	Sem_Type_'	Temp1	DoS	FL_Mon
64	normal	h	Sem_off	VVH	1.00	four_vh
65	normal	vh	Sem_off	VVL	1.00	three_vl
66	normal	vh	Sem_off	VL	1.00	vl
67	normal	vh	Sem_off	L	0.90	vl
68	normal	vh	Sem_off	M	1.00	three_vl
69	normal	vh	Sem_off	H	1.00	five_vl
70	normal	vh	Sem_off	VH	1.00	four_vl
71	normal	vh	Sem_off	VVH	1.00	five_vl
72	normal	h	Sem_On	VVL	1.00	vh
73	normal	h	Sem_On	VL	1.00	vh
74	normal	h	Sem_On	L	1.00	vh
75	normal	h	Sem_On	M	1.00	vh
76	normal	h	Sem_On	H	1.00	vh
77	normal	h	Sem_On	VH	1.00	vh
78	normal	h	Sem_On	VVH	1.00	four_vh
79	normal	vh	Sem_On	VVL	1.00	three_vh
80	normal	vh	Sem_On	VL	1.00	two_vh
81	normal	vh	Sem_On	L	1.00	five_vh
82	normal	vh	Sem_On	M	1.00	m
83	normal	vh	Sem_On	H	1.00	four_vh
84	normal	vh	Sem_On	H	1.00	five_vh
85	normal	vh	Sem_On	VVH	1.00	five_vh
86	normal	two_vh	Sem_On	VVL	1.00	five_vl
87	normal	two_vh	Sem_On	VL	1.00	five_vl
88	normal	two_vh	Sem_On	L	1.00	four_vh
89	normal	two_vh	Sem_On	M	1.00	five_vh
90	normal	two_vh	Sem_On	H	1.00	vl
91	normal	two_vh	Sem_On	VH	0.90	four_vl
92	normal	two_vh	Sem_On	VVH	1.00	three_vl
93	normal	two_vh	Sem_off	VVL	1.00	four_vh
94	normal	two_vh	Sem_off	VL	1.00	three_vh
95	normal	two_vh	Sem_off	L	1.00	vh
96	normal	two_vh	Sem_off	M	1.00	h
97	normal	two_vh	Sem_off	H	1.00	h
98	normal	two_vh	Sem_off	VH	0.90	l
99	normal	two_vh	Sem_off	VVH	1.00	five_vh
100	normal	three_vh	Sem_off	VVL	1.00	two_vh

