Estimating Solar Energy Potential in Perak using Clearness Index and Artificial Neural Network

by

Abdul Faliq Qushairi bin Abdul Razak

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
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Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

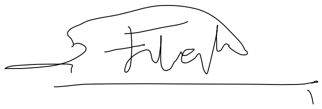
____

(Dr. Morteza Khalajji Assadi)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
Sept 2013

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.



ABDUL FALIQ QUSHAIRI BIN ABDUL RAZAK

ABSTRACT

This paper presents an estimation and comparison of monthly mean daily global solar radiation using clearness index and artificial neural network (ANN) in Seri Iskandar, Perak (4° 24'N latitude,100° 58'E longitude,24m altitude) with other cities in Malaysia. The study is needed to determine the solar data in Perak when there is no solar radiation data recorded due to several factors such as high cost and maintenance. Little work had been done to estimate the solar radiation in Perak states. None had been done in Seri Iskandar, Perak. Therefore, this study will provide a reliable and long term global radiation data needed in Perak states, thus giving benefits to the key players in solar industry. The outcomes of this study will be highly needed for technical and economical investigation for most of the areas with similar clearness index conditions that have no records of solar data.

In this study, the meteorological data from 2010 to 2012 consists of three cities (Ipoh, Bayan Lepas, KLIA) are used for calculating the clearness index and for training the neural network. The results of the clearness index are used to estimate the solar radiation in Seri Iskandar with the objectives to yield closer value to the measured data. As for neural network, the ANN model is based on the feed forward back propagation type that uses neurons from 3 to 25. The data from UTP Solar Research Site, Seri Iskandar (2010 – 2012) is used for testing the network developed. Estimated data obtained is then compared with the measured radiation data using statistical parameters such as root mean square error (RMSE).

Results obtained shows that the highest monthly mean global radiation is on February of the year (20.45 $MJ/m^2/day$). Annual average was 18.25 $MJ/m^2/day$ and the average clearness index is found to be 0.52. As for ANN, it is best to use neurons from 3 to 13 due to their stability in generating the required results. The best RMSE yields for clearness index and ANN is 0.39 and 1.02 respectively. The clearness index is more accurate compare to ANN when there is limited supply of data. In overall, Perak states is comparable with other states in Malaysia that is known already to have great solar intensity like Terengganu. Therefore, Perak states show a good prospect and have strong solar radiation for the applications of solar energy.

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ABBREVIATIONS & NOMENCLATURES

UTP	University Technology of PETRONAS
KLIA	Kuala Lumpur International Airport
ANN	Artificial Neural Network
RMSE	Root Mean Square Error
FYP	Final Year Project
LM	Levenberg Marquardt
MSEREG	Mean Square Error with Regularization

CHAPTER 1: INTRODUCTION

1.1 Background Study

Nowadays, energy situation becomes the most highlighted issues on the world with the increase in number of population that every other countries facing on. The conventional fossil fuels will be depleted soon, therefore, more focus and attentions has been given on renewable energy due to their limitless characteristics. This includes solar, wind, biomass, tidal etc. Figure 1.1 below shows a distribution in terms of renewable energy by type, used all around the world in 2012.

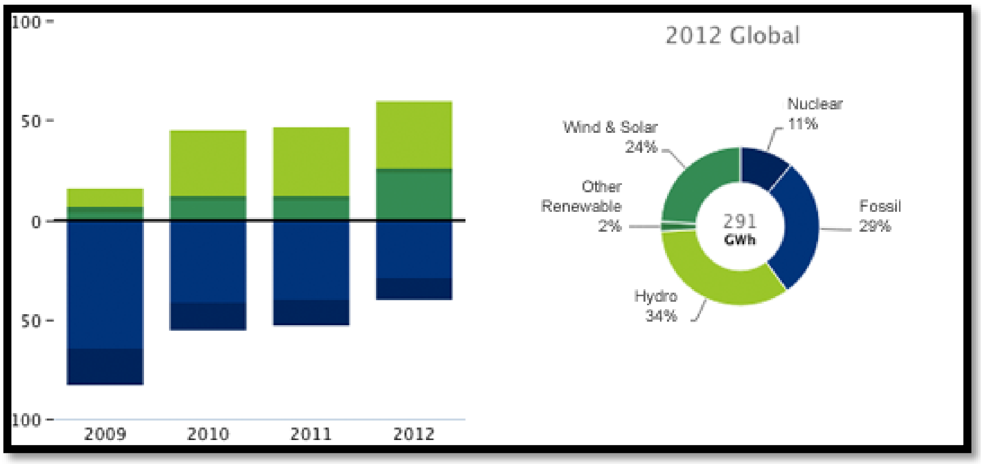

Figure 1.1: Chart distribution of global renewable energy 2012

From all kind of renewable energy shows earlier, solar energy becomes one of the type that been focus on by countries that receives vast amount of sunlight such as tropical country. Using sun as a source of energy, solar energy serves human beings for more than one application that not just to generate electricity, but for other applications as well such as water heating, battery charging and cooking. Not just that, it is reported that each year the amount of solar energy receives by the earth is approximately around 1000 PW of energy (Hasanuzzaman and Rahim, 2012).

By definition, solar energy or solar radiation is the total frequency spectrum of electromagnetic radiation that induced by the sun. It is classified by two main parts which are extraterrestrial solar radiation and the global solar radiation. The extraterrestrial solar radiation is basically the total solar energy outside the atmosphere while the global solar radiation is the total solar energy under the atmosphere.

This global solar radiation reaches the earth through two ways; with one of the way is direct radiation where the earth receives radiation directly from the sun. The second way is through diffuse radiation. By this way, the radiation from the sun is being blocked by some particles or molecules causing them to scatter all around the surface of the earth. The total of these two radiations form the global solar radiation which is the main subject to be investigated in this study.

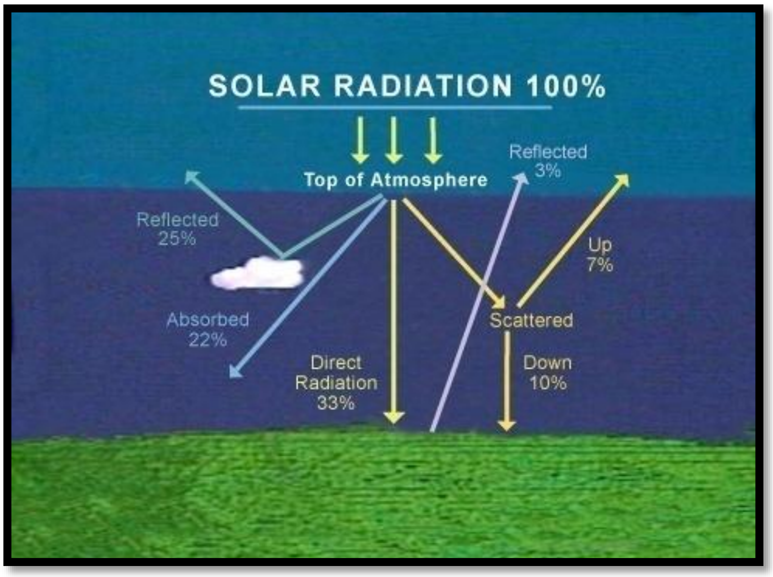

Figure 1.2: Distribution of solar radiation

Figure 1.2 shown above illustrates the percentage of radiation distributed after passing through the atmosphere. Only part of the radiation is being absorbed by the earth while some of it being reflected back towards space. The amount of solar radiation reaches the earth can vary greatly depending on many factors. This includes latitude, season of the year, atmosphere diffusion, shape of the surface as well as cloud cover. For instance, the cloud cover profoundly reduces the solar radiation up to 50% in which fluctuating the global solar radiation in the range of 2 kW/m^2 to 6 kW/m^2 daily (Khatib, Mohamed, Sopian and Mahmoud, 2012). Figure 1.3 below shows the annual global solar radiation that takes place around the world with the lighter color area receives great solar intensity.

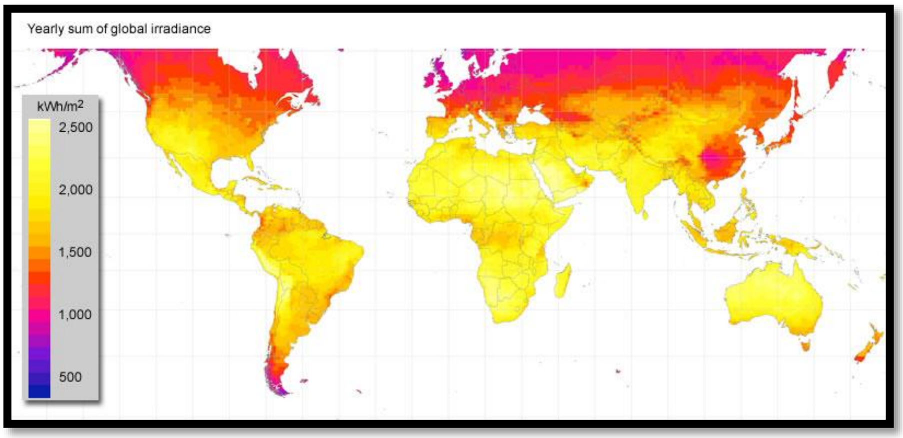

Figure 1.3: Annual global solar radiation around the world

While Figure 1.4 below shows the annual global solar radiation in Malaysia (Mekhilef et al., 2012). The solar intensity is great on the darker color areas.

