

POWER GENERATION FORECAST SOFTWARE

By

SITI NUR BAIZURA BINTI MUSTAPHA

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
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Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

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CERTIFICATION OF APPROVAL

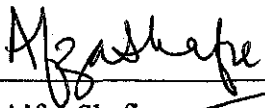
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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
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Approved:



Dr. A'fza Shafie

Project Supervisor


UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2007

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.



Siti Nur Baizura Binti Mustapha

ABSTRACT

The ability to estimate power generation is highly desirable. With a good estimation, an adequate amount of power can be generated and then supply to the whole country without over-producing it. One way of obtaining this estimate is through the availability of forecasting models. These models would benefit the local utility as well as local Independent Power Producers (IPPs) in planning for future power generation. In this project, two models were proposed and developed. They include Multiple Linear Regression Model which consists of few independent variables and dependent variable and the Curve Fit Model that is developed based on the annual Power Generation. For easy access, a software that incorporates these models was developed. User can choose either one of these two models to forecast the desired Power Generation. Visual Basic 6.0 Programming Language was chosen for this software development.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

At present, national energy producer, Tenaga Nasional Berhad (TNB) has a surplus amount of energy reserve margin to be utilized for power generation. However, Malaysia will not always remain as an energy exporter. Eventually, energy imports will exceed energy exports and then the price of energy from these non-renewable resources namely coal, natural gas and oil will rise. Thus, it is important to forecast the power generation so that not only the utilization of these energy resources can be planned efficiently but also, suitable alternatives or renewable energy resources can be identified and developed.

For that reason, forecasting software which incorporates two types of statistical models has been developed in this project. The models include multiple linear regression model and curve fit model. Both models will be utilized to assist planners to forecast the power generation while the software intends to allow easy and effortless interactions between user and the software. Therefore, with right planning approach, local utilities together with Independent Power Producers (IPP) can generate and supply power to customers consistently and continuously by ensuring a balance between demand and supply at all times.

1.2 Problem Statement

The use of power electricity in Malaysia has grown dramatically over the last 20 years as a result of the economic growth [1]. Therefore, sufficient amount of power electricity needs to be supplied to the customers. However, at the moment, power generation in Malaysia is dependent on non-renewable energy resources such as Coal, Natural Gas and Petroleum which will be exhausted eventually. According to the National Depletion Policy of 1980, at the current rate of production, established oil reserves are expected to last for another 16 years while known natural gas are likely to last for another 70 years respectively [2]. Thus, it is essential to forecast power generation so that the utilization of these resources can be planned efficiently to maintain power quality.

Domain specific modeling is a software engineering methodology for designing systems such as computer systems. It is usually employed in forecasting activities and commonly, the models are represented in mathematical forms. However, the development of model is cumbersome and time consuming even though they are useful and widely use in many areas especially in engineering field. Misuse, disuse and nonuse of models often occur during the interpretation and development of models [3] due to:

1. Complexity between relationships of the variables
2. Difficulties in understanding big and complex models
3. Unavailability of the required input data or parameters
4. Least interaction between decision makers and the model

Thus, this increases the need for better management of quantitative models. At the same time, the enhancement of technology has provided an opportunity to incorporate even the most complex models into software for easy interaction between user and the model. Not only will this software allow for handling complex models, it will also allow user to carry out estimation and prediction needed in the decision making events. This will improve the quality of decision making.

1.3 Objective

The main objective of this project is to develop a software to forecast power generation in Malaysia. This software will incorporate quantitative models that will assist planner for short term forecasting activities in Power Generation field which is for five years period.

In order to achieve the objective, the focuses of this project include:

- i. Developing suitable quantitative models
- ii. Simulations of the results
- iii. Identifying a suitable programming language for the software development
- iv. Developing user-interactive and user-friendly software

1.4 Scope of Study

The allotted time frame of two semesters is sufficient to develop the forecasting software.

The scopes for the first semester are as follows:

- i. Reviewing the reliability and short comings of electric power generation forecast methodology in Malaysia.
- ii. Identifying and analyzing variables that contributes to the power generation in Malaysia.
- iii. Collection of data.

In the second semester, the scopes of the project include:

- i. Developing Statistical Modeling. The methods that have been utilized are Multiple Linear Regression Method and Curve Fit Method.
- ii. Developing interactive and user friendly forecasting software that incorporates these models via Visual Basic 6.0 Programming Language.

The overall scope of project is given by the Gantt chart in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.1 Power Generation in Malaysia

Power generation is actually the first process in delivering electricity to consumers. It usually takes place at Power Plants that utilize fossil fuel as its sources. In Malaysia, power electricity is generated by three local utilities as well as from Independent Power Producers (IPPs). The three major local electric utilities are Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Electricity Services Company (SESCO). They are responsible in connecting its customers with power from hydroelectric and thermal plants network system which is made up of transmission lines, substations and distribution lines.

2.2 Factors Contribute to Power Generation in Malaysia

2.2.1 Population Growth

Population growth is one of the key determinants that lead to the increase of total power electricity demand in Malaysia. It is closely linked to the rising demand for housing and services as well as the economic growth and technology enhancement [4]. This is due to the improvement in living standards and household incomes. Therefore, since population in Malaysia increases every year, it is expected that the demand for electricity in Malaysia increases as well.

2.2.2 Power Consumption by Sectors

Since power electricity is the main energy resources for every sector, the power electricity consumers will also come from various sectors. To be precise, the power electricity consumer is defined as any person or entity taking electricity supplies from local utilities or IPPs' supply line [5]. According to Electricity Supply Department 2004, the total number of customers for the three local utilities in Malaysia was 6.46 millions of which 83.3% was domestic, 15.5% commercial, 0.4% industrial and 0.8% others. At the end of 2003, the industrial sector consumed 50.8% of the 70,030 GWh of electricity supplied by the three utilities while the commercial sector and residential sector consume 29.0% and 19.0% respectively [6].

2.2.2.1 Industrial Sector

Industrial consumer means a consumer engaging in manufacturing of goods and products [5]. This means that the industrial consumer does not involve in any activity that is normally associated with the retail or wholesale trade. For example, they may include the consumer that involves in parts assemblies, food processing, pumping for water treatment plant or quarrying of minerals, stone or other natural resources and etc.

In Malaysia, the growth in the consumption of power electricity is heavily influenced by strong demand from the industrial sector. The consumption from this sector is projected to increase at 5.4 percent annually over the outlook period [7]. This has become apparent since about 70 percent of electricity consumption in the industrial sector at national level had actually been consumed by electric motors alone. Additionally, the total wattage of lamps and air-conditioning installed for the purpose of office use shall not exceed 20% of the total wattage of all electrical equipment installed.

2.2.2.2 Domestic (Residential) Sector

Domestic consumer means a consumer occupying a private dwelling which is not used as a hotel, boarding house or used for the purpose of carrying out any form of business, trade, professional activities or services [5]. According to APERC Analysis 2006, the electricity demand for residential sector in Malaysia will also experience strong growth of 4.9 percent per year due to the living standards improvement. However, this growth is slower if compared with the 5.8 percent annual growth rate between 1997 and 2002. This is the consequences of the increasing efficiency of household appliances such as refrigerators and air-conditioners. Nonetheless, in 2030, per capita electricity demand and consumption is projected to be more than double than the one in 2002. This is higher than the APEC region which has the average at 6833 kWh/person [7].

2.2.2.3 Commercial Sector

Commercial consumer means a consumer occupying or operating an office block or any service providers who consumes electricity for business or commercial activities [5]. They may include the telecommunication and transportation services, hotels, retail complex, shop-houses, street lightings at tolled highway, entertainment or sports outlet, educational institution and etc. In commercial sector, electricity is expected to grow at an annual rate of 2.7 percent due to the increasing demand for cooling and lighting in commercial buildings [7].

2.2.2.4 Public Lighting Sector

The consumer for public lighting consists of the street lighting consumer and the neon and floodlight consumer. Street lighting consumer means a consumer lighting up public roads, highways and bridges (excluding tolled highway) while Neon and Floodlight Consumer means a consumer lighting up neon and flood light installations [5]. Examples of these installations include for the roadside advertisements, billboards, buildings, traffic lights, bus-stops and telephone kiosks or for decorating the façade of buildings.

2.2.3 Power Losses

Power losses usually occur especially during transmission and distribution of power electricity to consumers. As such, the power transmission is defined as a process of transmitting power electricity to consumers over long distance through overhead power transmission lines. It transfers a bulk amount of electrical power from one place to another. This results in a high voltage transmission which is about 110 kV or above. It is necessary to do so in order for the fraction of energy lost to be reduced. For a given amount of power transmitted, a higher voltage reduces the current and thus it will reduce the resistive losses in the conductor too. Nonetheless, electrical power is always partially lost during transmission. This applies to short distances too. The equation for the power losses is given by the below equation:

| | | |
|-------------------|--------|----------------------------------|
| $P_{loss} = RI^2$ | where; | $P_{loss} = \text{Power Losses}$ |
| | | $R = \text{Resistance}$ |
| | | $I = \text{Current}$ |

Figure 1 : Power Loss Equation

Due to this relationship, it is best to transmit energy with voltages as high as possible. Since current is reduced, the power lost during transmission will also be reduced.

2.2.4 Electricity Installed Capacity

Installed capacity is defined as the measure of a power station's electric generating capacity at full production. It is usually measured in megawatts (MW). Even though the installed capacity plays an important role in the power generation, the installed power generator in a power plant does not run simultaneously for the entire time. In most cases, one of the power generators will be in the standby mode. If any of the generators tripped, the standby generator will start to run. In addition, there might be a case when the power generator needs to be shutdown to do some maintenance job. According to Electricity Supply Department 2004, at the end of 2003, the total installed generation capacity of the

utilities and IPPs in the country was 18,800 MW with a plant mix of 58.2% gas turbine and combined cycle. This includes 19.3% coal, 11.3% hydro, 7.5% oil, 3.4% diesel and the remaining others. The total capacity of co-generation in operation was 800 MW which produces 3,500 GWh of electricity [6]. In Malaysia, there are two types of electricity installed capacity. They are the Conventional Thermal Capacity and Hydro Capacity.

2.2.4.1 Conventional Thermal Capacity

In order to produce electric power, TNB's thermal plants use conventional steam turbine and steam generator. They are fired by non-renewable energy sources namely coal, natural gas and oil.

Coal is widely used in the power generation in most countries. When coal is burnt, the chemical energy stored in coal is converted successively into thermal energy, mechanical energy and finally, electrical energy. In Malaysia, the consumption of coal for power generation is expected to reach 19.0 million tonnes in 2010 due to the commissioning of two new coal based generation plants in Peninsular Malaysia. [8].

Another main resource of power generation in Malaysia is natural gas. It is processed through the use of gas turbines and steam turbines to produce power electricity. High efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. If compared to other fossil fuels such as oil and coal, natural gas burns are cleaner. In addition, Malaysia contains 75 trillion cubic feet (Tcf) of proven natural gas reserves [4]. Therefore, the consumption of natural gas in Peninsular Malaysia is expected to increase at an average rate of 4.3 percent per annum to reach 2647 mmscfd (million standard cubic feet) in 2010. In this case, the power sector is

expected to be the major user of natural gas with the estimated consumption of 1653mmscfd in 2010 [8].

Petroleum is also another resource for the power generation in Malaysia. However, this type of fossil fuel is not widely used in the power generation due to the high price of oil. Furthermore, petroleum also emits a lot of carbon dioxide during combustion. According to EIA, Malaysia possesses oil reserves of 3.0 billion barrels in which this amount has turned down from a peak of 4.3 billion barrels in 1996. However, regardless of the declining oil reserves, Malaysia's oil production has been increasing since 2002 as a result of the new offshore development. Thus, the average total production of oil has increased from 860,000 bbl/d (barrels per day) in 2004 to 871 000 bbl/in 2005 [4].

2.2.4.2 Hydro Capacity

The basic concept of hydroelectric power generation is the utilization of energy from flowing water as it descends from a height. Potential energy is converted to electrical energy. Hydroelectric power is suitable to be the leading source of renewable energy in Malaysia since water can be found in abundance. It provides about 97% of all power generated by renewable energy sources worldwide. A hydroelectric power station requires a means of conveying water to produce the force that is necessary to spin a turbine that is linked to an electric generator. Commonly, this is through a medium such as a pipeline or tunnel to a turbine-generator which is spun by the passing water.

In Malaysia, the Bakun Project which has a capacity of 2,400 Megawatt (MW) will become Malaysia's largest power plant [9]. This project will contribute significantly towards meeting increasing power demand in the Peninsula and Sarawak as well as ensuring security of power supply. This project includes the 670 kilometres cables to transmit power generated from Bakun in Sarawak to Peninsula Malaysia. In the absence

of this project, the country will become overly dependent on thermal sources for which imported fuels would be increasingly necessary in the future.

2.3 Modeling

Modeling is defined as the process of generating a model as a theoretical representation of some event. It is usually represented mathematically. It is widely used and performed in many areas including the engineering disciplines. Thus, the statistical analyses that are performed in this project have the objective to create mathematical and statistical model which is the result from demographic analysis studies. It requires careful selection of analytical techniques, verification of assumptions and verification of data. Since different modeling has different goals, only Multiple Linear Regression Analysis and Curve Fit Analysis will be considered in this project.

2.3.1 Multiple Linear Regression Analysis

Regression Analysis is a statistical tool for the investigation of relationships between variables. It is used when independent variables are correlated with one another and with the best prediction of a dependent variable from several independent variables. There are three major regression models which include Standard or Simultaneous Regression, Hierarchical Regression and Stepwise Regression.

These models are different from one another in terms of the order of entry of the independent variables into the equation and also in terms of the treatment of overlapping variability due to correlation of the independent variables. Correlations of the independent variables are based on the Least Square Methods which minimize error between observed and estimated values.

In the *standard or simultaneous model*, all independent variables enter the regression equation at once. This is to examine the relationship between the whole set of predictors and the dependent variable. In Statistical Package for the Social Science (SPSS) software, this model can be developed by selecting the “Enter Method”. It forces the entry of variable into the modeling. SPSS will enter all specified variables regardless of significance levels at one time.

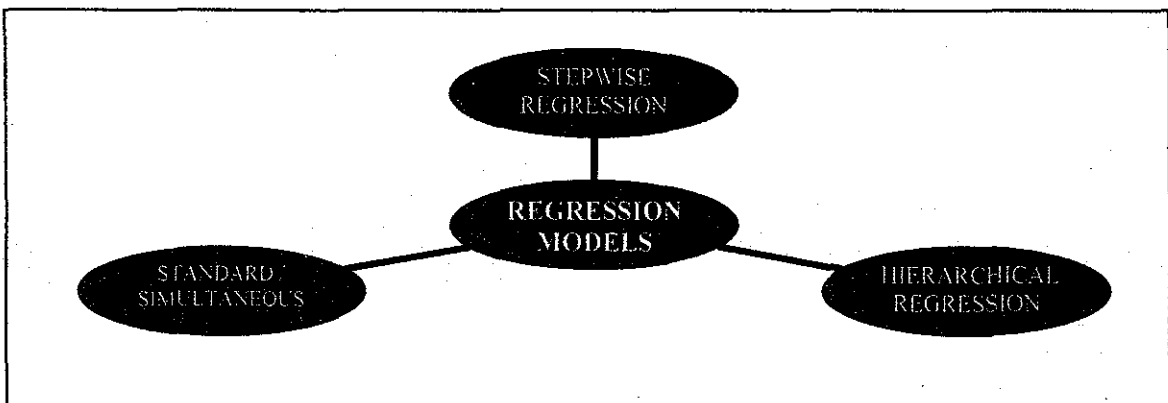


Figure 2 : Three Major Regression Models

In hierarchical multiple regression, the order of entry of the independent variables are determined based on the theoretical knowledge. SPSS uses “Removal Method” in order to obtain this model. It forces SPSS to remove all specified variables and repeat the analysis. However, it requires an initial regression analysis using the Enter procedure before the removal steps can be carried on.