Figure C3: Modified Rule Block Monday

Spreadsheet Rule Editor - Monday

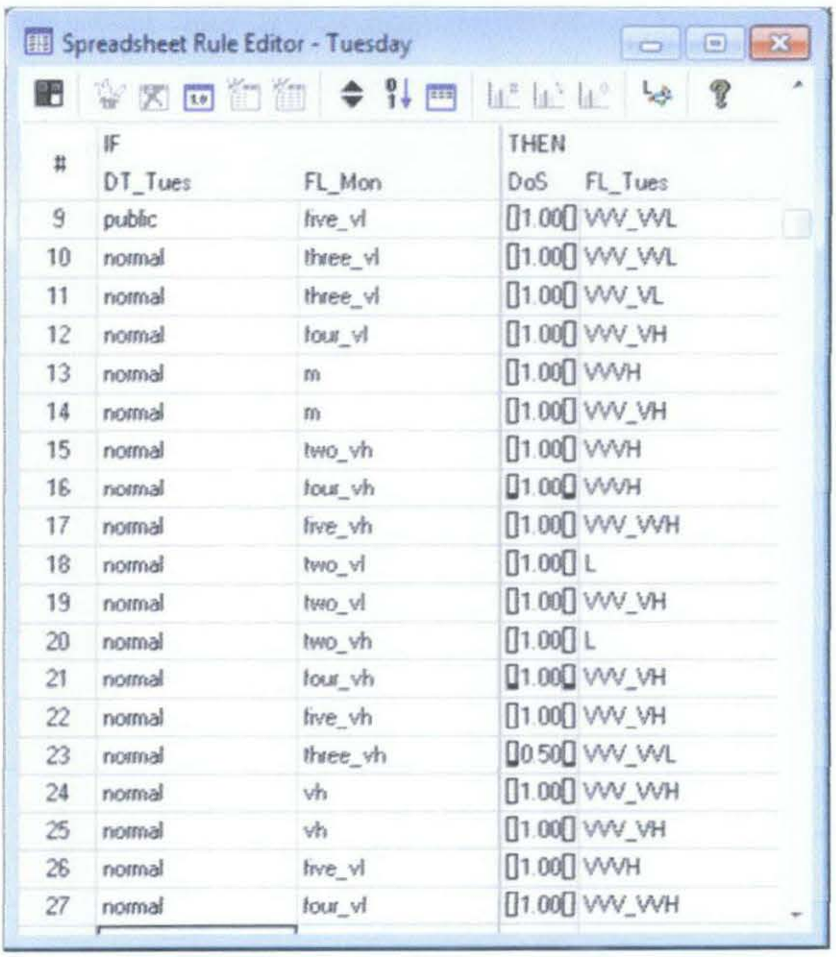
#	IF DT_Mon	Load_Prev_	Sem_Type_'	Temp1	THEN DoS	FL_Mon
100	normal	three_vh	Sem_off	VVL	1.00	two_vh
101	normal	three_vh	Sem_off	VL	1.00	two_vh
102	normal	three_vh	Sem_off	L	1.00	two_vh
103	normal	three_vh	Sem_off	M	1.00	three_vh
104	normal	three_vh	Sem_off	H	1.00	three_vh
105	normal	three_vh	Sem_off	VH	1.00	three_vl
106	normal	three_vh	Sem_off	VVH	1.00	three_vh
107	normal	four_vh	Sem_off	VVL	1.00	vh
108	normal	four_vh	Sem_off	VL	1.00	h
109	normal	four_vh	Sem_off	L	1.00	two_vh
110	normal	four_vh	Sem_off	M	1.00	h
111	normal	four_vh	Sem_off	H	1.00	l
112	normal	four_vh	Sem_off	VH	1.00	vh
113	normal	four_vh	Sem_off	VVH	1.00	vh
114	normal	five_vh	Sem_off	VVL	1.00	vh
115	normal	five_vh	Sem_off	VL	1.00	vh
116	normal	five_vh	Sem_off	L	1.00	two_vh
117	normal	five_vh	Sem_off	M	1.00	two_vh
118	normal	five_vh	Sem_off	H	1.00	vh
119	normal	five_vh	Sem_off	VH	1.00	vh
120	normal	five_vh	Sem_off	VVH	1.00	vh
121	normal	three_vh	Sem_On	VVL	1.00	vh
122	normal	three_vh	Sem_On	VL	0.40	vh
123	normal	three_vh	Sem_On	L	1.00	two_vh
124	normal	three_vh	Sem_On	M	1.00	vh
125	normal	three_vh	Sem_On	H	1.00	h
126	normal	three_vh	Sem_On	VH	1.00	two_vh
127	normal	three_vh	Sem_On	VVH	1.00	three_vh
128	normal	four_vh	Sem_On	VVL	1.00	two_vh
129	normal	four_vh	Sem_On	VL	1.00	four_vh
130	normal	four_vh	Sem_On	L	1.00	five_vh
131	normal	four_vh	Sem_On	M	1.00	m
132	normal	four_vh	Sem_On	H	1.00	four_vh
133	normal	four_vh	Sem_On	VH	0.80	five_vh
134	normal	four_vh	Sem_On	VVH	0.40	five_vh
135	normal	five_vh	Sem_On	VVL	1.00	m