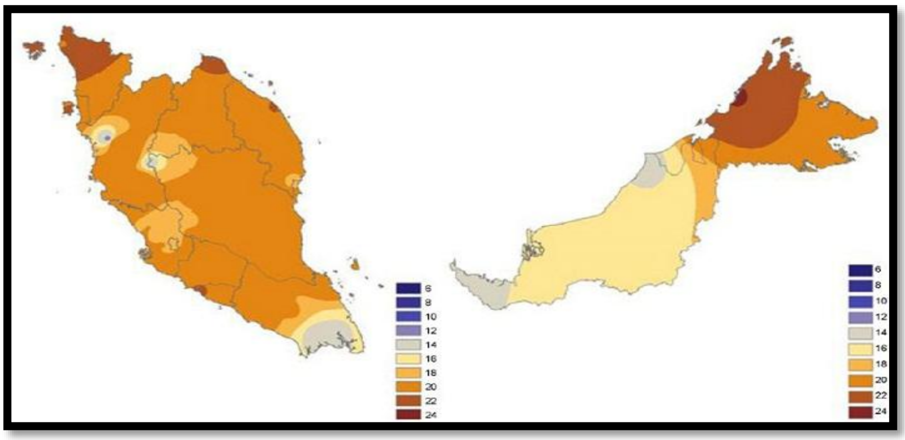

Figure 1.4: Annual global solar radiation in Malaysia

In Figure 1.3, it can be seen that the solar radiation have a greater intensity on the equatorial region with the average yearly sum radiation above 1500 kWh/m^2. As for Malaysia itself which is also located in the equatorial region, it can be seen that Malaysia also receives vast amounts of sunlight with most of them lies on the peninsular Malaysia and Sabah states. Thus, from the first observation, Malaysia is one of the good prospects and has great potential to take full use of solar energy.

1.2 Problem Statement

As a developing country, Malaysia shows an increase in the energy consumption each year (*10th Malaysian Plan*, n.d.). Aside from relying on conventional fossil fuel, the approach towards renewable energy has been considered to support the energy demand in Malaysia. Furthermore, the 9th Malaysia plan showed that Malaysia fails to achieve the renewable energy target. Lies on the equatorial region, Malaysia have become a good prospect to adapt solar energy in this time being. However, there is not much solar radiation data aside from the one coming from meteorological stations which mostly available in one city per state and is not accurate enough to cover the whole state due to large areas including Perak. Therefore, this study will provide the method to estimate the data in Perak states using clearness index and ANN, so that comparison can be made with other studies using the same method of other cities within Malaysia. It will be useful for technical and economical investigations for the industry player before operating the solar energy systems.

1.3 Objective

The main objective of the study is to provide fundamental inputs for solar energy applications to major key players in private sector and government itself. This is in correlation with the current 10th Malaysia Plan which is to achieve the renewable energy target of 985MW by 2015 to contribute 5.5% of total electricity generation. Specifically, this study aims to:

i. Estimates monthly mean daily solar global horizontal radiation in Seri Iskandar using clearness index and ANN.

ii. Compares the results obtained between the clearness index with other cities in Malaysia and ANN modelling technique.

1.4 Scope of Study

This study focuses on the monthly mean daily global radiation in Seri Iskandar using the clearness index and ANN as the estimation technique. As a matter of fact, direct solar radiation and diffuse radiation will not be included in this study. Moreover, this study is not about measuring the solar radiation as the data required can be obtained from meteorological stations in Malaysia.

1.5 Relevancy of the Project

This project is highly relevant with the Mechanical Engineering Programme as it directly involves with the Alternative Energy course which is one of the specialization courses of the programme. This project will use MATLAB software, which is one of the widely used simulation software in engineering study. Furthermore, this energy-based project is highly related with the industry nowadays due to increase in awareness regarding the energy problem in conjunction with the industrial globalization. Therefore, this kind of project is highly relevant to be part of FYP research.

1.6 Feasibility of the Project

In term of feasibility, this project is highly feasible and could be finish within the time frame given (26 weeks). The MATLAB software to be used is widely available and can be access freely in any laboratory in Block-19, UTP. Besides, there are also a number of experience post graduate students that have been using this software as part of their project. This project is divided into two types, the calculation and the simulation. Preferences and more time should be given on the literature review and the understanding of MATLAB programming. The author has planned to finish these two things within FYP I period. The results and discussions shall be start when the FYP II commenced. This could save a lot of time, thus making this project feasible so that it can be finish within stipulated time.

CHAPTER 2: LITERATURE REVIEW

2.1 Clearness Index Estimation Method

The monthly average clearness index, K_T, is defined as the ratio of monthly average daily radiation on a horizontal surface, H_M to the monthly average daily extraterrestrial radiation, H_O. It may vary from around 0.8 to nearer 0.2 depending on the clearness conditions. Kudish and Ianetz (1995) defined this clearness index into three categories upon the analysis of the Beer Sheva (cities in Israel) data, as follows:

Clear days: $K_T > 0.65$

Partially cloudy days: $0.35 < K_T < 0.65$

Cloudy days: $K_T < 0.35$

According to the definition, the equation form for this method is as follow:

$$\frac{H_M}{H_o} = K_T \qquad (2.1)$$

Where, both H_M and H_o is in $MJm^{-2}d^{-1}$. This value of H_o is somehow leads to another bigger equation as follows.

$$H_o = \frac{24}{\pi} I_{sc} \left(1 + 0.033 \cos\frac{360D}{365}\right) \left(cos\varphi cos\delta sin\omega_s + \frac{2\pi\omega_s}{360} sin\varphi sin\delta\right) \qquad (2.2)$$

Where, $I_{sc}, D, \varphi, \delta$ and ω_s are solar constant (1367 $\frac{W}{m^2}$), number of the days of the year starting from first January, latitude of the site (°), solar declination (°) and instant sunrise hour angle for the given month respectively. The solar declination and the instant sunrise hour angle can be computed by two equations below respectively (Duffie and Beckman, 1991).

$$\delta = 23.45 sin\left[\frac{360\,(D+284)}{365}\right] \qquad (2.3)$$

$$\omega_s = \cos^{-1}(-tan\delta tan\varphi) \qquad (2.4)$$

As for the D value which is the important variable to compute all those equation, Duffie and Beckman (1991) stated to use the Table 2.1 below with the requirements to use it only for the latitude below 66.5°.

Table 2.1: Recommended average days for months and values of D by months

Month	D for *i*th Day of Month	For Average Day of Month		
		Date	D	δ
January	*i*	17	17	-20.9
February	*31+i*	16	47	-13
March	*59+i*	16	75	-2.4
April	*90+i*	15	105	9.4
May	*120+i*	15	135	18.8
June	*151+i*	11	162	23.1
July	*181+i*	17	198	21.2
August	*212+i*	16	228	13.5
September	*243+i*	15	258	2.2
October	*273+i*	15	288	-9.6
November	*304+i*	14	318	-18.9
December	*334+i*	10	344	-23

The estimation using clearness index had been used in many countries. Two decade ago, Kudish and Ianetz (1995) made a daily analysis for the global and beam radiation in Beer Sheva, Israel. In the same year, Hinai and Alawi (1995) estimated clearness index for a typical day to come out with hourly value of solar radiation components such as beam and diffuse in Oman. These are one of the earliest attempts to estimate using the clearness index. Still in Oman, Ali, Atsu & Joseph (2002) estimates the clearness index through neural network which in then coming out with the monthly mean global radiation as their results. For recent example, Poudyal et. al (2012) estimates the global solar radiation using clearness index and cloud-transmittance factor in Nepal.

In Malaysia, few works been conducted to estimate solar radiation using clearness index method. The only relevant study made was by Muzathik (2013) in estimating global solar radiation using clearness index in Kuala Terengganu. In his study, he compared the results in Kuala Terengganu with other cities including Kota Kinabalu, Kota Bharu and Kuching that been done in a study by Kamaruzzaman and Sopian (1992). These studies however only involve the east coastal region and Borneo region. Table 2.2 and Table 2.3 in the following show the values of clearness index and global solar radiation in cities within east coastal region and Borneo region.

Table 2.2: Monthly and annually average clearness index of Kuala Terengganu, Kuching, Kota Kinabalu and Kota Bharu (Muzathik, 2013)

Months	**Clearness Index**			
	Kuala Terengganu	**Kuching**	**Kota Kinabalu**	**Kota Bharu**
January	0.54	0.35	0.55	0.51
February	0.62	0.38	0.57	0.52
March	0.57	0.41	0.56	0.53
April	0.64	0.36	0.59	0.54
May	0.54	0.37	0.53	0.48
June	0.48	0.48	0.53	0.48
July	0.53	0.45	0.51	0.45
August	0.53	0.41	0.51	0.46
September	0.53	0.43	0.50	0.50
October	0.44	0.41	0.53	0.47
November	0.49	0.41	0.53	0.39
December	0.42	0.36	0.54	0.37
Annual Average	0.53	0.40	0.54	0.47

Table 2.3: Monthly mean daily values of global solar radiation for Kuala Terengganu, Kuching, Kota Kinabalu and Kota Bharu (Muzathik, 2013)

Months	**Global Solar Radiation (MJ/m^2/day)**			
	Kuala Terengganu	**Kuching**	**Kota Kinabalu**	**Kota Bharu**
January	17.91	12.02	17.71	16.26
February	21.60	13.35	19.36	17.72
March	21.40	15.39	20.97	19.72
April	23.64	13.07	21.64	19.74
May	20.34	13.42	20.16	18.23
June	17.42	16.28	19.11	17.10
July	19.43	16.57	19.41	17.17
August	19.15	15.14	19.44	17.42
September	20.20	15.79	18.20	18.12
October	16.40	15.23	19.21	17.09
November	16.24	14.92	18.08	13.28
December	13.38	12.56	18.00	12.15
Annual Average	18.92	14.48	19.27	17.00

2.2 Artificial Neural Network (ANN)

Caudill and Butler (1993) described ANN as an information processing systems that are non-algorithmic, non-digital and intensely parallel. It connects neuron with the large numbers of weighted links, where the information can pass. This neuron receives and combines the input before performing some non linear mathematical operation that produces output. The inputs might consist of latitude, longitude, altitude, sunshine duration, month of the year etc.