In contrast, Stepwise Regression enters the independent variables in sequence. The order of entry is determined by statistical criteria generated by stepwise procedure. Method of entry can be forward, backward or combination or both. Methods for entering the variables of this modeling into SPSS for a Stepwise Regression Model are described as in the next page:

1. **Forward Selection**

It enters variables one at a time. The predictor variable that has the highest correlation with the criterion variable is entered into the equation first. The rest variables are entered into the equation depending on the contribution of each predictor.

2. **Backward Elimination**

Unlike Forward Selection Method, Backward Elimination enters all independent variables at one time but after that, sequentially removes them. The variable that has the lowest correlation with the dependent variable will be eliminated first. The process will cease when there are no more variables that meet the requirement for removal.

3. **Stepwise Selection**

This is a combination of forward and backward procedures. It is the most frequently used of the regression methods. It gives more precise output since it removes the weakened variable which has been entered earlier. These weakened variables lose its predictive validity when other variables come in.

2.3.2 *Curve Fit Analysis*

From *Curve Fitting, Wikipedia*, curve fitting is defined as finding a curve which matches a series of data points and other possible constraints [10]. Relationship between two variables on a scatter plot is best described by sketching of a line or curve. This is by extending the trendline of a graph by n periods. One way to perform curve fitting is by fitting lines or polynomial curves to data points.

Generally, a first degree polynomial equation is an exact fit through any two points. If the order of the equation is increased to a second degree polynomial, the new equation will

definitely fit to three points while a third degree polynomial will fit four points. Thus, for an order of m degree polynomial, the equation will exactly fit $m + 1$ point.

In curve fitting, it is important to get an approximate fit even though the degree of the polynomial equation could be increased and an exact match can be obtained. This is because high order polynomials can be highly oscillatory while low order polynomials tend to be smooth. However, an infinite number of solutions may exist if the degree of the polynomial curve is higher than the needed one for an exact fit. This will result in the problem of the decision making on which one to be chosen. Thus, it is usually best to choose as low degree as possible for an exact match on all constraints if an approximate fit is acceptable.

2.4 Laws and Principles of User Interface Design

Most engineering software is about communicating with other programmers. Generally, it is specifically designed with the intention of enabling some group of people to accomplish a specific set of tasks with the ease of use. According to Alan Cooper, software should work the way users expect it to and not make users feel stupid because they can not understand how to perform particular tasks [11]. This means that software designer should always think about the user when designing user interface. Nevertheless, designer must abide by the Laws of Interface Design when designing software. The two rules are described in Table 1 below:

Table 1 : Laws of User Interface Design [12]

| First Law | Second Law |
|---|---|
| User's work shall not be harm by the software even through idleness | <ul style="list-style-type: none"> • User's work should be simplified • Programme does not consume too much time and effort when it is being used |

Once the Laws are fulfilled, the software designer has to comply with User Interface Design Principles. These principles are important for improving the quality of user interface design. They can be used to guide or evaluate design at any time during the software development process. In practice, these principles are often re-framed or re-structured to suit a particular company or project, or by professional designers. They are described in Table 2 below.

Table 2 : User Interface Design Principles [12]

| Principle | Description |
|------------|--|
| Visibility | <ol style="list-style-type: none"> 1. Software must be focus and accomplish more with little effort. 2. All needed options and material for a given task should be visible without distracting the user with redundant information. 3. Do not overwhelm users with too many alternatives or confuse them with unneeded information. 4. Any warnings to the user must be explicit and easy to understand. |
| Feedback | <ol style="list-style-type: none"> 1. Users should always be informed of their actions, errors and changes of states or condition, through clear, concise and unambiguous language which is familiar to the user. 2. Communication to the user through visual or audio signals is crucial to inform them the function that is being performed. For example the status bar gives a lot of information on what the program is performing. |
| Simplicity | <ol style="list-style-type: none"> 1. Keep the interface and common tasks simple, organized, clear and easy to understand. 2. The interfaces should be designed using common configuration themes. 3. Avoid busy user interfaces so that the screens are still readable. Crowded screens are difficult to understand. Thus, difficult to use. 4. Provide good shortcuts. 5. Do not overuse or misuse color or graphics: |

| | |
|-------------|---|
| | <p>a) Always remember that some users may be colour blind</p> <p>b) Follow the contrast rule:</p> <ol style="list-style-type: none"> i. Dark text on light backgrounds ii. Light text on dark backgrounds |
| Structure | <ol style="list-style-type: none"> 1. User interface should be organized in meaningful way based on clear and consistent sequences that are apparent and recognizable to users. This means the components in the user interface should be group effectively. Items that are connected should be grouped together on the screen. Otherwise, they should be separated. 2. Navigation between major user interface items is important. Make sure that it is not difficult to get from one screen to another. 3. The software must keep the user in the loop. 4. Do not reduce options that are available to users. Users should have the power to choose. |
| Consistency | <ol style="list-style-type: none"> 1. The appearance, positioning and behaviors of all components should be reused to maintain consistency. Thus, it can reduce the need for users to rethink and remember. This results in lower training and support costs. For example, buttons can be put in consistent places on all windows with the same wording in labels and messages and a consistent color scheme throughout. 2. Set standards and stick to them. The only way to ensure consistency within the application is to set user interface design standards and then stick to them. |
| Tolerance | <ol style="list-style-type: none"> 1. Give the user more chances to amend their mistakes (errors) by providing easy recovery. For example, providing RESET button to clear unwanted information. 2. Software must be designed in a way that it will prevent user from making errors. |

2.5 Visual Basic 6.0 Programming Language

Visual Basic 6.0 programming language was designed to be straightforward and easy to learn and exploit. Thus, the programming language chosen to create the user interface for the software is Visual Basic 6.0. It creates the process for program development and revision much easier and requires much less time and effort. Programming in Visual Basic 6.0 is a combination of visually arranging components or controls on a window called a form, specifying attributes and actions of those components or controls and writing additional lines of code for more functionality. Hence, the first two methods have simplified the usage of Visual Basic 6.0 in creating a programme by eliminating the need to develop the unnecessary or basic code to construct the visual interface. The layout of the windows that contain the controls can be changed easily by dragging and dropping the controls to a new location, without necessitating a change in the code.

CHAPTER 3

PROJECT WORK

3.1 Overview

This project is divided into two main phases. The first phase is on the Mathematical area that is the *Development of Statistical Modeling Stage* while the second phase is on the Computer Systems area that is on the *Development of the User-friendly Software* as shown in Figure 3.

The workflow of this project started with thorough literature review and research to identify the problem statements as well as the quantifiable variables which affect the Power Generation in Malaysia. This is by referring to online journals and articles as well as via library books. In addition, personnel from local utility such as Tenaga Nasional Berhad were contacted and interviewed to obtain extra information. Once key variables have been identified and quantified, data for each variable was collected from the Energy Information Administration's (EIA) website and Malaysia's Yearly Book that was published by Department of Statistics Malaysia.

3.2 Mathematical Area – Statistical Models Development

Two models were considered for the project; Multiple Linear Regression Model and Curve Fit Model. Both models were developed using the Statistical Package for the Social Science (SPSS) Software.

For Regression analysis, all variables must be correlated with one another and with the best prediction of a dependent variable from several independent variables. These correlations are based on the Least Square Methods which will minimize error between observed and estimated value. In this project, data for Population and Consumption of Electricity by Domestic Sector were lagged. Then, linear regression is performed by selecting the variables that have the strongest relation with the dependent variable through SPSS software. To get the best model, “trial and error method” is performed. The model that has the best relation with the dependent variable will be chosen in which the final corresponding equation were obtained and incorporated into the software. For the curve fit model, a graph is fitted to all the data and the best curve that fit the data is chosen.

3.3 Computer System Area – Software Design Development

Second stage will commence right after the two models have been created. However, the interface which provides the interaction between the user and the software must be planned properly in order to develop user-friendly software. Visual Basic 6.0 programming language is utilized during the software development process. To ensure that this project is entirely finished, the completed statistical models will be incorporated into this software so that it can be used for forecasting purposes. Additionally, this software will also include database of the variables’ data that have been collected for the models development.

3.4 Testing/Evaluation

The amount of Power Generation in Malaysia was simulated based on the proposed models.

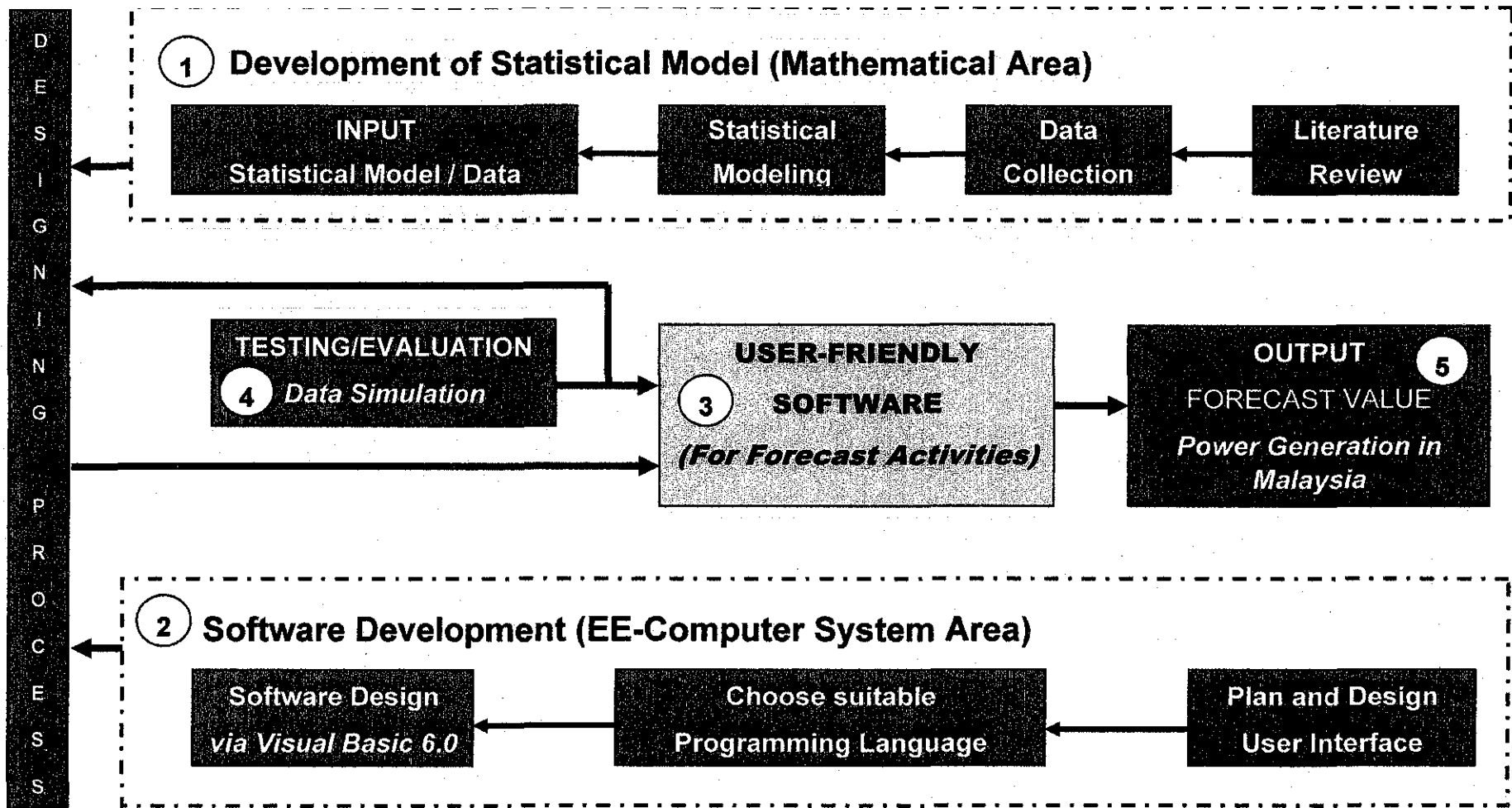


Figure 3 : Power Generation Forecast Software Development Structure

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data Analysis

The data for Net Power Generation in Malaysia from 1980-2004 [13] is given by Table 3 while its graph is given by Figure 4. After the graph has been plotted, it is observed that the pattern of the power generation is approximately linear. The power generation increases every year with constant increment during the first eighteen years. However, there was a slight change in between 1998 to 2000, as it experienced little increments if compared to the previous years. This situation reoccurred in 2002 and has been increasing ever since. Several variables have been identified. They are:

Y: Power Generation

X₁: Consumption of Electricity by Domestic Sector

X₂: Consumption of Electricity by Commercial Sector

X₃: Consumption of Electricity by Industrial Sector

X₄: Consumption of Electricity by Public Lighting

X₅: Power Losses

X₆: Population Growth

X₇: Electricity Installed Capacity – Conventional Thermal

X₈: Electricity Installed Capacity – Hydro

Please refer to Appendix B to view the data for each of the above variables. These data will be used to develop the forecasting statistical model. Variables X_1 , X_2 , X_3 and X_4 are the consumption of power electricity from each major sector. From Table B in Appendix B, it is observed that all four major sectors consume more electric power each year. Also, it is known that population in Malaysia increases every year with an average value in between 2%-3% per year. However, the increment was slightly more in 1999 that was about 4.1%. Nonetheless, this does not apply to the power losses during transmission. The losses are identified to have fluctuating trends. It decreased in the year 1989, 1999, 2000 and 2002. Nevertheless, the generated electricity keeps on increasing each year although the increment is not constant. Even though the installed capacity increases annually, it drops by 7.17% in the year 2000; being from 11.502 million kW in 1999 to 10.882 million kW in 2000 for conventional thermal while hydro decreases from 2.104 million kW to 1.814 million kW in the same year.