Figure C4: Rule Block Monday


Spreadsheet Rule Editor - Monday

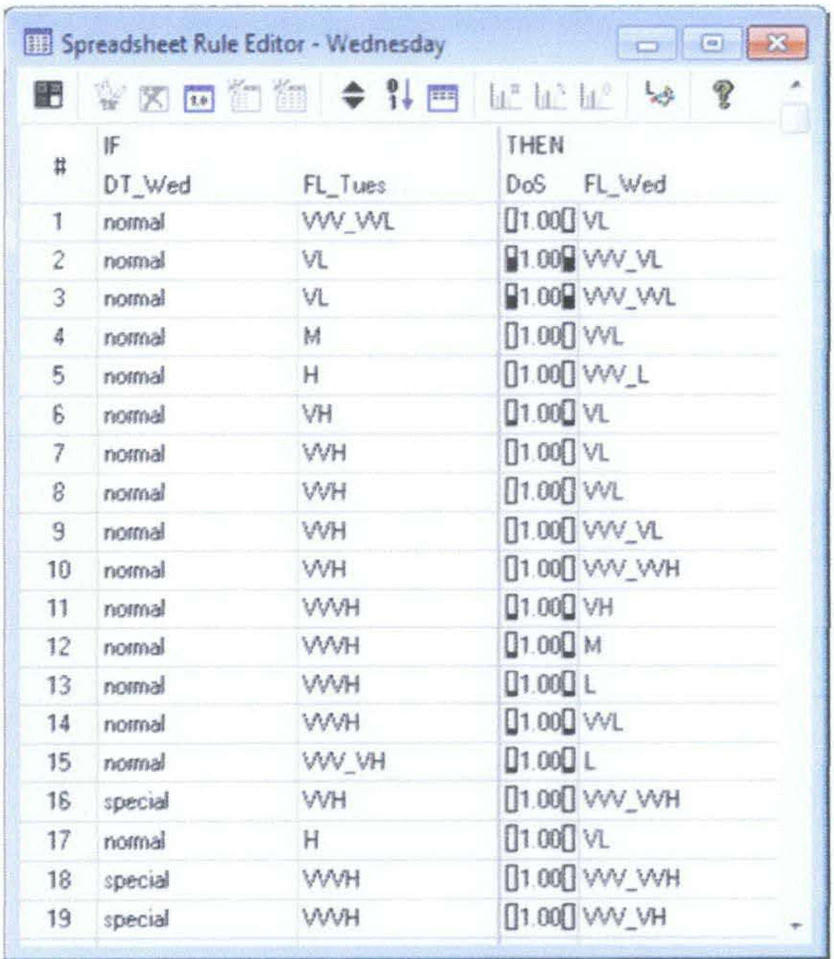
#	IF DT_Mon	Load_Prev_	Sem_Type_'	Temp1	THEN DoS	FL_Mon
136	normal	five_vh	Sem_On	VL	1.00	vh
137	normal	five_vh	Sem_On	L	1.00	three_vh
138	normal	five_vh	Sem_On	M	1.00	four_vh
139	normal	five_vh	Sem_On	H	1.00	three_vl
140	normal	five_vh	Sem_On	VH	1.00	three_vl
141	normal	four_vh	Sem_On	VVH	1.00	two_vh

Figure C5: Modified Rule Block Monday


Spreadsheet Rule Editor - Tuesday

#	IF DT_Tues	FL_Mon	THEN DoS	FL_Tues
9	public	five_vl	1.00	VVV_VVL
10	normal	three_vl	1.00	VVV_VVL
11	normal	three_vl	1.00	VVV_VL
12	normal	four_vl	1.00	VVV_VH
13	normal	m	1.00	VVVH
14	normal	m	1.00	VVV_VH
15	normal	two_vh	1.00	VVVH
16	normal	four_vh	1.00	VVVH
17	normal	five_vh	1.00	VVV_VVH
18	normal	two_vl	1.00	L
19	normal	two_vl	1.00	VVV_VH
20	normal	two_vh	1.00	L
21	normal	four_vh	1.00	VVV_VH
22	normal	five_vh	1.00	VVV_VH
23	normal	three_vh	0.50	VVV_VVL
24	normal	vh	1.00	VVV_VVH
25	normal	vh	1.00	VVV_VH
26	normal	five_vl	1.00	VVVH
27	normal	four_vl	1.00	VVV_VVH