MATLAB software is used to perform this ANN operation. Most of the estimation through ANN technique employed the multi-layer feed forward neural network in which can use different training algorithm such as the back propagation algorithm and the Levenberg Marquardt (LM) algorithm. From these two algorithms, it was found that LM algorithm is more accurate and yields the best results (Dhar, Tickoo, Koul & Dubey, 2009; Adamowski & Karapataki, 2010). While for activation function, it is believed that "tansig" equation is proven to be more accurate to use in ANN compare to "logsis" and "purelin" (Chayjan & Ena-Ashari, 2010). The "tansig" equation is as follows:

$$f(zi) = \frac{2}{(1+\exp\,(-2x))} - 1 \quad (2.5)$$

Where,

$$zi = \sum w_{ij}\, x_j + \beta_i \quad (2.6)$$

$zi \;= weighted\ sum\ of\ the\ inputs$

w_{ij}

$= weight\ layer\ on\ the\ connection\ from\ neuron\ j\ to\ neuron\ i\ at\ the\ hidden\ layer$

$\beta_i \;= bias\ of\ neuron\ i$

Figure 2.1 below shows an example of topology chart consists of 5 input neurons, hidden layer and 1 output neuron.

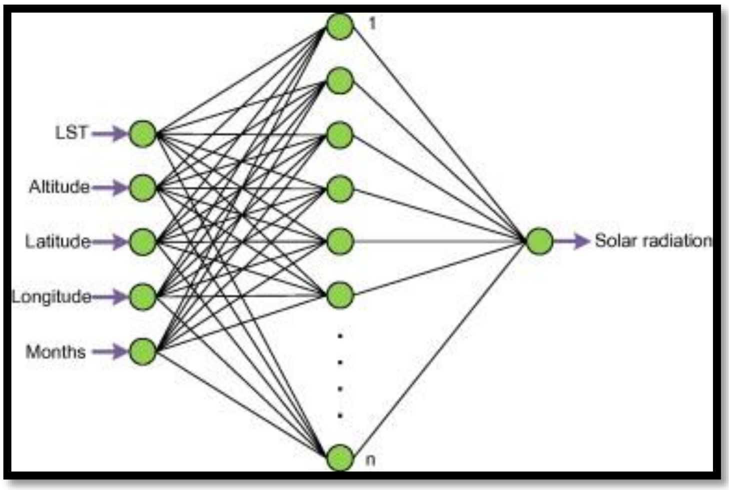

Figure 2.1: Topology Chart of Input-Hidden Layer-Output

This ANN technique was previously used by many researchers in their study. For instance, Fadare et al. (2010) made a study on feasibility of an ANN model for the prediction of monthly mean daily global radiation in several sites in Africa. In Asia region, there are also studies made to estimate monthly mean daily global radiation using ANN. One of them is by Reddy and Ranjan (2003) where they used multilayer feed forward network to estimate radiation in India. Most of these ANN models developed can be trained to generalize for any locations with similar climatic conditions (V. Sivamadhavi and R. Samuel, 2012). Another example is by Rumbayan and Nagasaka (2011) where they estimate global solar radiation by using data from other cities (Jakarta, Manado & Bengkulu) for training the networks and data from Makasar for testing the network.

In Malaysia, Sopian et al. (2012) used the ANN method based on the feed forward multi layer perception by predicting a clearness index first before estimating the daily global radiation. The inputs used are latitude, longitude, day number and sunshine ratio while the output is clearness index. In a review of solar energy modeling techniques in Malaysia, Khatib, Sopian & Mohamed (2012) found out that ANN model is the most superior and accurate to be use for determining solar energy in Malaysia as compare to linear model, non linear model and fuzzy logic. In their study, they found that ANN model yields the lowest value of MAPE and RMSE. This outcome is applicable for both global and direct solar radiation. In short, the ANN techniques offers much better way of predicting solar energy compare to conventional method. Almeida (2002) states that ANN has become more popular to be used as their mechanistic description of the dependency between the dependent and independent variables is either unknown or complex.

2.3 Potentiality in Malaysia

As a developing country, Malaysia encounters rapid increase of growth in industry area. This rapid increase in industrial sector requires high energy demand to fulfill the sector's electricity requirement. It is also expected that between 2009 to 2030, the Malaysia's electricity demand is expected to reach 18,947 MW in 2020 and 23, 092 MW in 2030 which is 35% increment from 14,007 MW in 2008 (Razak, 2009). Figure 2.2 below shows the overall energy demand in Malaysia from 1990 till 2010 (*National Energy Balance*, 2010).

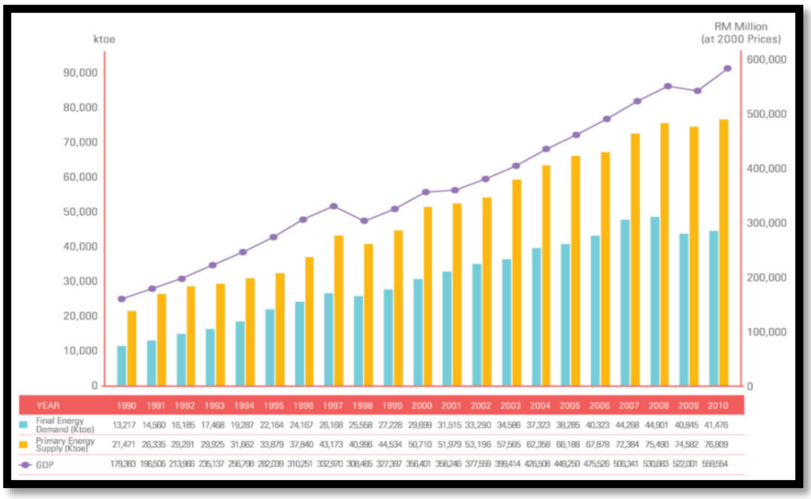

Figure 2.2: Overall energy demand in Malaysia

From the graph, even with the economic recession in 2009 which shows some decrease in the graph, the graph marginally increase in 2010 as the economic is recover back then. In order to support the fast industrialization, the energy becomes the main sector to focus on, with the renewable energy as its highlight. This step is in correlation with the current 10^{th} Malaysia Plan in which to achieve a renewable energy target 985 MW by 2015, contributing about 5.5% to Malaysia's total electricity generation mix (*10th Malaysian Plan*, n.d.).

As there are many types of renewable energy, Azman et al. (2011) comes out into conclusion that biomass energy is the most highly potential to be developed in Malaysia compare to other types. On the other hand, Chua and Oh (2011) believed that solar energy will be the forerunner compare to others and will surpass all the other renewable energy by 2050. This is due to the limitless of energy from the sun.

Moreover, it is also expected to become the most economical one besides expected to generate more than 10% of the world electricity by 2050 (Kadir, Rafeeu & Mariah, 2010). Furthermore, Mekhilef et al. (2012) pointed out that Malaysia receives high solar intensity with the average of 4000-5000 Wh/m2 with the average sunshine hours to be up till 8 hours per day. As an addition for that, Daut et al. (2012) states in their article that solar intensity greater than 3 kWh/m2 indicates that the sky is clear, high intensity and very good for solar application. Therefore, Malaysia will be a good prospect to apply solar energy in the future.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Project Activities

This research will take the quantitative approaches where several data will be analyzed mathematically and involves certain software such as MATLAB with Neural Network Tool. The following methodology describes the flow of the research for the whole project duration (FYP I & FYP II).

3.1.1 Selection of Sites

Figure 3.1: UTP Solar Research Site, Seri Iskandar

Selection of sites shall be based on the availability of solar radiation data on that site so that it is easier to validate the data estimated by comparing it with the measured data. This can be done by choosing any sites that have meteorological stations in it. In this study, UTP Solar Research Site in Seri Iskandar was chosen as the primary site to be tested. As an addition, data from meteorological stations in Ipoh, KLIA and Bayan Lepas were obtained to serve as input parameters for the testing sample. In other word, it will use the same approaches as study made by Rumbayan and Nagasaka (2011) as stated in Chapter 2, page 10, earlier.

3.1.2 Proposed Data Collection Method

Data to be collected must involve the measured global solar radiation and meteorological parameters such as month of the year, latitude, longitude etc. Specifically, it shall be monthly average daily global solar radiation for the period of three years minimum (2010-2012). This period of years must be nearer with the years of this project takes place since the climate for the chosen site can differs if the period of years is further apart.

In order to obtain the data, collaboration with the meteorological stations of Malaysia shall be made to generate valid results. As for Seri Iskandar itself, data needed can be obtain from the solar research site in UTP that storing all the required data. As soon as the data stated were obtained, estimation of monthly average daily global solar radiation can be done using clearness index and ANN.