Table 3 : Data for Net Power Generation in Malaysia (1980-2004)

| Years | ^a Net Power Generation (Billion kWh) |
|-------|---|
| 1980 | 10.186 |
| 1981 | 10.895 |
| 1982 | 11.498 |
| 1983 | 12.686 |
| 1984 | 13.651 |
| 1985 | 14.995 |
| 1986 | 16.287 |
| 1987 | 17.616 |
| 1988 | 19.361 |
| 1989 | 21.890 |
| 1990 | 25.262 |
| 1991 | 28.335 |
| 1992 | 31.887 |
| 1993 | 35.579 |
| 1994 | 40.058 |
| 1995 | 46.656 |
| 1996 | 52.999 |
| 1997 | 58.674 |
| 1998 | 60.471 |
| 1999 | 62.546 |
| 2000 | 66.678 |
| 2001 | 72.280 |
| 2002 | 75.328 |
| 2003 | 84.022 |
| 2004 | 90.661 |

^a Malaysia's Yearly Book (1981-2005)

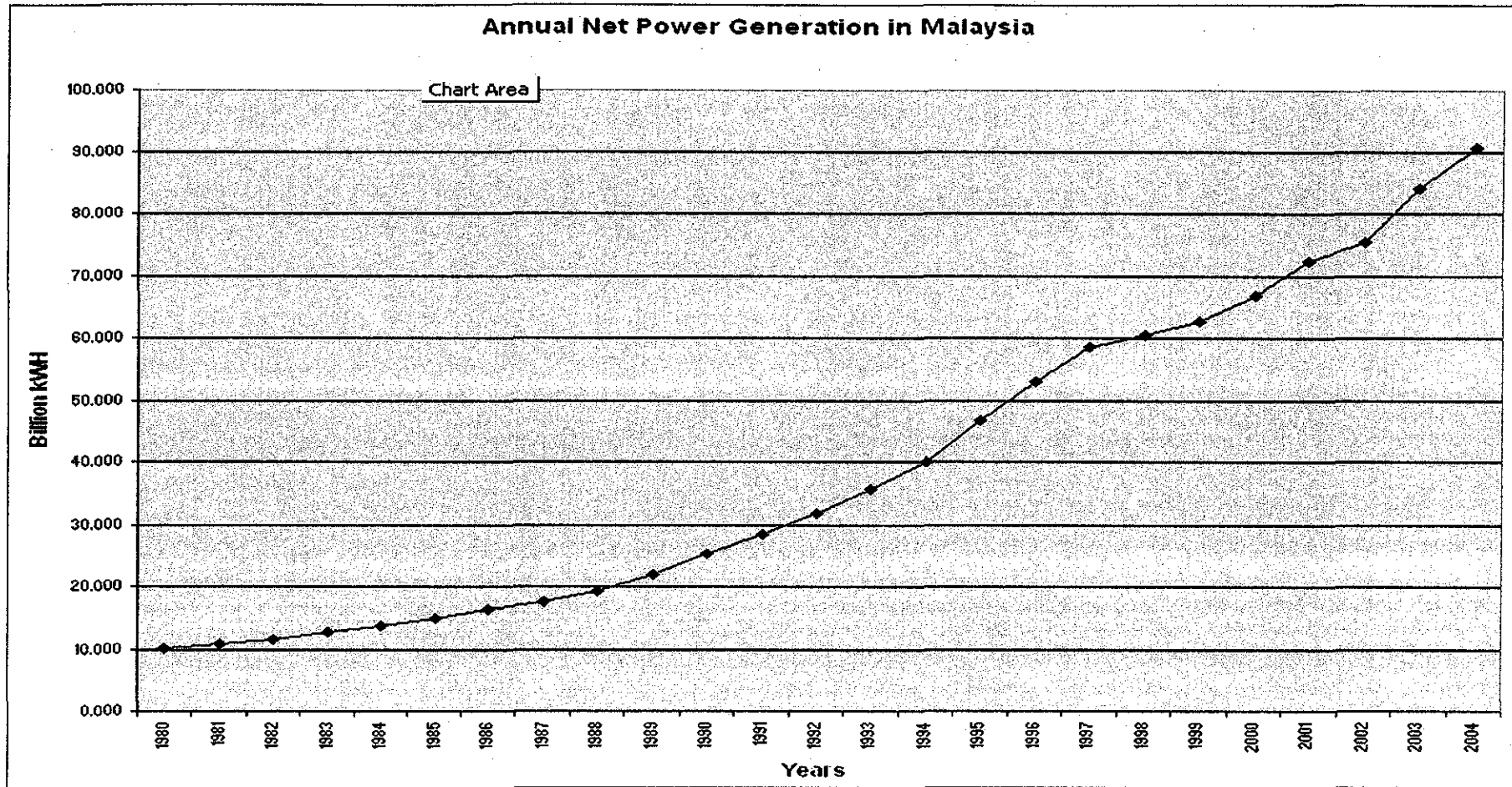


Figure 4 : Plotted Graph for Annual Power Generation in Malaysia

4.2 Multiple Linear Regression Modeling

Before the models can be constructed, it is important to correlate all variables with one another to see the strength of the relationship between each variable. Based on the coefficient from the Pearson Correlation (Refer to Table 4), it is known that all of the variables are strongly correlated with one another. All correlation is approximately equals to 1 which means that they have perfect correlations.

Table 4 : Pearson Correlation Coefficients between Each Pair of Variables

| | | Power Gen. | Power Losses | Dom Lag1 | Cons. Comm | Cons. Ind. | Cons. PL | Thermal | Hydro | Pop Lag 1 |
|-------------------|-----------------|------------|--------------|----------|------------|------------|----------|---------|-------|-----------|
| Pearson Correlati | Power Generatio | 1.000 | .998 | .975 | .997 | .998 | .940 | .971 | .933 | .950 |
| | Power Losses | .998 | 1.000 | .980 | .998 | .997 | .956 | .978 | .929 | .947 |
| | Dom Lag1 | .975 | .980 | 1.000 | .980 | .970 | .962 | .957 | .915 | .966 |
| | Cons. Comm | .997 | .998 | .980 | 1.000 | .995 | .954 | .981 | .936 | .949 |
| | Cons. Ind. | .998 | .997 | .970 | .995 | 1.000 | .945 | .971 | .920 | .937 |
| | Cons. PL | .940 | .956 | .962 | .954 | .945 | 1.000 | .951 | .875 | .900 |
| | Thermal | .971 | .978 | .957 | .981 | .971 | .951 | 1.000 | .882 | .918 |
| | Hydro | .933 | .929 | .915 | .936 | .920 | .875 | .882 | 1.000 | .935 |
| | Pop Lag 1 | .950 | .947 | .966 | .949 | .937 | .900 | .918 | .935 | 1.000 |

However, in the earlier stage of this project, even though the value of R, R^2 and adjusted R^2 is approximate to one, the model could not be developed since there was one variable that has been excluded. Thus, it is necessary to transform the data into Time Series by lagging the original data. Then, the most recent data (new data) will be reutilized in order to find the best model. The steps to obtain the best model are described in the next page:

- i. All variables are to be lagged by first order
- ii. Perform trial and error method. Inputs of this Enter Method are the combinations of data from all variables. This combination can be purely all new data (variables of the lag data) or the combination of the new data with the original data into the *Regression – Forced Enter Method*
- iii. Analyze the output result
- iv. Choose the best modeling that has the smallest significant
- v. Obtain the best model

In this project, it is known that the combination of the new data (Lagged Population and Lagged Consumption of Electricity by Domestic Sector) and the original data into the Regression forced Enter Method has produce the best model. This is proven in Table 5 where R, R² and adjusted R² are equal to one and it has the smallest significant if compared to other models. Also, all variables are included inside this model.

Table 5 : Model summary of Power Generation

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|----------|----------|-------------------|----------------------------|
| 1 | 1.000(a) | 1.000 | 1.000 | .400090 |

Table 6 : Correlations between the Variables for Power Generation

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|----------------------------|-----------------------------|------------|---------------------------|--------|------|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -6.784 | 2.273 | | -2.985 | .014 |
| | Power Losses | 5.766 | 2.288 | .377 | 2.520 | .030 |
| | LAGS (Domestic,1) | -.680 | .373 | -.094 | -1.822 | .098 |
| | Consumption Commercial | 2.498 | .627 | .583 | 3.983 | .003 |
| | Consumption Industrial | .607 | .192 | .288 | 3.155 | .010 |
| | Consumption PublicLighting | -10.741 | 3.479 | -.082 | -3.087 | .011 |
| | Capacity Thermal | -.729 | .242 | -.127 | -3.019 | .013 |
| | Capacity Hydro | -1.834 | 1.038 | -.047 | -1.767 | .108 |
| | LAGS (Population,1) | .641 | .198 | .094 | 3.231 | .009 |

After analyzing these parameters, a regression model can now be developed and finalized. This is by referring to the values inside Table 6. The value of Beta that is under the Standardized Coefficients will be taken as the constant of the Regression Model that is being constructed. As such, the chosen model is as Figure 5 below:

$$Y = 0.377 X_{\text{Losses}} - 0.094 X_{\text{Domestic-1}} + 0.583 X_{\text{Commercial}} + 0.288 X_{\text{Industrial}} - 0.082 X_{\text{Public Lighting}} - 0.127 X_{\text{Thermal}} - 0.047 X_{\text{Hydro}} + 0.094 X_{\text{Population-1}}$$

Figure 5 : Multiple Linear Regression Model

From the above equation, it is known that there are only two variables that were lagged by first order. They are “*Population*” and “*Consumption of Electricity by Domestic Sector*”. The other variables remain the same. From the equation too, it is known that power generation in Malaysia will increase if there are an increment in power losses, the consumption of electricity from commercial sector and from the industrial sector. Also, the increase of Power Generation is also contributed by population growth. However, the population growth will be lagged by one year or one period. This means that the amount of the population growth will only affect the power generation a year after that. It is also proven in this equation that the power generation in our country is also affected by the consumption of electricity by public lighting and domestic sector as well as from both electricity capacities. As the consumption for these two sector decreases, the generation will be higher. Nevertheless, the domestic sector will also be lagged by one degree which means that the usage of electricity by this year can only be useful to get the forecast power generation for the coming years. Please refer to Table 7 to see the data that has been applied in the Regression Modeling.

Table 7 : Input Data for Regression Modeling in SPSS (Original and Lagged)

| Years | Generation | Population Lag | Losses | Domestic Lag | Commercial | Industrial | Public Lighting | Thermal | Hydro |
|-------|------------|----------------|--------|--------------|------------|------------|-----------------|---------|-------|
| 1980 | 10.186 | - | 0.713 | - | 2.515 | 3.952 | 0.08 | 2.399 | 0.606 |
| 1981 | 10.895 | 13.764 | 0.763 | 1.454 | 2.713 | 4.124 | 0.088 | 2.44 | 0.649 |
| 1982 | 11.498 | 14.128 | 0.805 | 1.647 | 2.884 | 4.311 | 0.091 | 2.468 | 0.674 |
| 1983 | 12.686 | 14.507 | 0.888 | 1.783 | 2.972 | 4.445 | 0.105 | 2.551 | 0.767 |
| 1984 | 13.651 | 14.888 | 0.965 | 1.999 | 3.66 | 4.988 | 0.114 | 2.725 | 0.954 |
| 1985 | 14.995 | 15.272 | 1.05 | 2.389 | 4.145 | 5.138 | 0.118 | 2.993 | 1.035 |
| 1986 | 16.287 | 15.682 | 1.07 | 2.684 | 4.434 | 5.392 | 0.131 | 3.133 | 1.04 |
| 1987 | 17.616 | 16.11 | 1.153 | 2.898 | 4.753 | 5.978 | 0.138 | 3.35 | 1.251 |
| 1988 | 19.361 | 16.526 | 1.291 | 3.181 | 5.02 | 6.506 | 0.145 | 3.4 | 1.422 |
| 1989 | 21.89 | 16.942 | 1.455 | 3.324 | 5.446 | 8.251 | 0.174 | 3.48 | 1.437 |
| 1990 | 25.262 | 17.353 | 1.677 | 3.571 | 6.03 | 9.487 | 0.185 | 3.53 | 1.437 |
| 1991 | 28.335 | 17.756 | 1.877 | 3.989 | 6.611 | 11.19 | 0.192 | 3.58 | 1.457 |
| 1992 | 31.887 | 18.328 | 1.943 | 4.395 | 7.453 | 13.121 | 0.203 | 4.606 | 1.454 |
| 1993 | 35.579 | 18.762 | 2.302 | 4.879 | 8.121 | 15.153 | 0.227 | 5.155 | 1.545 |
| 1994 | 40.058 | 16.564 | 2.595 | 5.229 | 9.431 | 17.576 | 0.261 | 5.28 | 1.577 |
| 1996 | 52.999 | 20.112 | 3.399 | 6.32 | 12.28 | 22.69 | 0.328 | 8.84 | 1.76 |
| 1995 | 46.656 | 21.169 | 3.011 | 7.532 | 10.861 | 20.015 | 0.288 | 7.34 | 1.66 |
| 1997 | 58.674 | 20.689 | 3.82 | 7.01 | 13.886 | 26.71 | 0.379 | 10.268 | 2.232 |
| 1998 | 60.471 | 21.666 | 4.009 | 8.637 | 14.809 | 25.939 | 0.425 | 11.516 | 2.025 |
| 1999 | 62.546 | 22.18 | 4.316 | 9.847 | 15.413 | 28.58 | 0.619 | 11.502 | 2.104 |

4.3 Curve Fit Modeling

The third order polynomial equation is used to get the best curve fit of the net power generation in Malaysia. Below is the formula that has been produced by this method:

| | |
|---|-------|
| $\text{Power Generation} = -0.0037 X^3 + 0.2612 X^2 - 1.1731 X + 12.364;$ | where |
| $X: \text{Year (Year Forecast} - \text{Year Initial of Data Collected)}$ | |

Figure 6 : Curve Fit Model

To obtain the forecast value for the Power Generation in Malaysia, users need to key-in the year that they wish to observe. The keyed-in year will be transformed into a digit in which it will be the value of X . This X is actually the subtraction of the initial year of the collected data from the forecast year that is determined by users. However, forecasting via this model is limited to five years only. Please refer to Figure 7 below to see the graph pattern of the real data for the Power Generation in Malaysia and the curve fit trendline which has been extended for five years ahead.

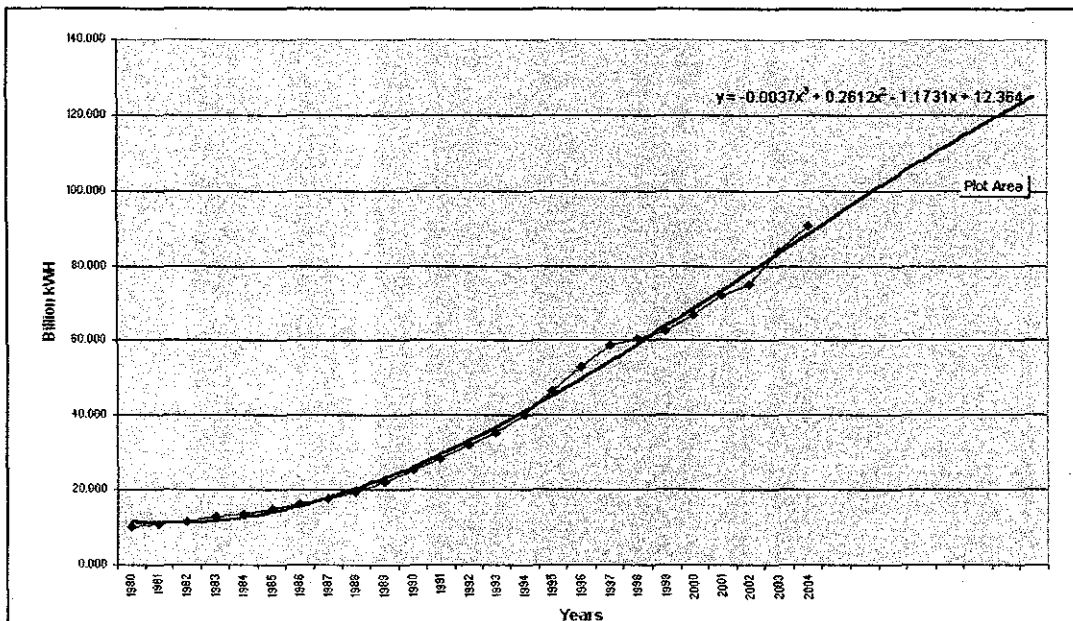


Figure 7 : Graph for Real and Predicted (Future) Power Generation in Malaysia

4.4 Power Generation Forecast Software

4.4.1 User Interface Design and Functions

When user starts using P.Gen Software, the loading page as shown in Figure 8 will be uploaded first. This page serves as a transition to open the programme. After few seconds, this loading page will be unloaded and replaced by the main page of P.Gen Software (Figure 9). There are three main links in the main page. They include P.Gen Database, P.Gen Forecaster and Report Generator. In this project, only P.Gen Forecaster and P.Gen Database link are activated. Extra features such as the Report Generator link remains disabled. It would be further enhance in the future.