Figure C6: Modified Rule Block Tuesday



Spreadsheet Rule Editor - Wednesday

#	IF		THEN	
	DT_Wed	FL_Tues	DoS	FL_Wed
1	normal	VVV_VVL	1.00	VL
2	normal	VL	1.00	VVV_VL
3	normal	VL	1.00	VVV_VVL
4	normal	M	1.00	VVL
5	normal	H	1.00	VVV_L
6	normal	VH	1.00	VL
7	normal	VVH	1.00	VL
8	normal	VVH	1.00	VVL
9	normal	VVH	1.00	VVV_VL
10	normal	VVH	1.00	VVV_VVH
11	normal	VVVH	1.00	VH
12	normal	VVVH	1.00	M
13	normal	VVVH	1.00	L
14	normal	VVVH	1.00	VVL
15	normal	VVV_VH	1.00	L
16	special	VVH	1.00	VVV_VVH
17	normal	H	1.00	VL
18	special	VVVH	1.00	VVV_VVH
19	special	VVVH	1.00	VVV_VH

Figure C7: Modified Rule Block Wednesday

Spreadsheet Rule Editor - Thursday

#	IF DT_Thurs	FL_Wed	THEN DoS	FL_Thurs
1	normal	WV_WL	1.00	L
2	normal	WV_L	1.00	H
3	normal	WV_L	1.00	WV_VH
4	normal	WL	1.00	H
5	normal	WL	1.00	VH
6	normal	VL	1.00	WV_WH
7	normal	VL	1.00	H
8	normal	L	1.00	WH
9	normal	L	1.00	WV_H
10	normal	M	1.00	WH
11	normal	M	1.00	WV_H
12	normal	M	1.00	WV_VH
13	normal	H	1.00	WV_H
14	normal	WV_WH	1.00	WH
15	normal	WV_VH	1.00	WV_H

Figure C8: Modified Rule Block Thursday

Spreadsheet Rule Editor - Friday

#	IF DT_Fri	FL_Thurs	THEN DoS	FL_Fri
1	normal	WV_WL	1.00	M
2	normal	WV_VL	1.00	M
3	normal	WV_L	1.00	M
4	normal	WL	1.00	M
5	normal	VL	1.00	M
6	normal	L	1.00	M
7	normal	M	1.00	M
8	normal	H	1.00	H
9	normal	VH	1.00	VH
10	normal	WH	1.00	WV_H
11	normal	WV_H	1.00	WV_H
12	public	WV_H	1.00	M
13	normal	WV_WH	1.00	WV_VH
14	public	WV_H	1.00	WV_VL
15	public	WV_VH	1.00	WV_WL

Figure C9: Modified Rule Block Friday

Spreadsheet Rule Editor - Saturday

#	IF DayType	PastLoad	SemType	TempSat	THEN DoS	FL_Sat
1	normal	L	sem_on	VH	1.00	VH
2	normal	M	sem_on	VH	1.00	VVH
3	normal	M	sem_on	VVH	1.00	VVVH
4	normal	L	sem_on	VVH	1.00	L
5	normal	VH	sem_on	H	0.00	VVVH
6	normal	VH	sem_on	VH	1.00	VVVH
7	normal	VVH	sem_on	H	1.00	M
8	normal	VVH	sem_on	VH	1.00	VVVH
9	normal	VVVH	sem_on	VH	0.90	VVH
10	normal	VVVH	sem_on	VH	0.90	M
11	normal	VH	sem_on	VVH	1.00	VVH
12	normal	VVH	sem_on	VVH	0.00	H
13	normal	VVVH	sem_on	VVH	1.00	VH
14	normal	VVVH	sem_on	VVH	0.40	H
15	public	M	sem_on	VH	1.00	VL
16	public	M	sem_on	VVH	1.00	L
17	public	H	sem_on	VH	1.00	H
18	public	H	sem_on	VVH	1.00	L
19	public	VH	sem_on	H	1.00	VVVL
20	public	VVH	sem_on	H	1.00	L
21	public	VVH	sem_on	VH	1.00	M
22	normal	M	sem_on	VH	1.00	VVVH
23	normal	L	sem_off	VVH	1.00	L
24	normal	M	sem_off	VVH	1.00	VL
25	normal	L	sem_off	VH	1.00	VVL
26	normal	M	sem_off	VH	1.00	VVVL
27	normal	VVL	sem_off	VH	1.00	H
28	normal	VL	sem_off	VH	1.00	L
29	normal	VVL	sem_off	VVH	1.00	H
30	normal	VL	sem_off	VVH	1.00	L