The procedure to estimate data using clearness index are as follows:

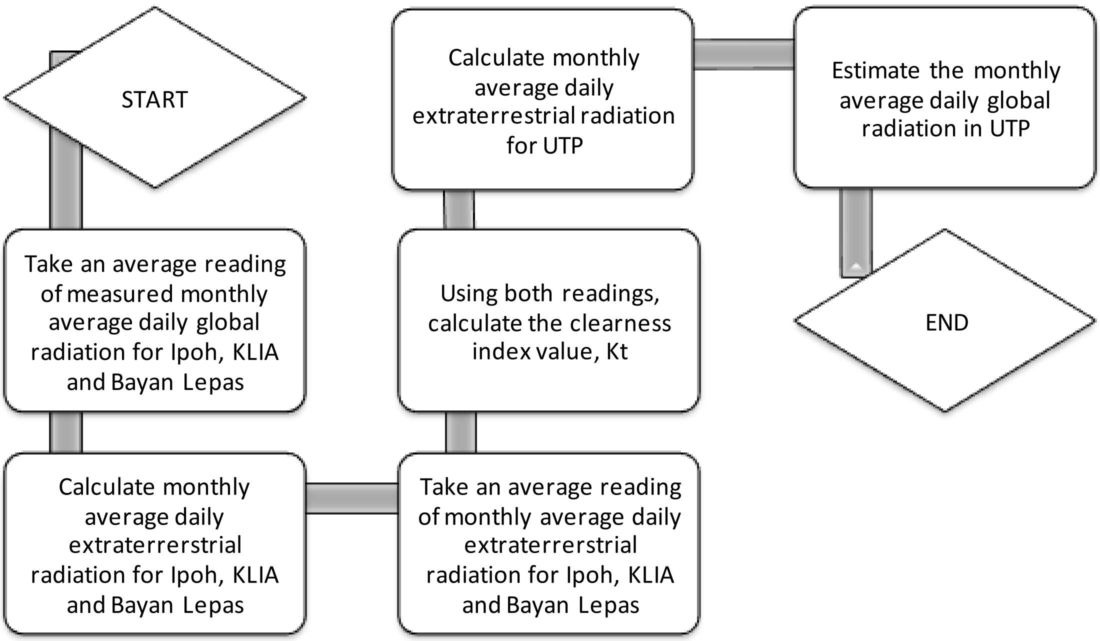

Figure 3.2: Process flow chart for clearness index technique

i. Take an average reading of measured monthly average daily global solar radiation, H_M for Ipoh, KLIA and Bayan Lepas from January 2010 to December 2012 (36 months)

ii. Calculate monthly average daily extraterrestrial radiation for Ipoh, KLIA and Bayan Lepas from January 2010 to December 2012 (36 months)

iii. Take an average reading of monthly average daily extraterrestrial radiation for Ipoh, KLIA and Bayan Lepas from January 2010 to December 2012 (36 months)

iv. From both average readings, calculate the clearness index value, K_T

v. Calculate monthly average daily extraterrestrial radiation for UTP, H_o, from January 2010 to December 2012 (36 months)

vi. Estimate the monthly average daily global solar radiation in UTP by multiplying the clearness index, K_T with monthly average daily extraterrestrial radiation of UTP, H_o

For estimation using ANN, the procedure is as follows:

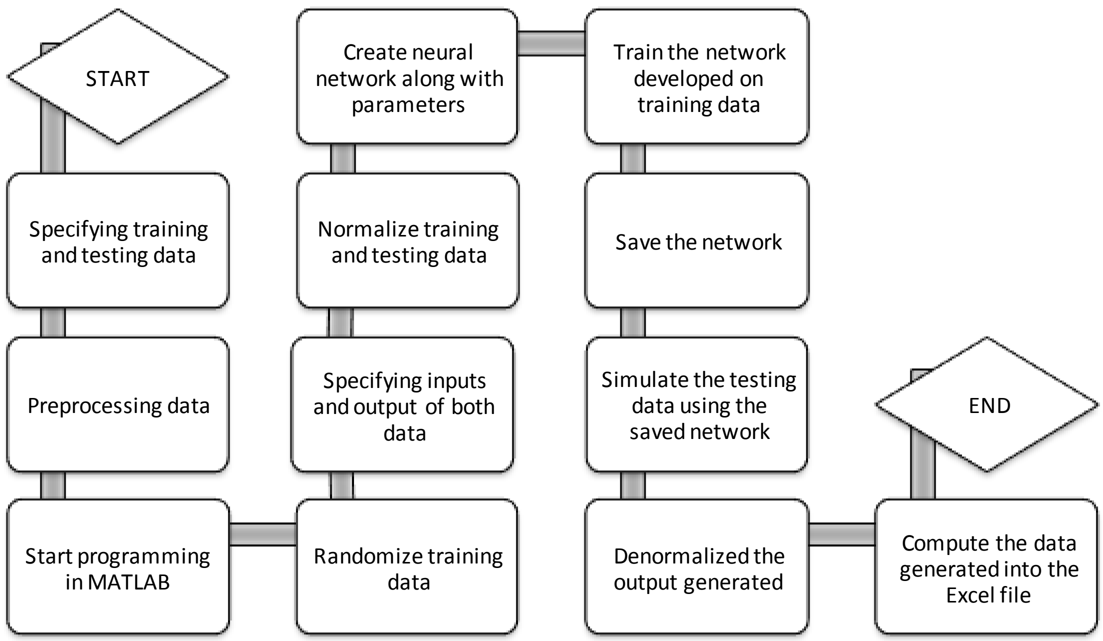

Figure 3.3: Process flow chart for ANN technique

i. Specify inputs and target by separating the data into training data (Ipoh, KLIA, Bayan Lepas) and testing data (UTP) respectively

ii. Store data collected previously into two separate excel file i.e. "Training_Data.xls" and "Testing_Data.xls". Any missing data shall be solved first. In this case, there is no missing data.

iii. Start programming in MATLAB by reading the stored data

- Training_Data=xlsread ('Training_Data.xls');
- Testing_Data=xlsread ('Testing_Data.xls');

iv. Randomize training data sample by using the function "randperm". This will provide a random permutation of the 108 integers in the training sample, thus provide better generalization. The order of the columns is left unchanged.

- Shuffling_Inputs = Training_Data(randperm(108),1:9);

v. Specify the randomized training data and testing data into set of inputs and output. Inputs for both data include 8 variables consist of Latitude, Longitude, Month of the Year, Altitude, Solar Declination, Sunrise Hour Angle, Day Length and Monthly Average Daily Extraterrestrial Radiation while output for both data is the Monthly Average Daily Global Solar Radiation.

- Training_Set=Shuffling_Inputs(1:108, 1:8)% specify Input for Training [2010 - 2012]
- Target_Set=Shuffling_Inputs(1:108, 9)% specify Output for Training [2010 - 2012]
- Testing_Set=Data_Target(1:36, 1:8)% specify Input for Testing [2010 - 2012]
- Testing_Target_Set=Data_Target(1:36, 9)% specify Output for Testing [2010 - 2012]

vi. Normalize data (training and testing) by using the function "mapstd" to yield zero mean and achieve unity standard deviation. The range here is -1 to 1 as the raw data contains negative value. In the source code following, [pn], [tn], [testn] and [tarn] contain the normalized values of inputs and output for training and testing data respectively, while [ps], [ts], [tests] and [tars] contain the means and standard deviations of their original values.

- [pn, ps] = mapstd(Training_Set);
- [tn, ts] = mapstd(Target_Set);
- [testn, tests] = mapstd(Testing_Set);
- [tarn, tars] = mapstd(Testing_Target_Set);

vii. Create the neural network by using the Neural Network Tool (Start > Toolboxes > Neural Network > Neural Network Tool). Then, precede the step by configuring the network parameters based on the feed forward back-propagation type. Table below shows the design parameters of the ANN model used in this study.

Table 3.1: Design parameters of ANN model

Design Parameter	Selected Value	Remarks
No. of Hidden Layer	1	Simplest/Non-complex
No. of Neurons	3 to 25	Suitable range of neuron to use. Based on the method used by Rumbayan and Nagasaka (2011)
Transfer Function	tansig	$F(x) = \frac{2}{(1 + \exp(-2x))} - 1$
Training Function	trainlm	Levenberg-Marquardt back-propagation
Learning Function	learngdm	Capability of updating weights/biases to achieve the results that contains minimum error
Learning Rate	0.4	Adaptive learning rate that controls the weights and biases
Performance Function	Msereg	Chosen to avoid over fitting (Sivamadhavi & Selvaraj, 2012)
Goals	0.01	Goals to be obtained during testing phase

viii. Train the network developed earlier with the input, [pn] and output, [tn] of the training data. Readjust the weights and biases when necessary to minimize the error. Save the network by calling the functions "save('MyNetwork');". Check the network performance.

ix. Simulate the network of testing data using network trained and saved earlier. This can be done by calling the function "y = sim(MyNetwork, testn); % simulate network". After network simulated, the output from the testing data shall be de-normalized to reverse it into the same unit with the original value. Thus, comparison with the measured data can be made. The appropriate function for this is "y_again = mapstd('reverse', y, tars) % denormalized". At this point, estimated data have been generated, thus simply putting the value into excel sheet for analysis purposes.

3.1.3 Data Analysis

Once estimated data had been obtained, the study will proceed onto the analysis part. It is a good move to represent the results in term of table of summary since there are large amounts of data collected and generated. In addition for that, the visualization of results through the use of graph is helpful especially to show at what month or when the solar radiation is high. These collected data will then be compared with other cities that been in the recent study such as Muzathik (2013).