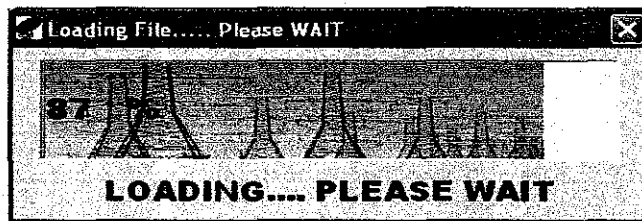


Figure 8 : Loading Page

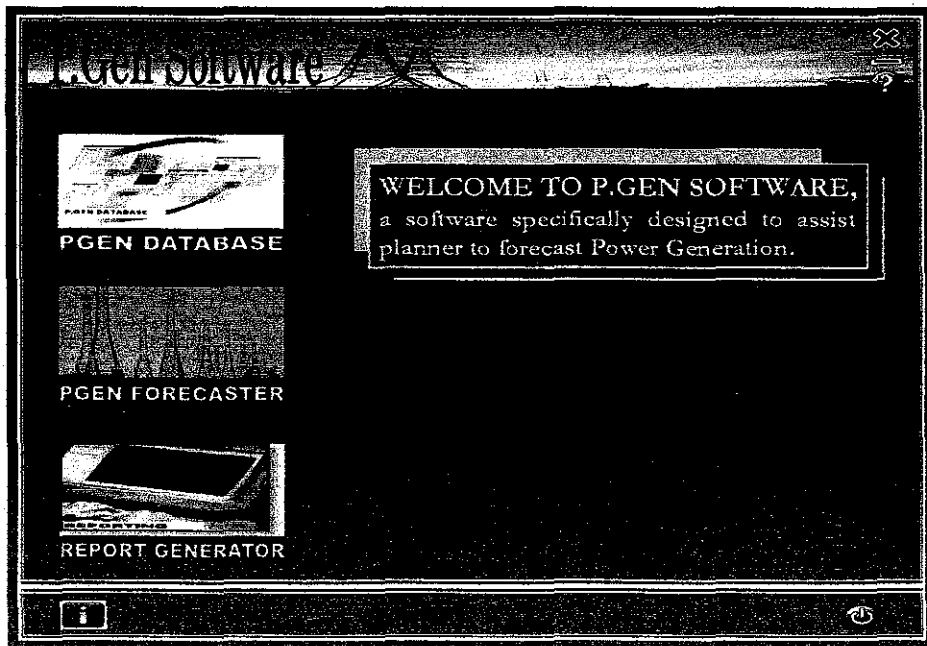


Figure 9 : Main Page

P.Gen Database as in Figure 10 will be displayed if the first link to P.Gen Database in the main page is clicked. User can view the database of all the identified variables by clicking at the command buttons that are located at the left column of the interface. Users are allowed to save and print this data in Excel form.

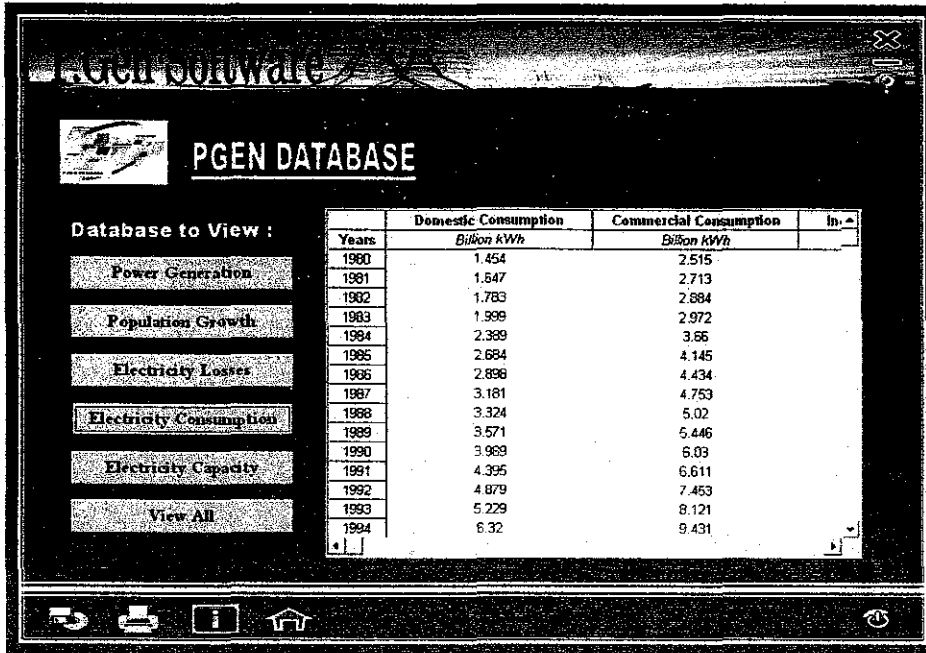


Figure 10 : P.Gen Database

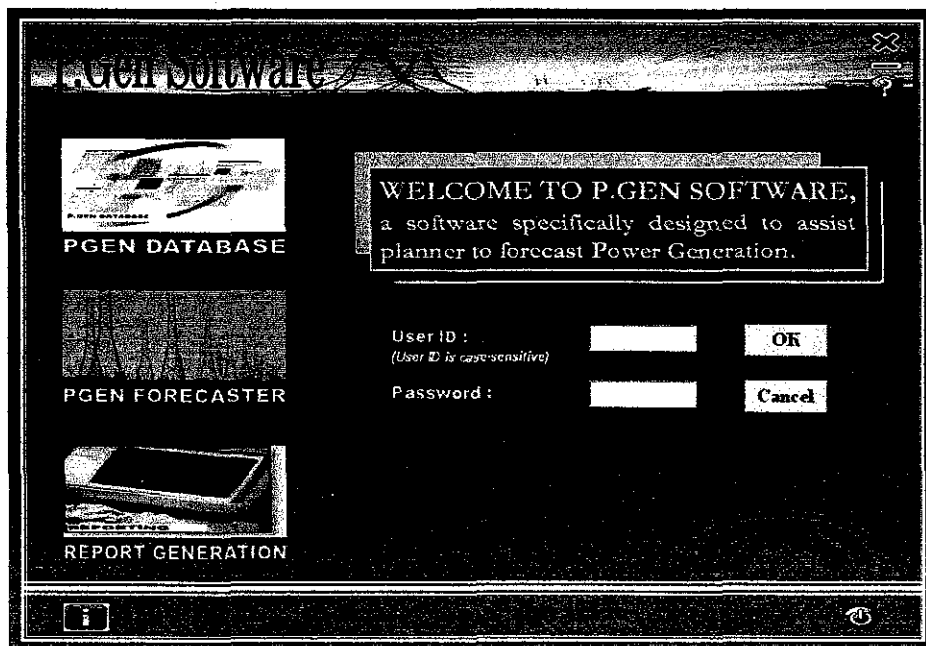


Figure 11 : Main Page with Login ID and Password Authentication

When P.Gen Forecaster link is clicked, the condition as in Figure 11 will occur. Thus, it is known that the access to P.Gen Forecaster is only possible with authentication of login ID and password. Thus, the access to this software is limited to certain people only.

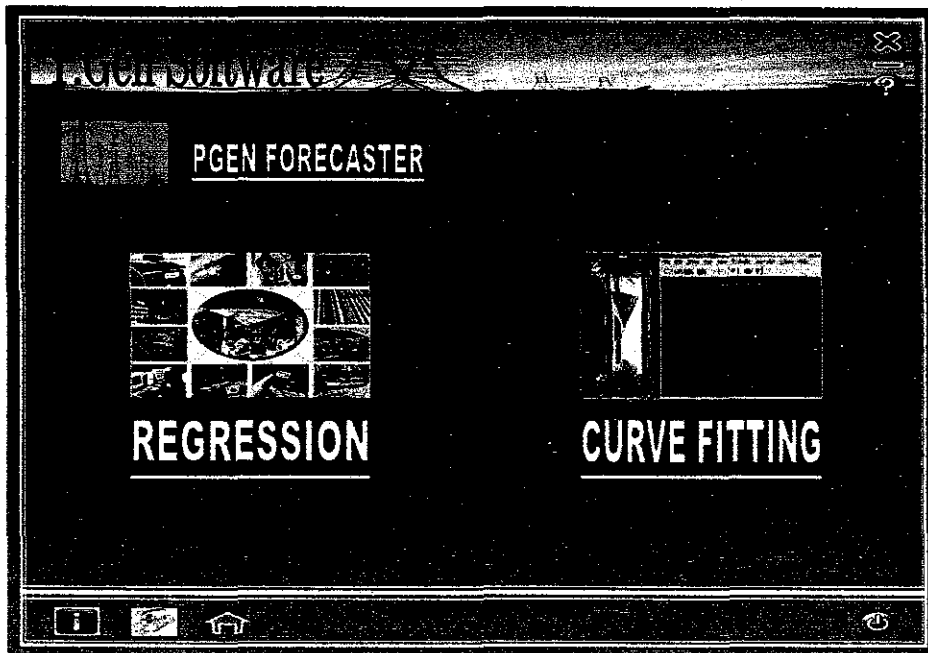


Figure 12 : P.Gen Forecaster

If the user has the access to this section, the user will be linked to the P.Gen Forecaster interface as in Figure 12. Here, users are given the opportunity to choose either one of the two approaches that are available in this software, to forecast the power generation. The first option allows user to be linked to the Regression Page (Figure 13) while the second option will lead user to the Curve Fit Page (Figure 16).

Upon the access into the Regression Page, user can start to forecast the power generation. This is by inserting the values inside all the textboxes that are located in the middle column of the interface. The values are limited to a certain range so that it will not exceed five years forecast. There will be a range indicator besides each label when user clicks on the textboxes for the corresponding variables. These textboxes represent the value for each of the variables that have been considered to contribute to power

generation. Then, user has to click at the GENERATE button when all correct value for all variables have been inserted inside the textboxes.

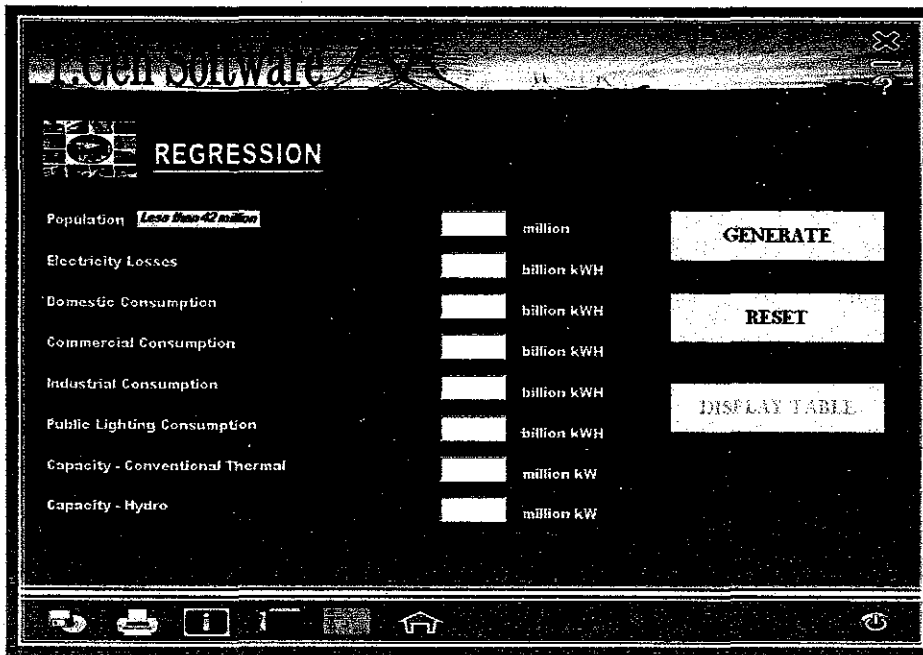


Figure 13 : Regression Page before Values are inserted

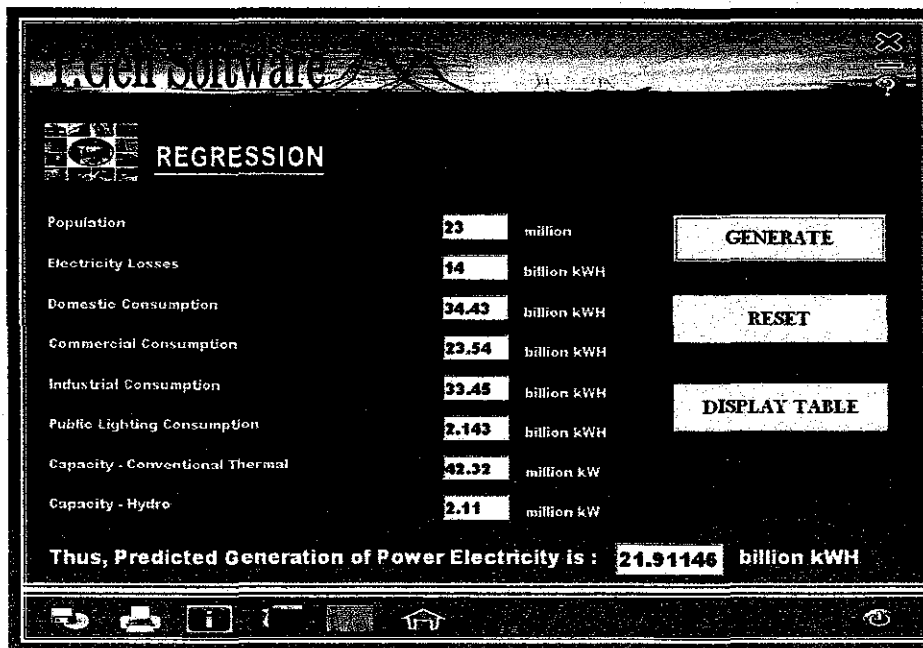


Figure 14 : Regression Page after values are inserted and GENERATE activated

Next, the DISPLAY TABLE button has been enabled. At the same time, the software will display the value of the forecast Power Generation at the bottom of the Regression Page as shown in Figure 14. The submitted values of all the variables and the forecast power generation are captured and stored inside a temporary file called "Reg_Table_temp.xls". Then, it will be displayed in table form in Regression (Table) page as shown in Figure 15. However, user can only stores the latest ten values of the forecast Power Generation inside this temporary file. To view this table, click the DISPLAY TABLE button that is available in Regression Page, shown in Figure 14. Also, notice that the labels in left column of the Regression Page (Figure 12 and 13) have the link to the Information Page which contains a brief explanation about each variable. Refer to Appendix D12 to see the example of the Information Page.