Figure C10: Modified Rule Block Saturday

Spreadsheet Rule Editor - Sunday

#	IF				THEN	
	DT_Sun	Load_Prev_	Sem_type_S	Temp7	DoS	FL_Sun
1	normal	VVVL	sem_off	M	1.00	VVVL
2	normal	VVL	sem_off	M	1.00	VL
3	normal	VVL	sem_off	H	1.00	VL
4	normal	VVVL	sem_off	H	1.00	VVL
5	normal	VVVL	sem_off	VH	1.00	L
6	normal	VVL	sem_off	VH	1.00	L
7	normal	VL	sem_off	H	1.00	VVVL
8	normal	VL	sem_off	H	1.00	L
9	normal	L	sem_off	H	1.00	VVVL
10	normal	L	sem_off	H	1.00	VVL
11	normal	L	sem_off	VH	1.00	VL
12	normal	VL	sem_off	VH	1.00	L
13	normal	L	sem_off	VH	1.00	VVVL
14	normal	M	sem_off	VH	1.00	VVVL
15	special	M	sem_on	VH	1.00	VVVH
16	special	H	sem_on	VH	1.00	VVVH
17	public	L	sem_on	VH	1.00	VH
18	public	M	sem_on	VH	1.00	L
19	public	M	sem_on	VVL	1.00	VVL
20	public	H	sem_on	VVL	1.00	VVL
21	public	H	sem_on	L	1.00	L
22	public	VH	sem_on	L	1.00	L
23	public	H	sem_on	VH	1.00	L
24	public	VH	sem_on	VH	1.00	L
25	normal	L	sem_on	L	1.00	VH
26	normal	M	sem_on	L	1.00	VH
27	normal	L	sem_on	VH	1.00	M
28	normal	M	sem_on	VH	1.00	VH
29	public	VVVH	sem_on	L	1.00	L
30	normal	H	sem_on	VH	1.00	VVL
31	normal	H	sem_on	VH	1.00	VVVL
32	normal	M	sem_off	H	1.00	VVL
33	normal	H	sem_off	H	1.00	VVL
34	normal	M	sem_on	H	1.00	M
35	normal	H	sem_on	H	1.00	H
36	normal	VH	sem_on	H	1.00	H
37	normal	L	sem_on	VH	1.00	VH
38	normal	VH	sem_on	VVH	1.00	H
39	normal	H	sem_on	VVH	1.00	VH

Figure C11: Modified Rule Block Sunday

APPENDIX D

UTP Electricity Load Demand and Maximum Daily Temperature for Year 2010

	4-10 JAN	11-17 JAN	18-24 JAN	25-31 JAN	1-7 FEB	8-14 FEB	15-21 FEB
			ELECTRICITY DEMAND (kWh)				
Monday	4372.0	4896.0	4700.0	4988.0	5232.0	5420.0	2756.0
Tuesday	4476.0	4788.0	4872.0	5112.0	5228.0	5688.0	3252.0
Wednesday	4616.0	4688.0	4984.0	5064.0	5312.0	5576.0	5224.0
Thursday	4584.0	4648.0	4724.0	5060.0	5396.0	5380.0	5376.0
Friday	4416.0	4464.0	5116.0	3372.0	5252.0	5076.0	5532.0
Average weekday	4492.8	4696.8	4879.2	4719.2	5284.0	5428.0	4428.0
Saturday	2672.0	3388.0	3236.0	3184.0	3624.0	3420.0	3780.0
Sunday	2592.0	2512.0	2876.0	2828.0	3328.0	2760.0	3628.0
			MAXIMUM DAILY TEMPERATURE (°C)				
Monday	32.00	31.43	35.67	34.34	32.67	31.73	35.67
Tuesday	34.83	32.56	33.82	34.74	34.90	32.84	33.82
Wednesday	33.39	33.67	33.31	32.00	32.70	33.70	33.31
Thursday	31.17	33.19	33.75	34.83	34.31	33.20	33.75
Friday	33.52	33.12	33.64	34.70	33.05	33.67	33.64
Average weekday	32.98	32.79	34.04	34.12	33.53	33.03	34.04
Saturday	30.90	32.70	33.70	34.39	32.50	33.70	33.70
Sunday	30.52	34.06	33.48	35.36	30.83	34.06	33.48