3.1.4 Validation of Data

A statistical error will be used in this study which is root mean square error (RMSE).This statistical errors will be use to evaluate the accuracy of the data estimated from each modeling techniques with the measured one. Modeling techniques that has statistical errors close to zero is preferable as it is considered to be highly accurate. From this, the accurate modeling techniques for this study can be known.

$$RMSE = \sqrt{[\frac{1}{n}\sum_{1}^{n}(H_c - H_m)^2]} \quad (3.1)$$

Where, H_C is monthly average daily global radiation calculated, H_m is monthly average daily global radiation measured and n is number of samples.

3.2 Tools Required

The software to be used in order to develop the ANN model is basically the MATLAB R2009b version software with the Neural Network Tool. This software provide functions by systematically analyzed, designed and simulate the network between the inputs and output. Therefore, global solar radiation can be estimated using this software.

3.3 Gantt Chart

Table 3.2: Gantt chart

Project Activities	Weeks																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Title Awarded	■																									
Introduction																										
• *Background Study*		■	■																							
• *Problem Statement*		■																								
• *Objective/Scope of Study*		■																								
Literature Review																										
• *Techniques to use (K_T & ANN)*				■	■	■	■	■																		
• *Potentiality in Malaysia*						■																				
Methodology																										
• *Developing Methodology*							■	■																		
• *Work on Project Activities*								■	■	■	■	■	■	■	■	■										
Result & Discussion																										
• *Data Gathering*												■	■	■	■	■										
• *Data Analysis& Validation*																	■	■	■	■	■					
Conclusion & Recommendation																						■	■			
Submission of Report																										
• *Extended Proposal*				■																						
• *Interim Report*												■														
• *Progress Report*																			■							
• *Dissertation & Tech. Paper*																								■		

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Data Gathering

i. Modeling using clearness index

Results achieved using this technique is mainly dependable with the clearness index value generated. Data of Ho and Hm from Ipoh, KLIA and Bayan Lepas were taken in order to find the averages between these three sites. The Ho values were calculated using the equation described in Section 2.1 (Clearness Index Estimation Method) while Hm values were obtained from the Meteorological Stations of Malaysia. However, due to lengthy calculations, the results were plotted in term of graph basis. Again, this estimation is made by considering there is no radiation data available in the site of study. Figure 4.1 and Figure 4.2 in the following shows the average of Ho and Hm generated using data from three sites.

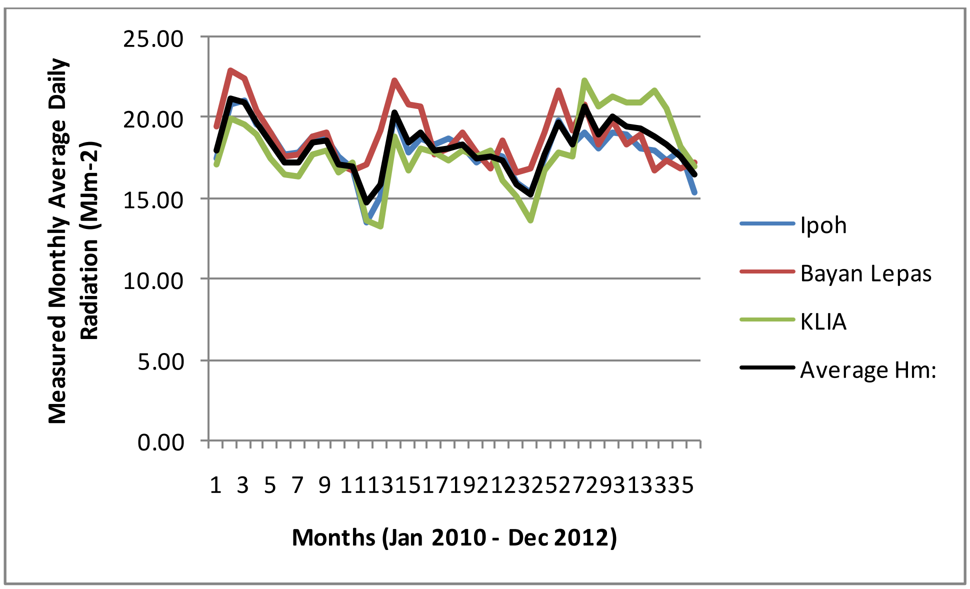

Figure 4.1: Average of measured monthly average daily radiation, Hm

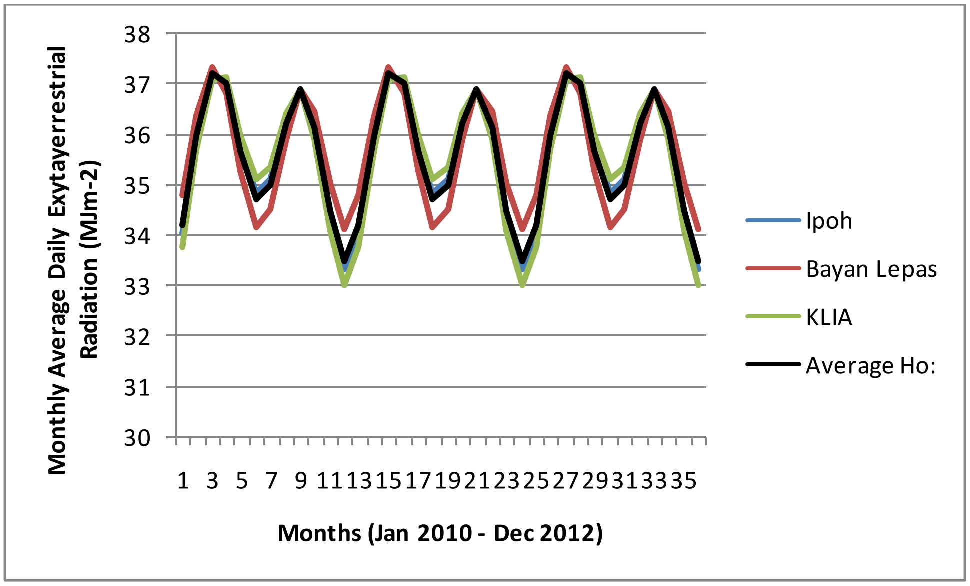

Figure 4.2: Average of monthly average daily extraterrestrial radiation, Ho

By dividing the Hm with Ho, the clearness index value, Kt can be estimated. Therefore, by correlating the clearness index, Kt using data from three sites (Ipoh, Bayan Lepas, KLIA) with the calculated Ho in Seri Iskandar, the estimated monthly average daily global solar radiation in Seri Iskandar can be obtained. Figure 4.3 below shows the clearness index generated using data from three sites.

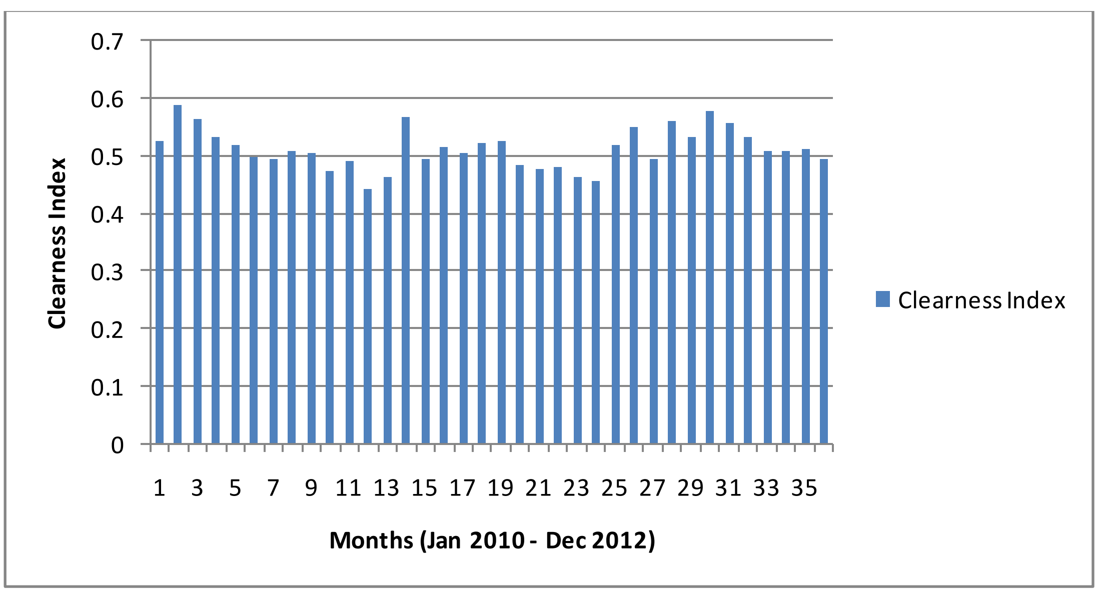

Figure 4.3: Clearness index based on three sites

Table 4.1 below shows the monthly mean daily extraterrestrial radiation generated in Seri Iskandar using the equation described at literature review.

Table 4.1: Monthly mean daily extraterrestrial radiation in Seri Iskandar

Monthly Mean Daily Extraterrestrial Radiation in Seri Iskandar		
2010	**2011**	**2012**
34.12	34.12	34.12
35.96	35.96	35.96
37.22	37.22	37.22
37.05	37.05	37.05
35.75	35.75	35.75
34.79	34.79	34.79
35.07	35.07	35.07
36.26	36.26	36.26
36.92	36.92	36.92
36.13	36.13	36.13
34.43	34.43	34.43
33.41	33.41	33.41

The graph in Figure 4.4 below shows the estimated monthly mean daily global radiation yielded by multiplying the clearness index with the monthly mean daily extraterrestrial radiation in Seri Iskandar.