There is also a "RESET" button in the Regression page. User clicks on it to clear the values that were inserted inside those text boxes earlier. However, this will not affect the data stored inside the temporary file. Error text messages along with the "beep" sound will be displayed and heard (Figure D2) if the user enters incorrect values such as non-integer value or value that exceeds the required input range. This is to warn the user to key-in the correct value only inside the text boxes.

| Power Generation (Billion kWh) | Population (Million) | Losses (Billion kWh) | Consumption by Sectors (Billion kWh) | | | | Electricity Installed Capacity (Million kW) | |
|-----------------------------------|-------------------------|-------------------------|---|------------|------------|-----------------|--|-------|
| | | | Domestic | Commercial | Industrial | Public Lighting | Conventional Thermal | Hydro |
| 21.911484 | 23 | 14 | 34.43 | 23.54 | 33.45 | 2.143 | 42.32 | 2.11 |
| 0 | | | | | | | | |
| 0 | | | | | | | | |
| 0 | | | | | | | | |
| 0 | | | | | | | | |
| 0 | | | | | | | | |
| 0 | | | | | | | | |
| 0 | | | | | | | | |
| 0 | | | | | | | | |

* Right click on the above table to Open/Edit in Excel

RESET

Figure 15 : Regression (Table) Page

Regression (Table) Page is shown in Figure 15. The arrow icon at the bottom right of the page is a link to go back to the Regression Page. In addition, user can reset or clear the storage of the temporary file by clicking at the RESET button. However, before the table is being cleared, P.Gen Software will wait for user's confirmation whether to save the current data that are stored in the table or not.

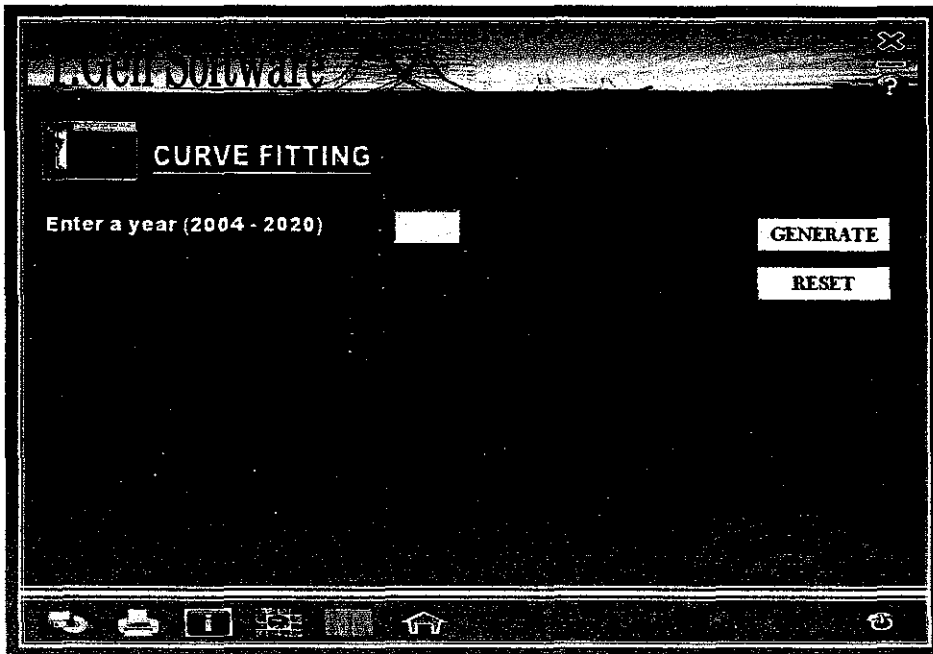


Figure 16 : Curve Fit Page before the desired year is inserted

The Curve Fitting Page which is the second option to forecast Power Generation in P.Gen Forecaster is shown in Figure 16. In this page, user has to key-in the forecast year. Then, GENERATE button is clicked.

This will display the result of the forecast power generation as shown in Figure 17. In this interface, users are allowed to view the values of the five years power generation forecast in graph and table forms. There are two models that are incorporated inside the Curve Fit Page. One is via Polynomial Curve Fit Model and the other one is by using Regression Curve Fit Model. It is also noticed that the values for both models are different. The Regression Curve Fit approach displays very low forecast Power

Generation if compared to the other model. This is because the values for the independent variables that have been identified are in polynomial form. However, these values are implemented into the Linear Regression Model. Thus, it will give a non-satisfactory result.

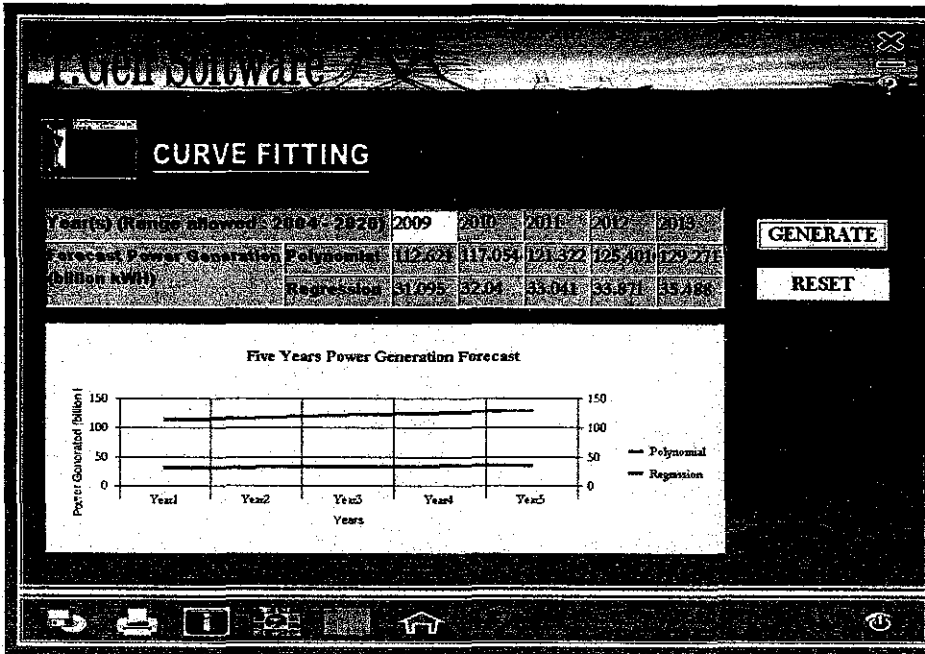


Figure 17 : Curve Fit Page after desired year is inserted and GENERATE is activated

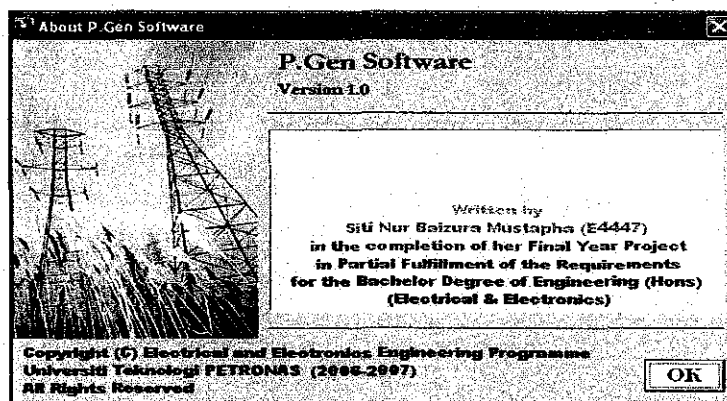




Figure 18 : About P.Gen Software

Notice that there is "Information" icon  at the bottom left of all interfaces. This icon will link the users to the Information Page of P.Gen Software (Figure 18). This

page shows the information of the software such as the software's copyright, name and version and also the name of the author.

Below is the "User Guide" or "Help" Page (Figure 19). The link is indicated by the question mark icon  in which it is displayed at the upper right of all user interfaces.

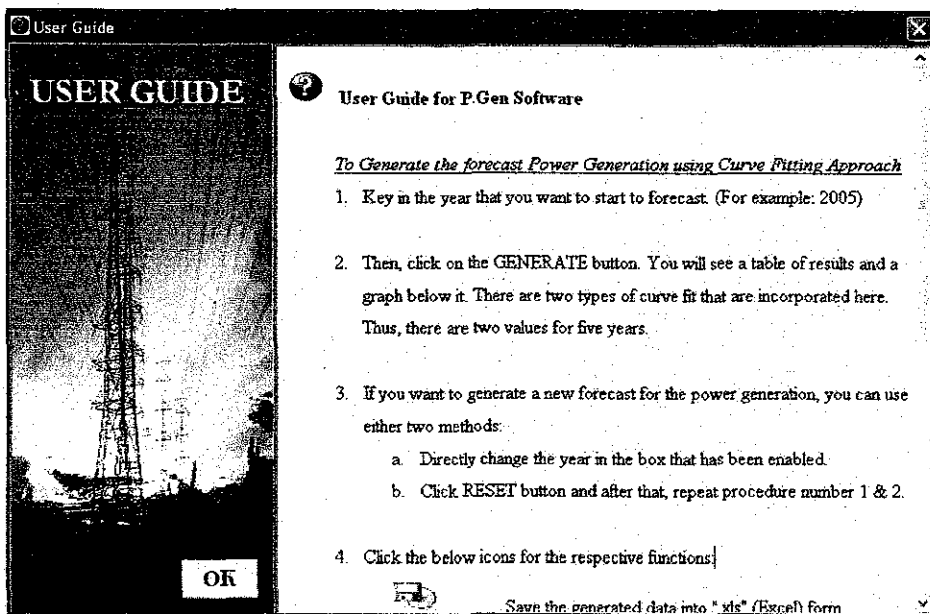


Figure 19 : User Guide / Help

4.4.2 User-friendly Software

In this project, the software is developed according to the two laws and six principles as discussed in the Literature Review earlier. All criteria have been achieved. They are as follows:

4.4.2.1 LAW 1: User's work shall not be harm

Since there is a minimize button on the upper right of the entire interface, user can minimize P.Gen Software's window to proceed with their other jobs. Thus, it will not interfere nor harm the user's work. Another example that meets this law is the

availability of login ID and password which will secure and maintain the confidentiality of the work performed. Thus, other people could not interfere nor harm the planner's work.

4.4.2.2 LAW 2: Simplify user's work with less time and effort to consume

User does not need to do the modeling to forecast the power generation since this software incorporates two models to forecast power generation. User will only be required to choose either one of the two approaches that are available. Then, this software will take over the hard work and will provide the user with the forecast values. Thus, user will spend less time and effort doing forecasting activities.

4.4.2.3 PRINCIPLE 1: VISIBILITY

The software is visible. Icons in this software are noticeable and easy to understand. This is proved with the usage of the "HELP", "PRINT" and "SAVE" icons. Furthermore, all messages inside this software are clear and concise. Error messages are also put into notice with a beep sound to remind the user that error has been identified. Refer to Appendix D1 and D2 to see the error message box that pops-up when error is detected.

4.4.2.4 PRINCIPLE 2: FEEDBACK

One obvious example of feedback can be observed through the availability of the status notification which is displayed at the bottom of the interface of Regression and Curve Fit Page (Refer to Appendix D8). This status notification will be displayed when GENERATE button is triggered since the forecast output will take few seconds to be displayed. Thus, user will know that the software has captured the user's request and the request is being processed.

Another example of feedback is that the software will acquire the confirmation from user whether the user really wants to perform any task such as saving file, printing

file or quitting the programme. With this kind of feedback, user will not make any mistakes such as quitting the programme without saving the current work.

4.4.2.5 PRINCIPLE 3: SIMPLICITY

This software has been created with simple, organize, clear and easy to understand interfaces. The background colour of the main interfaces is navy blue (dark background) with white font (light text) while the background colour for the extra interfaces such as the information and user guide pages, is light blue (light background) with black font (dark text). In addition, the information and instructions on how to perform the forecasting activities are adequate, clear and readable.

4.4.2.6 PRINCIPLE 4: STRUCTURE

The availability of link icons has provided great shortcuts which improved the difficulty to get from one screen to another. In this software, since the Regression Analysis consists of two main interfaces, only Regression Page has the link to Regression Table Page. Thus, it meets the criteria in which the connected items should be grouped together.

4.4.2.7 PRINCIPLE 5: CONSISTENCY

All icons are placed at the same position and behave the same way through out the software. The appearance of each icon remains the same and does not change.

4.4.2.8 PRINCIPLE 6: TOLERANCE

There are "RESET" buttons in Regression Page, Regression (Table) Page and also Curve Fit Page. User clicks at this button to clear the data that have been entered into the system. This software also prevent user from creating errors. For example, when user key-in wrong value in the textboxes inside the Regression or Curve Fit page, error message box will immediately pop-up to warn the user that mistakes have been performed.

Table 8 : Comparison of Software to the Law of User-Interface Design

| LAW | Does PGEN meet the Law? |
|--|--------------------------------|
| User's work is NOT harm even through idleness | YES |
| Simplify user's work with less time to consume | YES |

Table 9 : Comparison of Software to the User-Interface Design Principles

| PRINCIPLES | Does P.Gen meet the principles? |
|--------------------|--|
| VISIBILITY | YES |
| FEEDBACK | YES |
| CONSISTENCY | YES |
| SIMPLICITY | YES |
| STRUCTURE | YES |
| TOLERANCE | YES |

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A software that incorporates models to estimate power generation has been developed. It has served as an initial prototype to estimate power generation. The software simplifies the user's work and is harmless to any programme. This software provides two options to forecast power generation. Thus, it has visible, interactive and easy to understand interface with shortcuts to move from one screen to another. The two options are based on the two models namely, Multiple Linear Regression Model and Curve Fit Model. In order to generate these models, relevant variables that contribute to Power Generation were identified. They include Power Losses, Population Growth, Power Consumption by four major sectors namely Industrial, Commercial, Domestic and Public Lighting Sector, and finally, the Electricity Installed Capacity which consists of Conventional Thermal and Hydro Capacity. The models are as below:

$$\text{Generation of Electricity} = - 0.0037 X^3 + 0.2612 X^2 - 1.1731 X + 12.364;$$

where X : Years

Figure 20 : Multiple Linear Regression Model

$$Y = 0.377 X_{\text{Losses}} - 0.094 X_{\text{Domestic-1}} + 0.583 X_{\text{Commercial}} + 0.288 X_{\text{Industrial}} \\ - 0.082 X_{\text{Public Lighting}} - 0.127 X_{\text{Thermal}} - 0.047 X_{\text{Hydro}} + 0.094 X_{\text{Population-1}}$$

Figure 21 : Curve Fit Model

5.2 Recommendations

This project could be further developed via more sophisticated modeling techniques. The developer can add more data and reconstruct better Regression Model by developing multiple non-linear regression models. Furthermore, developer should improve the model by reducing the error between the predicted power generation and the actual power generation. This is by utilizing an advance statistical approach. On top of that, developer can also develop dynamic models rather than static models. Dynamic models will be able to give better prediction since it can be changed according to time. Thus, it can always be improved according to the latest data collected.

Meanwhile, more models can be incorporated inside this software so that more options are given to the planner to forecast power generation. Extra features of this software can also be added. Report Generator link can be activated by providing the user the power to create their own report by manipulating the previous data and the forecast data. Moreover, the software can be further enhanced so that it can be developed into a better system rather than just a simple forecasting software.