	22-28 FEB	1-7 MAC	8-14 MAC	15-21 MAC	22-28 MAC	29/3-4/4	5-11 APR
				ELECTRICITY DEMAND (kWh)			
Monday	5740.0	5872.0	5720.0	4516.0	5684.0	5844.0	5428.0
Tuesday	5880.0	5768.0	5808.0	4396.0	5376.0	5716.0	5568.0
Wednesday	5596.0	5728.0	6056.0	4660.0	5788.0	5930.0	5676.0
Thursday	4856.0	5800.0	5644.0	4640.0	5968.0	5380.0	5640.0
Friday	3032.0	5716.0	5284.0	4608.0	5872.0	5284.0	5592.0
Average weekday	5020.8	5776.8	5702.4	4564.0	5737.6	5630.8	5580.8
Saturday	3288.0	4220.0	3368.0	3304.0	3636.0	3760.0	3912.0
Sunday	3072.0	3824.0	2704.0	3456.0	3880.0	5428.0	3780.0
				MAXIMUM DAILY TEMPERATURE (°C)			
Monday	34.34	33.85	35.03	33.39	36.06	34.89	32.26
Tuesday	34.74	33.70	35.50	34.09	30.50	33.89	34.09
Wednesday	32.00	34.17	35.06	33.72	34.78	33.28	33.84
Thursday	34.83	35.22	32.64	34.31	36.81	34.14	32.95
Friday	34.70	35.11	33.64	34.64	33.87	34.42	34.03
Average weekday	34.12	34.41	34.37	34.03	34.40	34.12	33.43
Saturday	34.39	34.58	33.03	35.03	33.67	34.31	32.31
Sunday	35.36	34.67	32.81	32.59	35.22	31.23	34.81

	12-18 APR	19-25 APR	26/4-2/5	3-9 MAY	10-16 MAY	17-23 MAY	24-30 MAY
				ELECTRICITY DEMAND (kWh)			
Monday	5960.0	3596.0	5504.0	5248.0	5784.0	5596.0	5476.0
Tuesday	6088.0	5828.0	5224.0	5808.0	5552.0	5660.0	5728.0
Wednesday	6336.0	5784.0	5384.0	5764.0	5656.0	2145.0	5712.0
Thursday	5700.0	5924.0	5300.0	5648.0	5092.0	5460.0	5388.0
Friday	3372.0	5848.0	3320.0	5416.0	5060.0	5464.0	3304.0
Average weekday	5491.2	5396.0	4946.4	5576.8	5428.8	4865.0	5121.6
Saturday	3432.0	4044.0	3128.0	3504.0	3984.0	3704.0	3464.0
Sunday	3432.0	3640.0	2932.0	3468.0	3572.0	3604.0	3548.0
				MAXIMUM DAILY TEMPERATURE (°C)			
Monday	33.45	34.00	33.28	35.36	34.36	33.34	35.45
Tuesday	35.28	33.61	29.67	34.56	34.47	32.22	34.70
Wednesday	34.50	34.36	33.53	35.23	34.64	32.14	35.56
Thursday	35.06	33.06	35.22	34.71	32.25	35.20	34.36
Friday	35.17	33.97	33.23	34.61	35.09	35.00	33.53
Average weekday	34.69	33.80	32.99	34.89	34.16	33.58	34.72
Saturday	34.20	33.86	34.03	36.36	36.06	30.06	35.86
Sunday	32.95	35.20	33.92	30.48	36.72	35.39	34.48