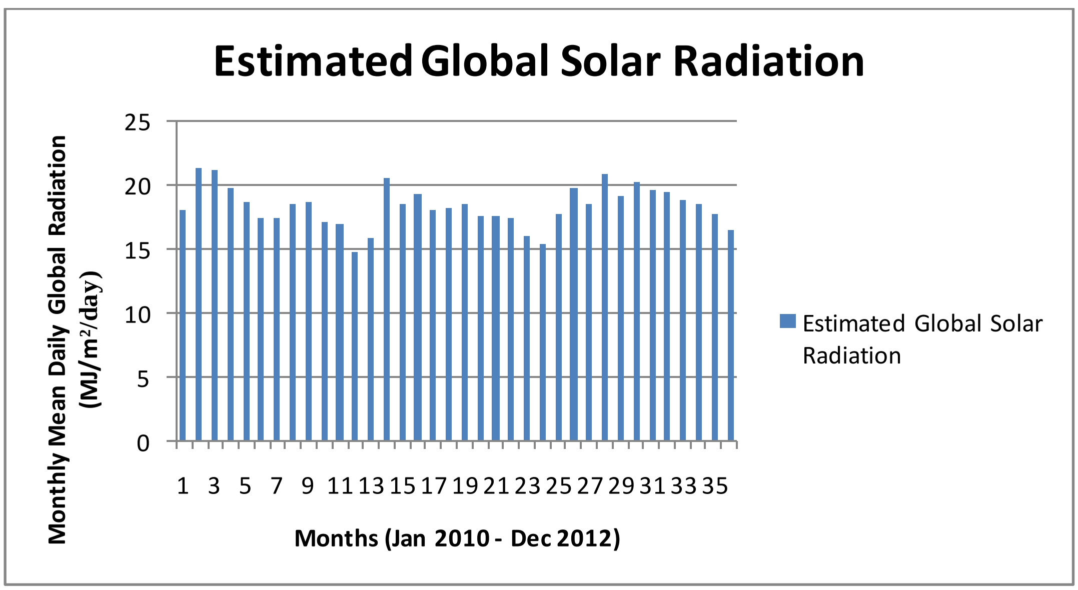

Figure 4.4: Estimated global solar radiation using clearness index

ii. Modeling using ANN

In this technique, data collected were divided into two categories, training set and testing set. Training set consist data from Ipoh, KLIA and Bayan Lepas while testing set consist data from UTP. All of this data were in 3 years period, from 2010 till 2012, and are the raw data can be seen in Appendix A. MATLAB software with Neural Network Tool was used for this modeling where the algorithm used is based on the feed forward back propagation with the training algorithm of Levenberg Marquardt. The inputs used consist of latitude, longitude, month of the year, altitude, solar declination, sunrise hour angle, day length and monthly average daily extraterrestrial radiation while the output to be achieved is estimated monthly average daily radiation.

Using Table 3.1 in Methodology Section as a reference, the neural network model had been successfully developed and all the important figures of the model can be seen in Appendix B. There are some coding required to developed this model, and this is shown in Appendix C. After several training, the testing process takes place and all the data obtained were presented in terms of RMSE value based on the range of neurons stated earlier (3 to 25). This is due to the fact that all the neurons used yield a different results, but still close to the measured data. It is safe to say that all neurons are acceptable and can be used in this case. As a matter of fact, there is no error during simulation and the coefficient of determination, r^2 obtained were below its maximum value which is 1. Table 4.2 below shows the RMSE value with respect to the neurons tested.

Table 4.2: RMSE value from neurons 3 to neurons 25

Neurons	3	4	5	6	7	8	9	10
RMSE	1.257727	1.385823	1.433366	1.023189	2.159211	1.226805	1.503169	2.200612
Neurons	11	12	13	14	15	16	17	18
RMSE	1.20023	1.100475	1.083215	2.931226	4.048556	2.607776	2.227918	2.301108
Neurons	19	20	21	22	23	24	25	
RMSE	3.668231	2.577232	1.369436	2.694431	1.557203	2.288551	2.883393	

4.2 Data Analysis

Clearness index generated earlier is compared with other cities within Malaysia that have high solar radiation comprises of Kuala Terengganu, Kuching, Kota Kinabalu and Kota Bharu as per shown in Table 4.3 below.

Table 4.3: Comparison between clearness index of Seri Iskandar with other states in Malaysia

Months	Clearness Index				
	Seri Iskandar	Kuala Terengganu	Kuching	Kota Kinabalu	Kota Bharu
January	0.51	0.54	0.35	0.55	0.51
February	0.57	0.62	0.38	0.57	0.52
March	0.52	0.57	0.41	0.56	0.53
April	0.54	0.64	0.36	0.59	0.54
May	0.52	0.54	0.37	0.53	0.48
June	0.54	0.48	0.48	0.53	0.48
July	0.53	0.53	0.45	0.51	0.45
August	0.51	0.53	0.41	0.51	0.46
September	0.50	0.53	0.43	0.50	0.50
October	0.49	0.44	0.41	0.53	0.47
November	0.49	0.49	0.41	0.53	0.39
December	0.47	0.42	0.36	0.54	0.37
Annual Average	0.52	0.53	0.40	0.54	0.47

Based on the table above, the annual average of clearness index for Seri Iskandar is approximately 0.52, making it comparable with other states that have greater clearness index such as Kuala Terengganu (0.53) and Kota Kinabalu (0.54). The clearness index pattern can be considered as stable throughout the year with the range varies from 0.47 to 0.57. This is by 0.1 differences which are slightly low, thus more stable as compare to Kuala Terengganu with differences of 0.2.

The high clearness index shows the existence of clear sky condition, thus the solar radiation tend to be high. This proves that Seri Iskandar area develops great potential of solar radiation. Figure 4.5 below shows the estimated solar radiation pattern for 2010, 2011 and 2012 for overall course of the year.

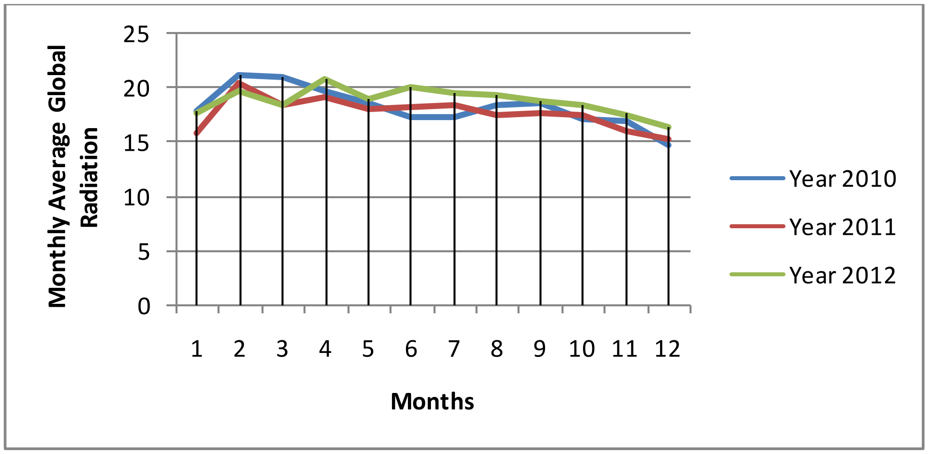

Figure 4.5: Solar radiation pattern for Seri Iskandar in 2010 to 2012

Based on the figure, it can be described that Seri Iskandar shows similar pattern of solar radiation for the 3-years period. This means that the climate is stable over the course of the three years and is believed to be the same for the after years (2013 onwards). Therefore, in a long term, it is a good move to develop solar application based on the graph patterns. Besides, the amount of solar radiation is pretty high especially from February to July based on the Figure 4.5. However, starting August of the year, the line pattern gradually drops till January next year. This is where the clearness index is low, in which making the solar radiation low as well.

Table 4.4: Comparison between global solar radiation of Seri Iskandar with other states in Malaysia

Months	**Global Solar Radiation (MJ/m²/day)**				
	Seri Iskandar	**Kuala Terengganu**	**Kuching**	**Kota Kinabalu**	**Kota Bharu**
January	17.18	17.91	12.02	17.71	16.26
February	20.45	21.60	13.35	19.36	17.72
March	19.29	21.40	15.39	20.97	19.72
April	19.88	23.64	13.07	21.64	19.74
May	18.54	20.34	13.42	20.16	18.23
June	18.53	17.42	16.28	19.11	17.10
July	18.42	19.43	16.57	19.41	17.17
August	18.46	19.15	15.14	19.44	17.42
September	18.32	20.20	15.79	18.20	18.12
October	17.63	16.40	15.23	19.21	17.09
November	16.82	16.24	14.92	18.08	13.28
December	15.48	13.38	12.56	18.00	12.15
Annual Average	18.25	18.92	14.48	19.27	17.00

Table 4.4 above shows the comparison made between Seri Iskandar and other places within Malaysia that obtained from previous study. It is clearly shown that the highest solar radiation occurs on the month of February with the value was 20.45 $MJ/m^2/day$. This is in line with the results from Table 4.3 where the clearness index is highest on February as well. The annual average of global solar radiation was 18.25 $MJ/m^2/day$. This is comparable with Kuala Terengganu and slightly lower from Kota Kinabalu with the differences around 1.0. It can also be seen that the solar radiation is gradually decreases starting October onwards. It is the period when the northeast monsoon occurs in which induces rainfall that could heavily affects the clearness index to be low, thus the global radiation is likely to be low as well.