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APPENDICES

APPENDIX A
GANTT CHART

| Final Year Project I Gantt Chart (Semester July 06) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|
| No. | Detail/ Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1 | Selection of Project Topic | | | | | | | | | | | | | | | |
| | - Propose Topic | | | | | | | | | | | | | | | |
| | - Topic assigned to students | | | | | | | | | | | | | | | |
| 2 | Preliminary Research Work | | | | | | | | | | | | | | | |
| | - Introduction | | | | | | | | | | | | | | | |
| | - Objective | | | | | | | | | | | | | | | |
| | - List of references/literature | | | | | | | | | | | | | | | |
| | - Project planning | | | | | | | | | | | | | | | |
| 3 | Submission of Preliminary Report | | | | | | | | | | | | | | | |
| 4 | Project Work | | | | | | | | | | | | | | | |
| | -Reference/Literature | | | | | | | | | | | | | | | |
| | -Data Gathering | | | | | | | | | | | | | | | |
| 5 | Submission of Progress Report | | | | | | | | | | | | | | | |
| 6 | Project work continue | | | | | | | | | | | | | | | |
| | -Data Gathering | | | | | | | | | | | | | | | |
| 7 | Submission of Interim Report Final Draft | | | | | | | | | | | | | | | |
| 8 | Submission of Interim Report | | | | | | | | | | | | | | | |
| 9 | Oral Presentation | | | | | | | | | | | | | | | |

Figure A1: Gantt chart for the First Semester

Final Year Project II Gantt Chart (Sem Jan 07)

| Detail/Week | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 |
|-------------|---|---|---|-------|--------|--------|--------|-------|--------|--------|--------|-------|----|----|--------|----|-------|-----------|----|----|-----------|--------|
| No | Date/Day | | | MON | 12-Feb | WED | MON | MON | 10-Mar | 19-Mar | MON | MON | | | MON | | WED | MON | | | 8-Jun | FRI |
| | | | | 5-Feb | 16-Feb | 21-Feb | 26-Feb | 5-Mar | 18-Mar | 23-Mar | 26-Mar | 2-Apr | | | 23-Apr | | 9-May | 14-May | | | 8-Jun | 22-Jun |
| | | | | | | | | | | | | | | | | | STUDY | EXAM WEEK | | | SEM BREAK | |
| 1 | MODELING | | | | | | | | M | | | | | | | | | | | | | |
| | Regression | | | | | | | | I | | | | | | | | | | | | | |
| | Curve Fitting | | | | | | | | D | | | | | | | | | | | | | |
| 2 | SOFTWARE DEVELOPMENT | | | | | | | | T | | | | | | | | | | | | | |
| | Interface | | | | | | | | E | | | | | | | | | | | | | |
| | Curve Fitting (Result in Table & Graph) | | | | | | | | R | | | | | | | | | | | | | |
| | Regression (Result & Table) | | | | | | | | W | | | | | | | | | | | | | |
| | Link | | | | | | | | | | | | | | | | | | | | | |
| | Extra Features (Help, Info, About, Save, Print) | | | | | | | | | | | | | | | | | | | | | |
| | Error Message Box | | | | | | | | R | | | | | | | | | | | | | |
| | Program Exe File | | | | | | | | E | | | | | | | | | | | | | |
| 3 | REPORT SUBMISSION | | | | | | | | A | | | | | | | | | | | | | |
| | Logbook Week 2 | | | | | | | | K | | | | | | | | | | | | | |
| | Logbook Week 3 | | | | | | | | | | | | | | | | | | | | | |
| | Progress Report 1 | | | | | | | | M | | | | | | | | | | | | | |
| | Logbook Week 4 | | | | | | | | I | | | | | | | | | | | | | |
| | Logbook Week 5 | | | | | | | | D | | | | | | | | | | | | | |
| | Logbook Week 6 | | | | | | | | T | | | | | | | | | | | | | |
| | Logbook Week 7 | | | | | | | | E | | | | | | | | | | | | | |
| | Progress Report 2 | | | | | | | | R | | | | | | | | | | | | | |
| | Logbook Week 8 | | | | | | | | M | | | | | | | | | | | | | |
| | Logbook Week 9 | | | | | | | | | | | | | | | | | | | | | |
| | Draft Report | | | | | | | | B | | | | | | | | | | | | | |
| | Final Software | | | | | | | | R | | | | | | | | | | | | | |
| | Technical Report | | | | | | | | E | | | | | | | | | | | | | |
| | Final Handover | | | | | | | | A | | | | | | | | | | | | | |
| 4 | Pre-EDX | | | | | | | | K | | | | | | | | | | | | | |
| | Poster and Slide Show | | | | | | | | | | | | | | | | | | | | | |
| 5 | ORAL PRESENTATION | | | | | | | | | | | | | | | | | | | | | |

APPENDIX B

DATABASE

Table B1: Data for Net Power Generation in Malaysia and Data for all variables that affect it

| Year | Net Power Generation | Electricity Consumption | | | | Power Losses | Population | Electricity Installed Capacity | | |
|------|----------------------|-------------------------|------------|------------|-----------------|--------------|------------|--------------------------------|-------|--------|
| | | Domestic | Commercial | Industrial | Public Lighting | | | Conventional Thermal | Hydro | Total |
| | Billion kWh | Billion kWh | | | | Billion kWh | Million | Million kW | | |
| 1980 | 10.186 | 1.454 | 2.515 | 3.952 | 0.080 | 0.713 | 13.764 | 2.399 | 0.606 | 3.046 |
| 1981 | 10.895 | 1.647 | 2.713 | 4.124 | 0.088 | 0.763 | 14.128 | 2.440 | 0.649 | 3.089 |
| 1982 | 11.498 | 1.783 | 2.884 | 4.311 | 0.091 | 0.805 | 14.507 | 2.468 | 0.674 | 3.142 |
| 1983 | 12.686 | 1.999 | 2.972 | 4.445 | 0.888 | 0.917 | 14.888 | 2.551 | 0.767 | 3.318 |
| 1984 | 13.651 | 2.389 | 3.660 | 4.988 | 0.114 | 0.965 | 15.272 | 2.725 | 0.954 | 3.679 |
| 1985 | 14.995 | 2.684 | 4.145 | 5.138 | 0.118 | 1.050 | 15.682 | 2.993 | 1.035 | 4.028 |
| 1986 | 16.287 | 2.898 | 4.434 | 5.392 | 0.131 | 1.070 | 16.110 | 3.133 | 1.040 | 4.173 |
| 1987 | 17.616 | 3.181 | 4.753 | 5.978 | 0.138 | 1.153 | 16.526 | 3.350 | 1.251 | 4.601 |
| 1988 | 19.361 | 3.324 | 5.020 | 6.506 | 0.145 | 1.291 | 16.942 | 3.400 | 1.422 | 4.822 |
| 1989 | 21.890 | 3.571 | 5.446 | 8.251 | 0.174 | 1.455 | 17.353 | 3.480 | 1.437 | 4.917 |
| 1990 | 25.262 | 3.989 | 6.030 | 9.487 | 0.185 | 1.677 | 17.756 | 3.530 | 1.437 | 4.967 |
| 1991 | 28.335 | 4.395 | 6.611 | 11.190 | 0.192 | 1.877 | 18.328 | 3.580 | 1.457 | 5.037 |
| 1992 | 31.887 | 4.879 | 7.453 | 13.121 | 0.203 | 1.943 | 18.762 | 4.606 | 1.454 | 6.060 |
| 1993 | 35.579 | 5.229 | 8.121 | 15.153 | 0.227 | 2.302 | 19.564 | 5.155 | 1.545 | 6.700 |
| 1994 | 40.058 | 6.320 | 9.431 | 17.576 | 0.261 | 2.595 | 20.112 | 5.280 | 1.577 | 6.857 |
| 1995 | 46.656 | 7.010 | 10.861 | 20.015 | 0.288 | 3.011 | 20.689 | 7.340 | 1.660 | 9.000 |
| 1996 | 52.999 | 7.532 | 12.280 | 22.690 | 0.328 | 3.399 | 21.169 | 8.840 | 1.760 | 10.600 |
| 1997 | 58.674 | 8.637 | 13.886 | 26.710 | 0.379 | 3.820 | 21.666 | 10.268 | 2.232 | 12.500 |
| 1998 | 60.471 | 9.847 | 14.809 | 25.939 | 0.425 | 4.009 | 22.180 | 11.516 | 2.025 | 13.541 |
| 1999 | 62.546 | 9.821 | 15.413 | 28.580 | 0.619 | 4.316 | 22.712 | 11.502 | 2.104 | 13.606 |
| 2000 | 66.678 | 10.866 | 16.866 | 32.534 | 0.621 | 4.580 | 23.495 | 10.882 | 1.814 | 12.696 |
| 2001 | 72.280 | 11.653 | 17.901 | 33.293 | 0.655 | 4.720 | 24.013 | 11.708 | 2.054 | 13.762 |
| 2002 | 75.328 | 13.041 | 19.417 | 34.162 | 0.742 | 4.901 | 24.527 | 12.695 | 2.118 | 14.813 |
| 2003 | 84.022 | 13.848 | 20.894 | 36.396 | 0.861 | 5.181 | 25.048 | 13.565 | 2.106 | 15.671 |
| 2004 | 90.661 | 14.243 | 22.082 | 38.110 | 0.760 | 5.477 | 25.581 | 18.004 | 2.078 | 20.082 |