	31/5-6/6	7-13 JUN	14-20 JUN	21-27 JUN	28/6-4/7	5-11 JULY	12-18 JULY
				ELECTRICITY DEMAND (kWh)			
Monday	5508.0	5052.0	4616.0	4988.0	3644.0	4576.0	4552.0
Tuesday	5380.0	4912.0	4328.0	4724.0	4636.0	4956.0	4600.0
Wednesday	5244.0	4868.0	4416.0	4528.0	4620.0	4800.0	4356.0
Thursday	5092.0	4768.0	4188.0	4764.0	4740.0	4732.0	4364.0
Friday	2996.0	4884.0	4596.0	4448.0	4504.0	5176.0	4336.0
Average weekday	4844.0	4896.8	4428.8	4690.4	4428.8	4848.0	4441.6
Saturday	3000.0	3068.0	3244.0	2800.0	2784.0	2928.0	2796.0
Sunday	3344.0	2916.0	2872.0	2756.0	2436.0	2624.0	2632.0
				MAXIMUM DAILY TEMPERATURE (°C)			
Monday	34.22	34.20	34.33	34.34	33.78	33.75	33.09
Tuesday	33.81	32.62	35.56	33.97	31.92	35.06	33.34
Wednesday	33.75	35.28	33.95	34.42	33.67	35.20	34.89
Thursday	36.06	32.64	31.95	33.53	34.70	34.17	33.36
Friday	31.67	34.28	32.50	26.41	31.31	33.28	34.67
Average weekday	33.90	33.80	33.66	32.53	33.08	34.29	33.87
Saturday	33.44	35.22	34.92	33.31	33.37	33.62	33.59
Sunday	33.11	34.64	34.28	34.75	30.39	32.38	31.36

	19-25 JULY	26/7-1/8	2-8 AUG	9-15 AUG	16-22 AUG	23-29 AUG	30/8-5/9
				ELECTRICITY DEMAND (kWh)			
Monday	4732.0	4816.0	5308.0	5368.0	4944.0	5192.0	5400.0
Tuesday	5120.0	4972.0	5124.0	5276.0	5044.0	5308.0	3292.0
Wednesday	4972.0	5192.0	5356.0	5348.0	5140.0	5664.0	5000.0
Thursday	4988.0	5052.0	5040.0	5256.0	5108.0	5548.0	5000.0
Friday	5180.0	4988.0	5388.0	5172.0	4752.0	3324.0	5060.0
Average weekday	4998.4	5004.0	5243.2	5284.0	4997.6	5007.2	4750.4
Saturday	3116.0	3028.0	3640.0	3568.0	3172.0	3392.0	2848.0
Sunday	2780.0	3296.0	3360.0	3020.0	3136.0	3248.0	2452.0
				MAXIMUM DAILY TEMPERATURE (°C)			
Monday	33.72	30.48	33.47	34.84	32.56	34.70	34.03
Tuesday	34.31	32.45	34.59	34.81	32.22	34.64	34.03
Wednesday	31.61	31.70	33.06	36.22	32.61	37.08	34.56
Thursday	35.70	34.50	30.14	35.45	33.53	35.97	32.92
Friday	33.59	32.39	34.45	33.47	33.75	34.17	34.50
Average weekday	33.79	32.30	33.14	34.96	32.93	35.31	34.01
Saturday	31.31	32.50	33.59	32.75	34.28	33.39	34.31
Sunday	34.56	33.20	33.08	33.17	32.95	34.03	32.28

	6-12 SEP	13-19 SEP	20-26 SEP	27/9 - 3/10	4-10 OKT	11-17 OKT	18-24 OKT
ELECTRICITY DEMAND (kWh)							
Monday	4504.0	3592.0	4932.0	5168.0	5092.0	5840.0	5628.0
Tuesday	4360.0	3676.0	5028.0	5364.0	5540.0	5840.0	5516.0
Wednesday	3952.0	3592.0	5360.0	5392.0	5276.0	5852.0	5284.0
Thursday	2280.0	2684.0	5064.0	5020.0	5352.0	5700.0	5080.0
Friday	2544.0	4028.0	4872.0	5064.0	5412.0	5404.0	5580.0
Average weekday	3528.0	3514.4	5051.2	5201.6	5334.4	5727.2	5417.6
Saturday	2460.0	2568.0	3548.0	3576.0	3616.0	4136.0	3528.0
Sunday	2364.0	2900.0	3024.0	3248.0	3288.0	4232.0	3676.0
MAXIMUM DAILY TEMPERATURE (°C)							
Monday	34.20	35.14	33.72	33.53	31.92	33.61	34.45
Tuesday	32.45	32.91	34.61	33.67	33.00	32.89	33.22
Wednesday	33.31	32.59	32.12	33.83	35.67	35.73	36.03
Thursday	32.59	25.70	33.81	32.78	35.31	34.92	35.56
Friday	34.53	34.23	33.42	32.84	32.23	32.84	34.31
Average weekday	33.42	32.11	33.54	33.33	33.63	34.00	34.71
Saturday	29.50	34.39	33.36	34.47	34.42	33.61	34.45
Sunday	33.81	34.25	34.17	33.78	35.22	34.00	35.70