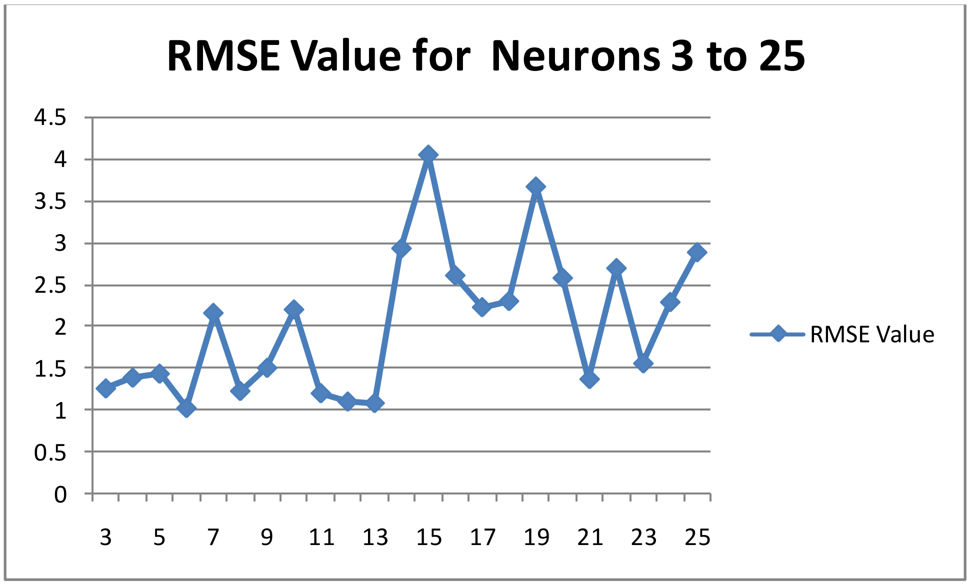

Figure 4.6: RMSE value for neurons 3 till 25

For ANN, the analysis can be made on the RMSE value with respect to the neurons setting from 3 to 25 as in Figure 4.6 above. It is clearly seen that the RMSE value is in stable pattern from neurons 3 to 13. For neurons above 13, the RMSE value tends to be unstable and differs greatly between neurons. Therefore, having said that to avoid complexity when use this model, it is safe to use neuron 3 to 13. Besides, the lowest RMSE had been achieved within this range when neuron is set to 6 with the RMSE value of 1.02. In fact, the r^2 obtained are in the range of 0.8 to 0.95 in this case.

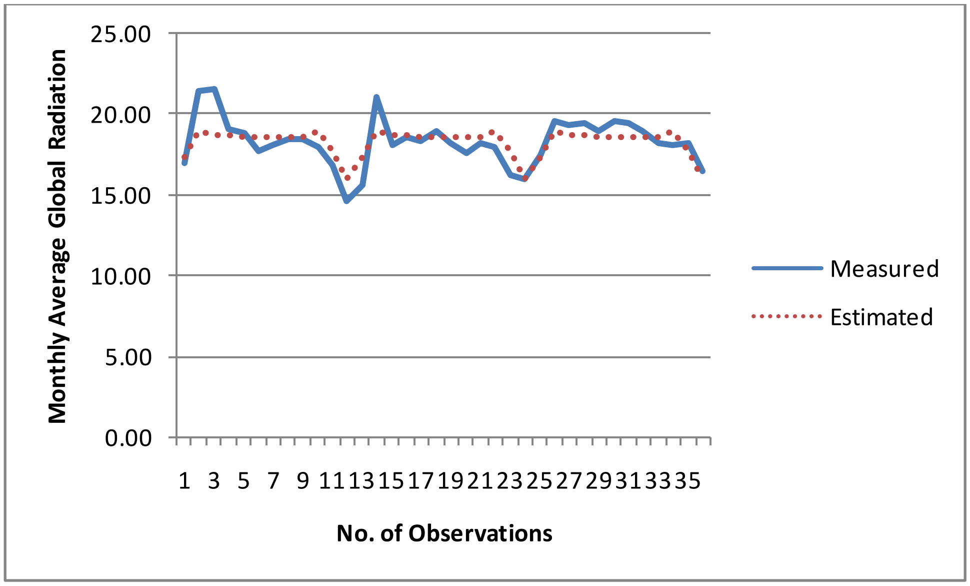

Figure 4.7: Measured and estimated monthly average global radiation in Seri Iskandar using ANN

Figure 4.7 above shows a comparison between the measured data with the estimated data. This is the pattern for the testing phase which been simulated after several training of ANN over 3 years period. For improvement, long term data shall be supply for training purposes. This enable the network to yield better results, thus making the testing phase conducted easily. In this case, only 3 years data is available for study as there is no data recorded for the previous year (before 2010).

4.3 Data Validation

The estimated value obtained by clearness index were then been compared with the real measured global radiation data. Graph in Figure 4.8 in the following shows the comparison between the measurements and calculations data.

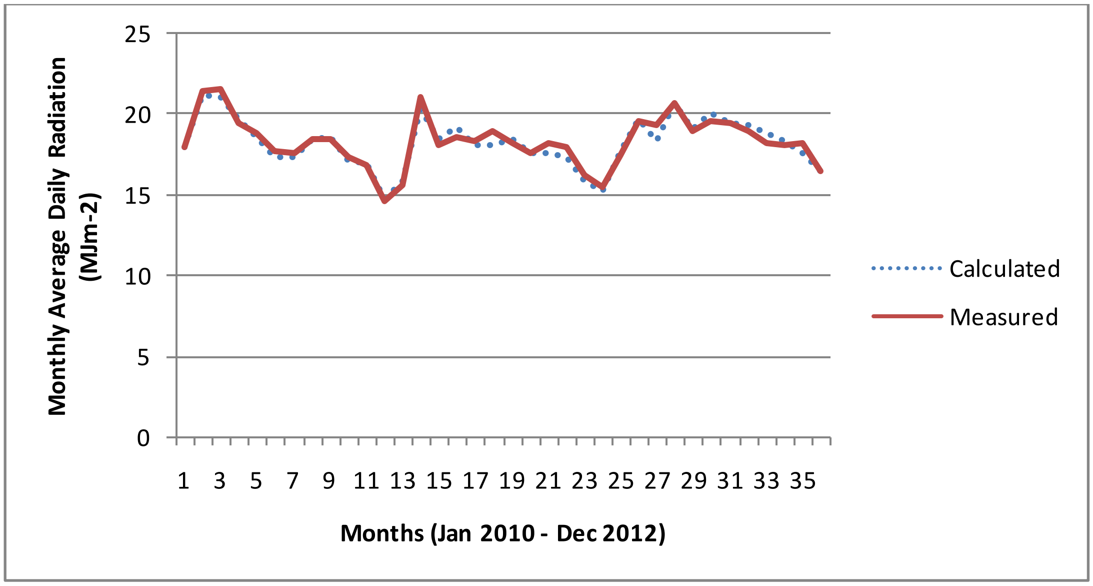

Figure 4.8: Graph of estimated value vs. measured value using clearness index

Based on the observation above, the figure shows a good agreement between the measured data and calculated data. Using the statistical parameters such as RMSE, it is found that the error between the measurements and calculations is relatively low, with the value of 0.39. This gives a good point that the estimation done earlier was made correctly as the objective of the validation here is to yields lowest possible value of RMSE. In this case, the RMSE value is acceptable (close to zero). Therefore, the clearness index model developed earlier can be used in Seri Iskandar or any place within Perak that having similar climatic conditions when the solar radiation data is not available.

For ANN, the RMSE value range from 1.02 to 4.00 for neurons 3 to 25. As been stated earlier to use neurons 3 to 13 due to their stability, this range of RMSE yields the maximum value to be 2.20 while the minimum value is still 1.02 when neuron is set to 6. Hence, as the RMSE is lower, the estimation using ANN model can also be used to generate the required result which is solar radiation. In short, other than the clearness index which use mathematical modeling, one can also estimate the solar radiation using simulation of ANN developed earlier for any area that do not have solar radiation data.

Between those estimation techniques which is clearness index and ANN, it is obvious that clearness index technique is more accurate compare to ANN as it yields the lowest RMSE value. This shows disagreement with previous studies that been done by Khatib, Sopian & Mohamed (2012) which states that ANN is the most superior compare to others. The probability of this disagreement might be due to the fact that the data supplied for ANN is limited in this study where only 3 years period were used. It is important to note that most ANN studies in Malaysia used long term data that accounts for 10 years and above including study made by Khatib, Sopian & Mohamed (2012).

Besides, the ANN is based on the flexibility, where in order to produce accurate results, more inputs must be provided so that the network can make better generalization. In A Review of Solar Energy Modeling Techniques by Khatib, Sopian & Mohamed (2012), it is found that the disadvantages of ANN method is that, it is not accurate in the presence of short term data. Therefore, in case of short term supplied of data (in this case 3 years) or less number of observation, it is best to use clearness index method for predicting the solar energy. Otherwise, the ANN method shall be selected.