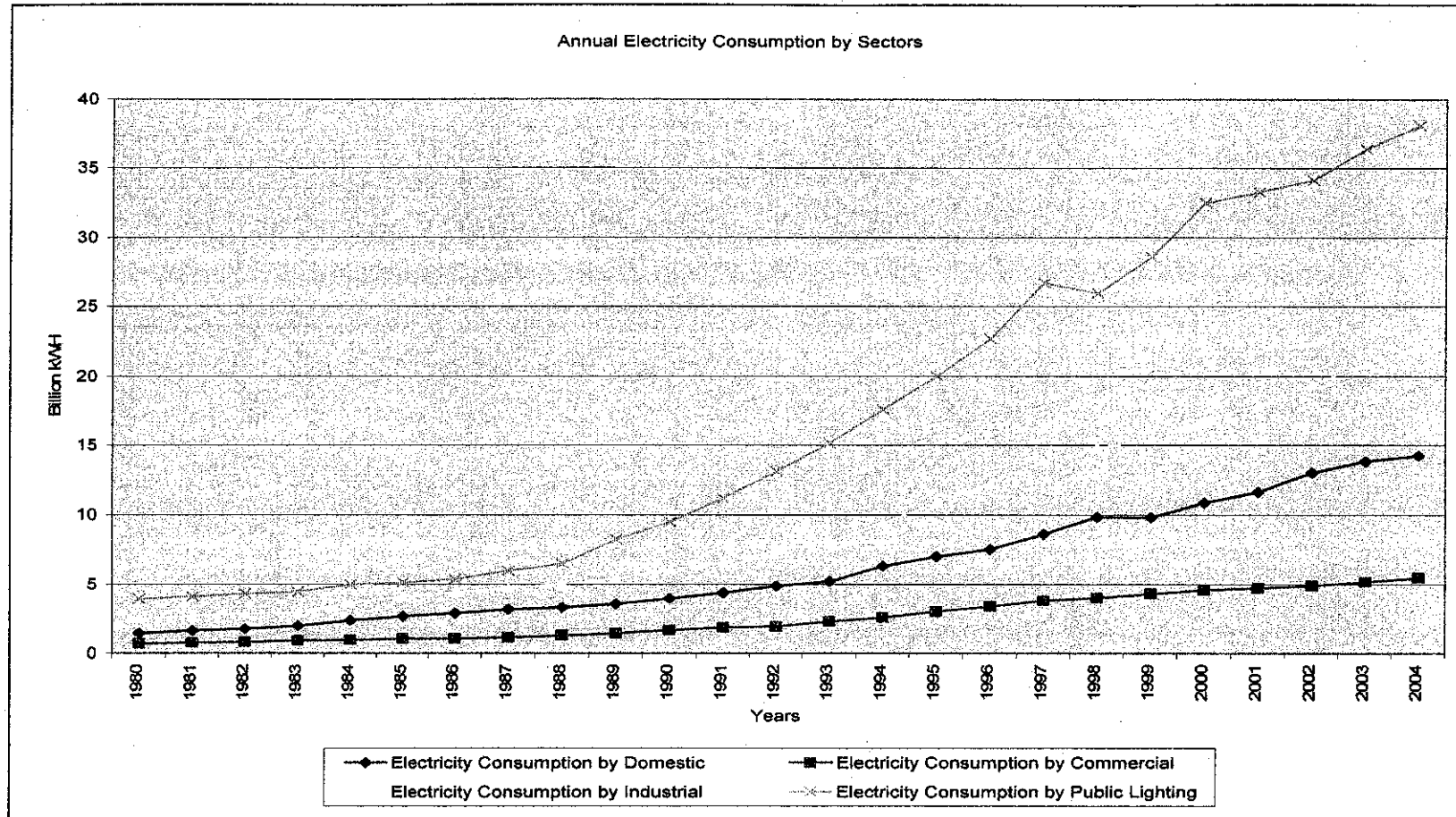


Figure B1: Graph for Annual Consumption of Electricity by Sectors

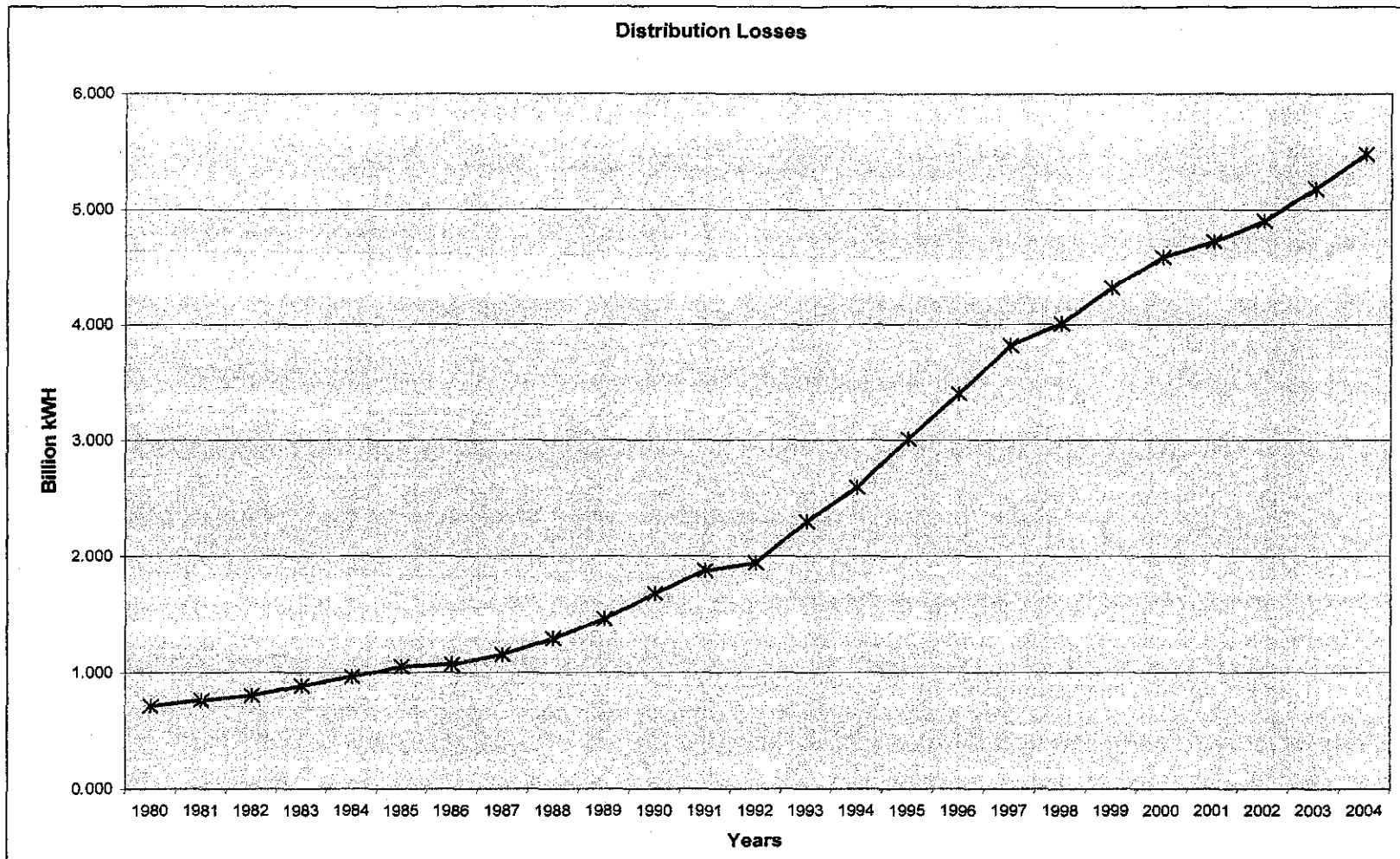


Figure B2: Graph for Power Losses

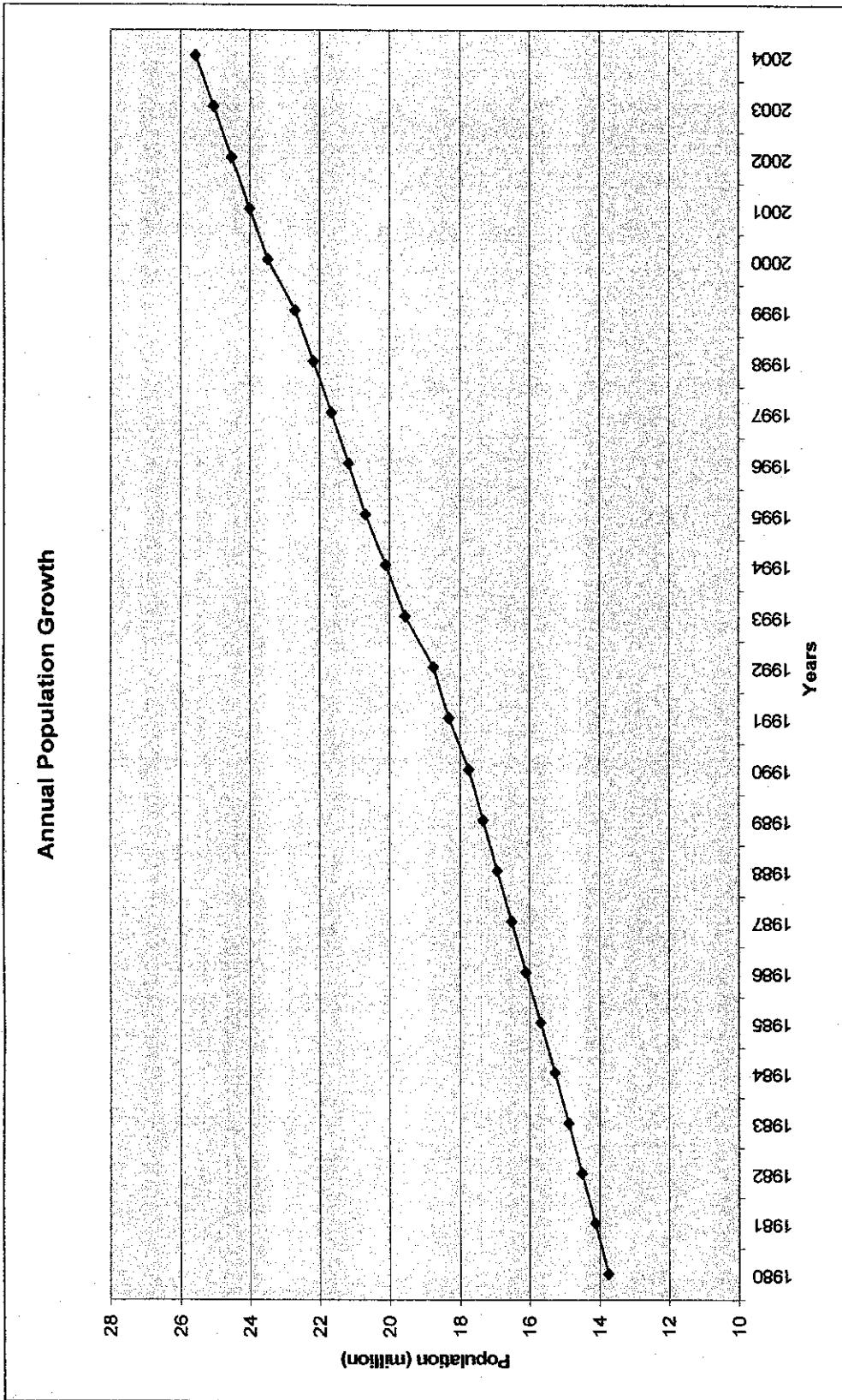


Figure B3: Graph for Annual Population Growth

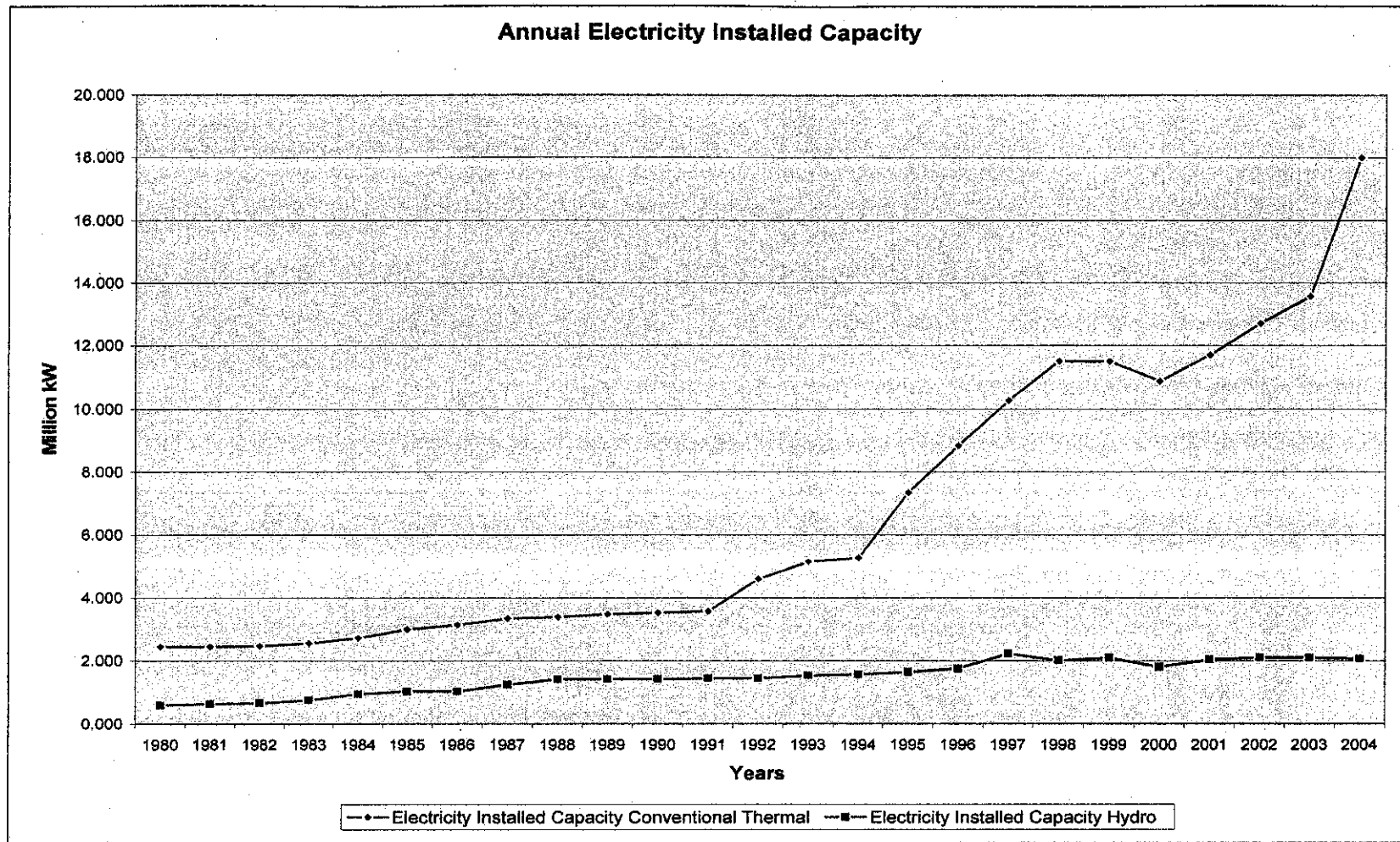


Figure B4: Graph for Annual Electricity Installed Capacity

APPENDIX C

REGRESSION MODELING

Descriptive Statistics

| | Mean | Std. Deviation | N |
|-----------------------------------|----------|----------------|----|
| NetGenerationOfElectricity | 30.59716 | 17.935847 | 19 |
| DistributionLosses | 2.02047 | 1.173838 | 19 |
| LAGS(Domestic,1) | 4.35621 | 2.476851 | 19 |
| ConsumptionIn CommercialSector | 7.41695 | 4.189554 | 19 |
| ConsumptionIn IndustrialSector | 12.61021 | 8.514476 | 19 |
| ConsumptionForPublic Lighting | .22163 | .137050 | 19 |
| CapacityConventional Thermal | 5.16616 | 3.125719 | 19 |
| CapacityHydro | 1.39368 | .460215 | 19 |
| LAGS(Population,1) | 17.49463 | 2.640735 | 19 |

Variables Entered/Removed^b

| Model | Variables Entered | Variables Removed | Method |
|-------|--|-------------------|--------|
| 1 | LAGS(Population,1), ConsumptionFor Public Lighting, Capacity Hydro, Capacity Conventional Thermal, ConsumptionIn Industrial Sector, LAGS(Domestic,1), ConsumptionIn CommercialSector, DistributionLosses ^a | | Enter |

a. All requested variables entered.

b. Dependent Variable: NetGenerationOfElectricity

Model Summary^b

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|--------------------|----------|-------------------|----------------------------|
| 1 | 1.000 ^a | 1.000 | 1.000 | .400090 |

- a. Predictors: (Constant), LAGS(Population,1), ConsumptionForPublicLighting, CapacityHydro, CapacityConventionalThermal, ConsumptionInIndustrialSector, LAGS(Domestic,1), ConsumptionInCommercialSector, DistributionLosses
- b. Dependent Variable: NetGenerationOfElectricity

ANOVA^b

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|-------|------------|----------------|----|-------------|----------|-------------------|
| 1 | Regression | 5788.902 | 8 | 723.613 | 4520.553 | .000 ^a |
| | Residual | 1.601 | 10 | .160 | | |
| | Total | 5790.503 | 18 | | | |

- a. Predictors: (Constant), LAGS(Population,1), ConsumptionForPublicLighting, CapacityHydro, CapacityConventionalThermal, ConsumptionInIndustrialSector, LAGS(Domestic,1), ConsumptionInCommercialSector, DistributionLosses
- b. Dependent Variable: NetGenerationOfElectricity

Residuals Statistics^a

| | Minimum | Maximum | Mean | Std. Deviation | N |
|----------------------|----------|----------|----------|----------------|----|
| Predicted Value | 10.81700 | 62.57730 | 30.59716 | 17.933368 | 19 |
| Residual | -.566979 | .533771 | .000000 | .298209 | 19 |
| Std. Predicted Value | -1.103 | 1.783 | .000 | 1.000 | 19 |
| Std. Residual | -1.417 | 1.334 | .000 | .745 | 19 |

- a. Dependent Variable: NetGenerationOfElectricity

Correlations

| | | Net Generation Of Electricity | Distribution Losses | LAGS(Domestic,1) | Consumption In Commercial Sector | Consumption In Industrial Sector | Consumption For Public Lighting | Capacity Conventional Thermal | Capacity Hydro | LAGS(Population,1) |
|---------------------|--------------------------------|-------------------------------|---------------------|------------------|----------------------------------|----------------------------------|---------------------------------|-------------------------------|----------------|--------------------|
| Pearson Correlation | NetGenerationOfElectricity | 1.000 | .998 | .975 | .997 | .998 | .940 | .971 | .933 | .950 |
| | DistributionLosses | .998 | 1.000 | .980 | .998 | .997 | .956 | .978 | .929 | .947 |
| | LAGS(Domestic,1) | .975 | .980 | 1.000 | .980 | .970 | .962 | .957 | .915 | .966 |
| | ConsumptionIn CommercialSector | .997 | .988 | .980 | 1.000 | .995 | .954 | .981 | .936 | .949 |
| | ConsumptionIn IndustrialSector | .998 | .997 | .970 | .995 | 1.000 | .945 | .971 | .920 | .937 |
| | ConsumptionForPublic Lighting | .940 | .956 | .962 | .954 | .945 | 1.000 | .951 | .875 | .900 |
| | CapacityConventional Thermal | .971 | .978 | .957 | .981 | .971 | .951 | 1.000 | .882 | .918 |
| | CapacityHydro | .933 | .929 | .915 | .936 | .920 | .875 | .882 | 1.000 | .935 |
| | LAGS(Population,1) | .950 | .947 | .966 | .949 | .937 | .900 | .918 | .935 | 1.000 |
| Sig. (1-tailed) | NetGenerationOfElectricity | | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| | DistributionLosses | .000 | | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| | LAGS(Domestic,1) | .000 | .000 | | .000 | .000 | .000 | .000 | .000 | .000 |
| | ConsumptionIn CommercialSector | .000 | .000 | .000 | | .000 | .000 | .000 | .000 | .000 |
| | ConsumptionIn IndustrialSector | .000 | .000 | .000 | .000 | | .000 | .000 | .000 | .000 |
| | ConsumptionForPublic Lighting | .000 | .000 | .000 | .000 | .000 | | .000 | .000 | .000 |
| | CapacityConventional Thermal | .000 | .000 | .000 | .000 | .000 | .000 | | .000 | .000 |
| | CapacityHydro | .000 | .000 | .000 | .000 | .000 | .000 | .000 | | .000 |
| | LAGS(Population,1) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |
| N | NetGenerationOfElectricity | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | DistributionLosses | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | LAGS(Domestic,1) | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | ConsumptionIn CommercialSector | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | ConsumptionIn IndustrialSector | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | ConsumptionForPublic Lighting | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | CapacityConventional Thermal | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | CapacityHydro | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | LAGS(Population,1) | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |

Coefficients ^a

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Correlations | | | Collinearity Statistics | |
|-------|-------------------------------|-----------------------------|------------|---------------------------|--------|------|--------------|---------|-------|-------------------------|---------|
| | | B | Std. Error | Beta | | | Zero-order | Partial | Part | Tolerance | VIF |
| 1 | (Constant) | -6.784 | 2.273 | | -2.985 | .014 | | | | | |
| | DistributionLosses | 5.766 | 2.288 | .377 | 2.520 | .030 | .998 | .623 | .013 | .001 | 811.362 |
| | LAGS(Domestic,1) | -.680 | .373 | -.094 | -1.822 | .098 | .975 | -.499 | -.010 | .010 | 96.118 |
| | ConsumptionInCommercialSector | 2.498 | .627 | .583 | 3.983 | .003 | .997 | .783 | .021 | .001 | 776.398 |
| | ConsumptionInIndustrialSector | .607 | .192 | .288 | 3.155 | .010 | .998 | .706 | .017 | .003 | 301.714 |
| | ConsumptionForPublicLighting | -10.741 | 3.479 | -.082 | -3.087 | .011 | .940 | -.699 | -.016 | .039 | 25.565 |
| | CapacityConventionalThermal | -.729 | .242 | -.127 | -3.019 | .013 | .971 | -.691 | -.016 | .016 | 64.089 |
| | CapacityHydro | -1.834 | 1.038 | -.047 | -1.767 | .108 | .933 | -.488 | -.009 | .039 | 25.654 |
| | LAGS(Population,1) | .641 | .198 | .094 | 3.231 | .009 | .950 | .715 | .017 | .032 | 30.877 |

a. Dependent Variable: NetGenerationOfElectricity

Collinearity Diagnostics ^a

| Model | Dimension | Eigenvalue | Condition Index | Variance Proportions | | | | | | | | | |
|-------|-----------|------------|-----------------|----------------------|---------------------|------------------|----------------------------------|----------------------------------|---------------------------------|-------------------------------|----------------|--------------------|-----|
| | | | | (Constant) | Distribution Losses | LAGS(Domestic,1) | Consumption In Commercial Sector | Consumption In Industrial Sector | Consumption For Public Lighting | Capacity Conventional Thermal | Capacity Hydro | LAGS(Population,1) | |
| 1 | 1 | 8.623 | 1.000 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| | 2 | .328 | 5.124 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| | 3 | .021 | 20.316 | .00 | .00 | .00 | .00 | .01 | .31 | .00 | .02 | .00 | .00 |
| | 4 | .014 | 25.040 | .01 | .00 | .02 | .00 | .00 | .04 | .13 | .08 | .00 | .00 |
| | 5 | .007 | 34.080 | .00 | .00 | .16 | .00 | .00 | .12 | .04 | .15 | .00 | .00 |
| | 6 | .006 | 38.698 | .02 | .00 | .07 | .00 | .05 | .10 | .18 | .05 | .00 | .00 |
| | 7 | .001 | 114.321 | .47 | .00 | .08 | .11 | .14 | .07 | .06 | .00 | .45 | .00 |
| | 8 | .000 | 162.369 | .28 | .33 | .42 | .10 | .74 | .02 | .32 | .36 | .24 | .00 |
| | 9 | .000 | 223.474 | .21 | .66 | .25 | .79 | .06 | .33 | .27 | .34 | .30 | .00 |

a. Dependent Variable: NetGenerationOfElectricity

APPENDIX D

PGEN SOFTWARE

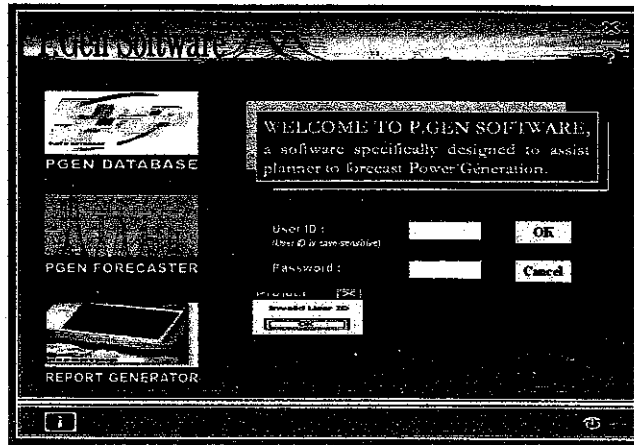


Figure D1: Error message box pop-ups when Invalid User ID or Password is entered

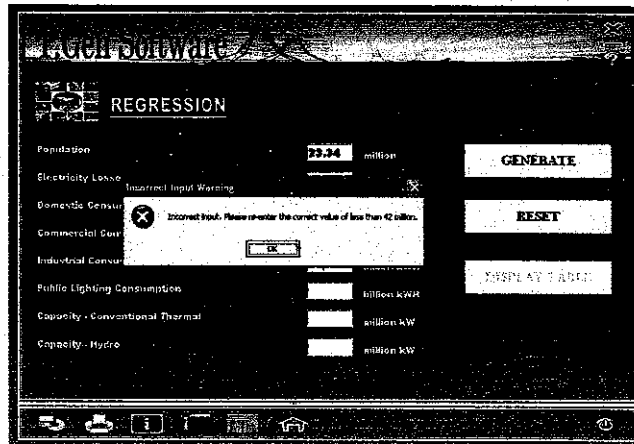


Figure D2: Error message box pop-ups when non-integer values or the value that exceeds the required range is entered inside the text box

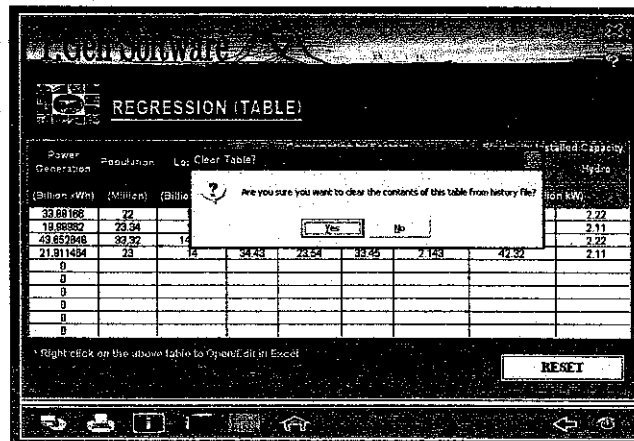


Figure D3: Confirmation to clear the table when RESET is clicked

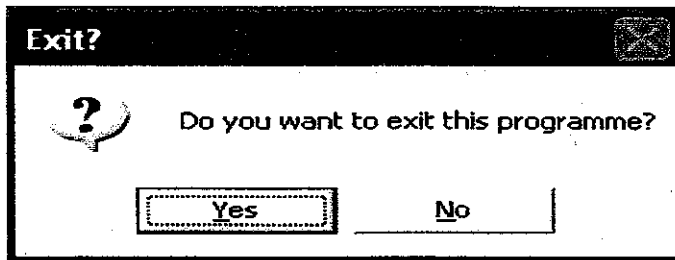


Figure D4: Confirmation to exit the programme

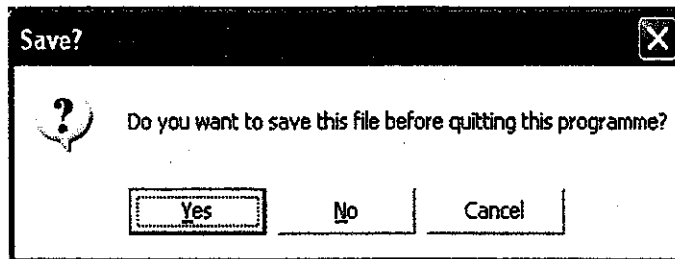


Figure D5: Confirmation to save the forecasted power generation

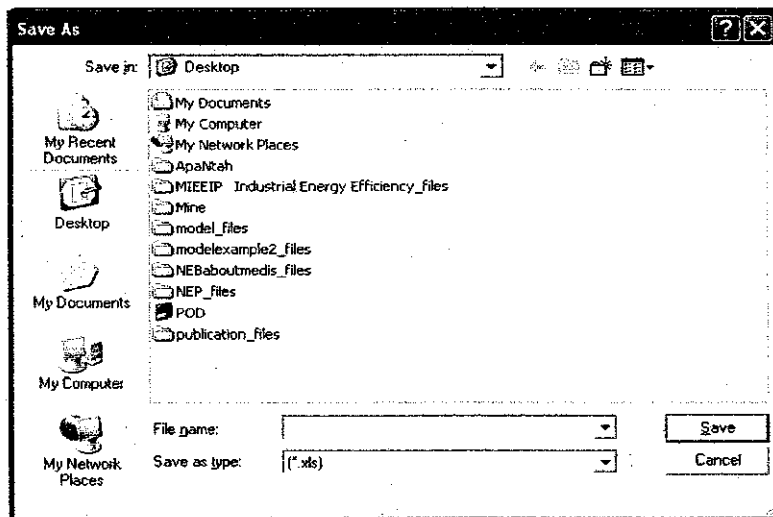


Figure D6: Saving forecast value

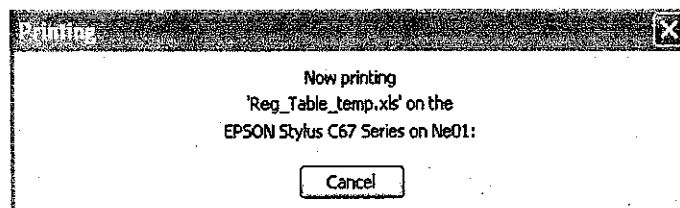


Figure D7: Printing in progress

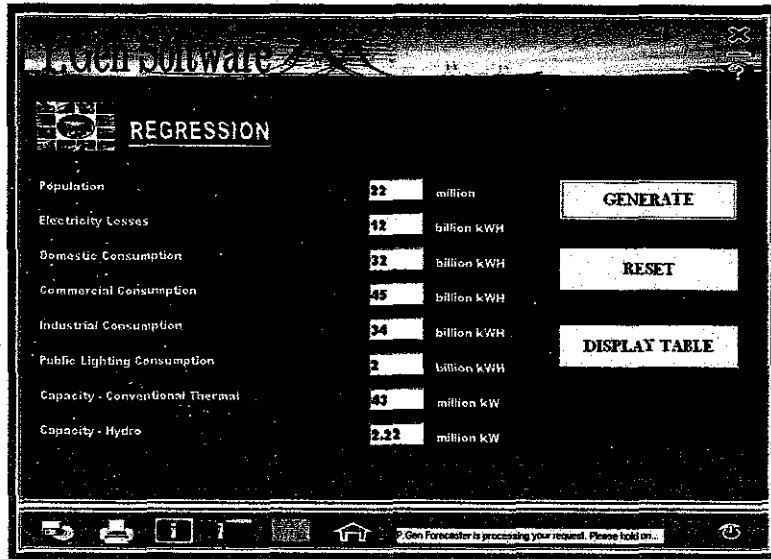


Figure D8: Status bar at the bottom of the interface to inform user that the software is processing the user's request to generate the forecast power generation

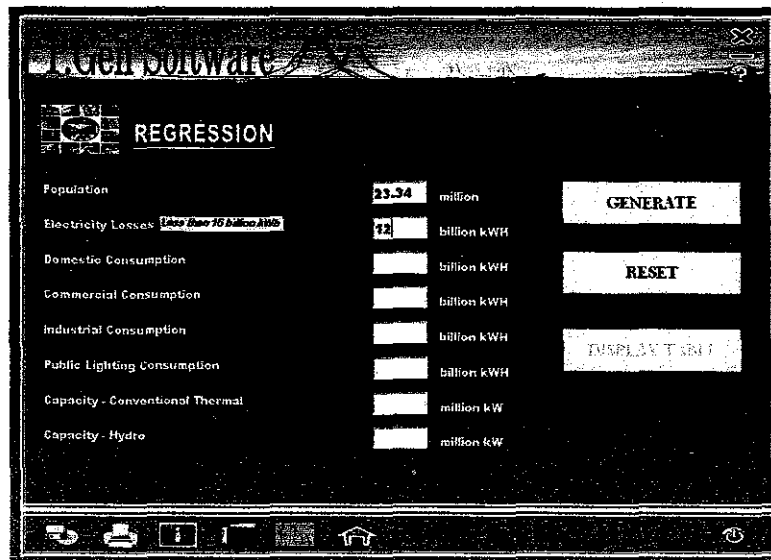


Figure D9:

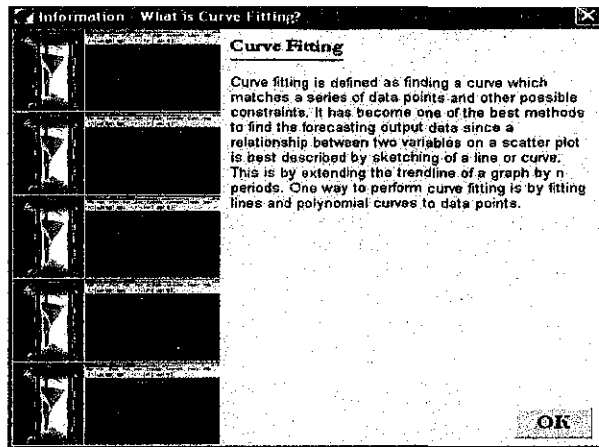


Figure D10: Information Page on Curve Fitting Analysis

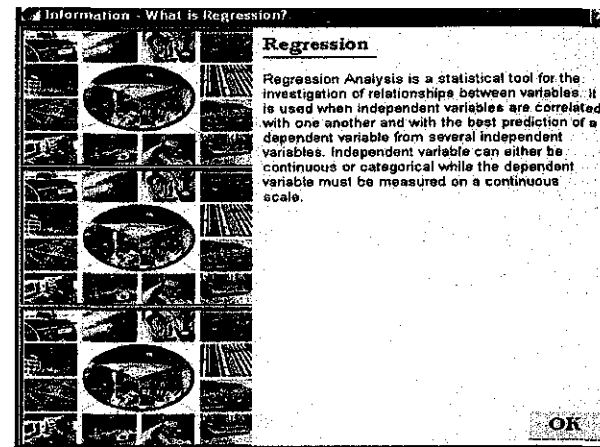


Figure D11: Information Page on Regression Analysis

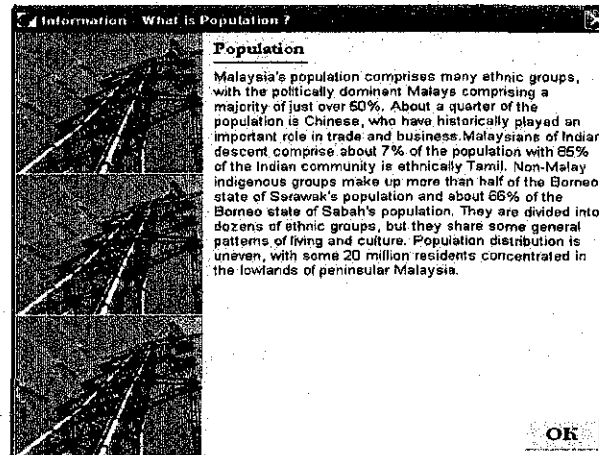


Figure D12: Information Page on Population Growth in Malaysia

(All other information pages are the same as Figure D12 except for the contents, which are different from one another)