	25-31 OKT	1-7 NOV	8-14 NOV	15-21 NOV	22-28 NOV	29/11-5/12	6-12 DEC
ELECTRICITY DEMAND (kWh)							
Monday	5488.0	4948.0	4796.0	5308.0	5124.0	5252.0	4280.0
Tuesday	5200.0	5112.0	4668.0	4948.0	5268.0	4824.0	2708.0
Wednesday	5304.0	5212.0	4888.0	2856.0	5248.0	4916.0	4328.0
Thursday	5388.0	5168.0	4860.0	4320.0	4968.0	4688.0	4088.0
Friday	5392.0	2876.0	4516.0	4800.0	4912.0	4680.0	4368.0
Average weekday	5354.4	4663.2	4745.6	4446.4	5104.0	4872.0	3954.4
Saturday	3168.0	3084.0	3400.0	3396.0	3672.0	2928.0	3028.0
Sunday	3088.0	2736.0	3344.0	3600.0	3388.0	2812.0	2668.0
MAXIMUM DAILY TEMPERATURE (°C)							
Monday	34.48	32.25	27.47	32.30	33.12	32.89	30.09
Tuesday	33.73	30.00	35.70	34.50	31.78	34.12	33.56
Wednesday	31.25	33.23	32.86	33.21	34.20	32.61	29.84
Thursday	28.67	34.14	33.00	34.53	32.81	32.73	33.14
Friday	33.00	35.17	32.56	32.86	33.70	32.73	28.64
Average weekday	32.23	32.96	32.32	33.48	33.12	33.02	31.05
Saturday	33.81	30.22	32.50	34.03	33.39	31.95	33.25
Sunday	34.12	28.45	32.00	31.48	32.78	31.62	30.06

	13-19 DEC	20-26 DEC	27-31 DEC
	ELECTRICITY DEMAND (kWh)		
Monday	4604.0	4236.0	4020.0
Tuesday	4252.0	4332.0	4192.0
Wednesday	4472.0	4584.0	3812.0
Thursday	4328.0	4236.0	3452.0
Friday	4128.0	2320.0	2060.0
Average weekday	4356.8	3941.6	3057.2
Saturday	2716.0	2204.0	-
Sunday	2204.0	2448.0	-
	MAXIMUM DAILY TEMPERATURE (°C)		
Monday	31.58	31.08	32.87
Tuesday	32.56	32.89	31.63
Wednesday	33.25	30.78	31.42
Thursday	31.17	32.44	30.50
Friday	33.61	31.20	28.86
Average weekday	32.43	31.68	31.06
Saturday	32.17	34.61	31.12
Sunday	29.90	31.56	30.23

APPENDIX E: GANTT CHART FYP 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Ttitle selection	■							MID SEMESTER BREAK							
2	Preliminary research work		■	■												
3	Submission of preliminary report				■											
4	Continue project work					■	■	■								
5	Submission of progress report									■						
5	Project work continue- Model															
6	Seminar										■	■				
7	Project work											■	■	■		
8	Draft report submission														■	
9	Fnal report submission															■

APPENDIX E: GANTT CHART FYP 2

	Task	January				February				March				April				May		
1.	Abstract Writing for SSPEC																			
2.	Expand current membership function																			
3.	Establishing new rule blocks																			
4.	Submission of Progress Report										14/3									
5.	Project work on Recommendation Task from Progress Report																			
6.	Submission of Draft report														3/4					
7.	Submission Final Report (soft bound)																28/4			
8.	Submission of Technical Paper																28/4			
9.	Oral Presentation																	3/5		
10.	Submission Final Report (hard bound)																			20/5