CHAPTER 5: CONCLUSION

Monthly mean daily global solar radiation in Seri Iskandar had been studied using estimation techniques of clearness index and ANN. Primary data involving meteorological parameters in UTP Solar Research Site, Seri Iskandar and secondary data including meteorological parameters in Ipoh, Bayan Lepas and KLIA had been used in this study to produce the required results. From the analysis that been done, following conclusions were obtained:

- Highest monthly mean global irradiation is on February of the year. The value was 20.45 MJ/m^2/day.
- Annual average global radiation in Seri Iskandar was 18.25 MJ/m^2/day.
- Average clearness index is found to be 0.52. This is comparable with other cities that have greater solar potential. i.e. Kuala Terengganu with 0.53 and Kota Kinabalu 0.54.
- Best neurons to be use in ANN is from 3 to 13 from the range of 3 to 25. This is due to their stability of graph pattern among each neuron when generating the required results. Lowest RMSE is 1.02 when neuron is set to 6.
- RMSE for clearness index and ANN is 0.39 and 1.02 respectively.
- Seri Iskandar shows similar pattern for over 3-years period. This shows the stable climate at Seri Iskandar. The amount of solar radiation is high on February till July. Then, it will gradually decrease starting August till January next year.
- Clearness index is shown to be more accurate compare to the ANN in case of limited data provided (in this case 3 years period).

These outcomes will give a new sight for solar potential in Seri Iskandar and Perak generally. Previously, most of the studies been done are lies on the east coast region as well as Borneo region. Thus, this study promotes the global solar energy potential in Perak states where like other states in Malaysia, the implementation of solar energy is still low due to lack of researched and high maintainability of solar measuring equipment.

For future works, the same studies shall also be done on the northern and southern region of Malaysia especially in the major cities. By doing this, comparison of clearness index can be made, thus increasing the market of solar energy industry as the data can be estimated without needing the measuring equipment. As for ANN, long term data of 10 years above shall be used in order to provide better generalization, thus improving the results. Besides, in a case where there is no negative value in the raw data, it's better to use normalization range from 0 to 1. This will yields better results as compare to range -1 to 1.

In a nutshell, this study achieved both of the objectives stated in the first place which are to estimate and compare the solar radiation using clearness index and ANN with other cities within Malaysia. Generally, Perak states is comparable with other states in Malaysia that is known already to have great solar intensity like Terengganu and Sabah. Therefore, Perak states or Seri Iskandar specifically, show a good prospect and have strong solar intensity for the applications of solar energy.

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APPENDIX A

RAW DATA USED FOR ANN

Table A-1: Raw data for Bayan Lepas, 2010-2012 (training data)

Latitude:	Longitude:	Month of the year:	Altitude:	Solar Declination:	Sunrise Hour Angle:	Day Length:	Monthly Average Daily Extraterrestrial Radiation (MJm-2):	Measured (MJ/m2):
5.3	100.267	1	3	-20.917	87.96811	17	33.73694	19.42
5.3	100.267	2	3	-12.9546	88.77724	47	35.70094	22.91
5.3	100.267	3	3	-2.41773	89.77558	75	37.12584	22.47
5.3	100.267	4	3	9.414893	90.88137	105	37.14979	20.52
5.3	100.267	5	3	18.79192	91.80889	135	36.00145	19.09
5.3	100.267	6	3	23.08591	92.26616	162	35.10578	17.64
5.3	100.267	7	3	21.18369	92.06032	198	35.3582	17.71
5.3	100.267	8	3	13.45496	91.27175	228	36.42704	18.88
5.3	100.267	9	3	2.216887	90.20576	258	36.90339	19.10
5.3	100.267	10	3	-9.5994	89.10103	288	35.92205	17.16
5.3	100.267	11	3	-18.912	88.17867	318	34.07765	16.78
5.3	100.267	12	3	-23.0496	87.73782	344	32.99377	17.12
5.3	100.267	1	3	-20.917	87.96811	17	33.73694	19.29
5.3	100.267	2	3	-12.9546	88.77724	47	35.70094	22.28
5.3	100.267	3	3	-2.41773	89.77558	75	37.12584	20.86
5.3	100.267	4	3	9.414893	90.88137	105	37.14979	20.70
5.3	100.267	5	3	18.79192	91.80889	135	36.00145	17.81
5.3	100.267	6	3	23.08591	92.26616	162	35.10578	18.19
5.3	100.267	7	3	21.18369	92.06032	198	35.3582	19.13
5.3	100.267	8	3	13.45496	91.27175	228	36.42704	17.83
5.3	100.267	9	3	2.216887	90.20576	258	36.90339	16.87
5.3	100.267	10	3	-9.5994	89.10103	288	35.92205	18.59
5.3	100.267	11	3	-18.912	88.17867	318	34.07765	16.66
5.3	100.267	12	3	-23.0496	87.73782	344	32.99377	16.94
5.3	100.267	1	3	-20.917	87.96811	17	33.73694	19.16
5.3	100.267	2	3	-12.9546	88.77724	47	35.70094	21.64
5.3	100.267	3	3	-2.41773	89.77558	75	37.12584	19.25
5.3	100.267	4	3	9.414893	90.88137	105	37.14979	20.88
5.3	100.267	5	3	18.79192	91.80889	135	36.00145	18.34
5.3	100.267	6	3	23.08591	92.26616	162	35.10578	19.85
5.3	100.267	7	3	21.18369	92.06032	198	35.3582	18.42
5.3	100.267	8	3	13.45496	91.27175	228	36.42704	18.97
5.3	100.267	9	3	2.216887	90.20576	258	36.90339	16.84
5.3	100.267	10	3	-9.5994	89.10103	288	35.92205	17.37
5.3	100.267	11	3	-18.912	88.17867	318	34.07765	16.89
5.3	100.267	12	3	-23.0496	87.73782	344	32.99377	17.30

Table A-2: Raw data for Ipoh, 2010-2012 (training data)

Latitude:	Longitude:	Month of the year:	Altitude:	Solar Declination:	Sunrise Hour Angle:	Day Length:	Monthly Average Daily Extraterrestial Radiation (MJm-2):	Measured (MJ/m2):
4.567	101.1	1	40	-20.917	88.24935	17	34.39599	17.40
4.567	101.1	2	40	-12.9546	88.94645	47	36.28112	20.87
4.567	101.1	3	40	-2.41773	89.80663	75	37.58337	21.07
4.567	101.1	4	40	9.414893	90.75941	105	37.45174	19.63
4.567	101.1	5	40	18.79192	91.55853	135	36.17165	19.05
4.567	101.1	6	40	23.08591	91.95246	162	35.21424	17.71
4.567	101.1	7	40	21.18369	91.77514	198	35.4934	17.84
4.567	101.1	8	40	13.45496	91.09575	228	36.67052	18.77
4.567	101.1	9	40	2.216887	90.17729	258	37.29725	18.69
4.567	101.1	10	40	-9.5994	89.22542	288	36.45953	17.61
4.567	101.1	11	40	-18.912	88.43075	318	34.71393	16.79
4.567	101.1	12	40	-23.0496	88.05097	344	33.66971	13.48
4.567	101.1	1	40	-20.917	88.24935	17	34.39599	15.12
4.567	101.1	2	40	-12.9546	88.94645	47	36.28112	20.16
4.567	101.1	3	40	-2.41773	89.80663	75	37.58337	17.85
4.567	101.1	4	40	9.414893	90.75941	105	37.45174	18.70
4.567	101.1	5	40	18.79192	91.55853	135	36.17165	18.39
4.567	101.1	6	40	23.08591	91.95246	162	35.21424	18.76
4.567	101.1	7	40	21.18369	91.77514	198	35.4934	18.19
4.567	101.1	8	40	13.45496	91.09575	228	36.67052	17.20
4.567	101.1	9	40	2.216887	90.17729	258	37.29725	17.87
4.567	101.1	10	40	-9.5994	89.22542	288	36.45953	17.53
4.567	101.1	11	40	-18.912	88.43075	318	34.71393	15.99
4.567	101.1	12	40	-23.0496	88.05097	344	33.66971	15.30
4.567	101.1	1	40	-20.917	88.24935	17	34.39599	17.43
4.567	101.1	2	40	-12.9546	88.94645	47	36.28112	19.84
4.567	101.1	3	40	-2.41773	89.80663	75	37.58337	18.37
4.567	101.1	4	40	9.414893	90.75941	105	37.45174	19.03
4.567	101.1	5	40	18.79192	91.55853	135	36.17165	18.03
4.567	101.1	6	40	23.08591	91.95246	162	35.21424	19.14
4.567	101.1	7	40	21.18369	91.77514	198	35.4934	19.01
4.567	101.1	8	40	13.45496	91.09575	228	36.67052	18.05
4.567	101.1	9	40	2.216887	90.17729	258	37.29725	17.95
4.567	101.1	10	40	-9.5994	89.22542	288	36.45953	17.31
4.567	101.1	11	40	-18.912	88.43075	318	34.71393	17.92
4.567	101.1	12	40	-23.0496	88.05097	344	33.66971	15.35

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Table A-3: Raw data for KLIA, 2010-2012 (training data)

Latitude:	Longitude:	Month of the year:	Altitude:	Solar Declination:	Sunrise Hour Angle:	Day Length:	Monthly Average Daily Extraterrestial Radiation (MJm-2):	Measured (MJ/m2):
2.73	101.7	1	21	-20.917	88.95574	17	34.79617	17.14
2.73	101.7	2	21	-12.9546	89.37152	47	36.41084	19.95
2.73	101.7	3	21	-2.41773	89.88465	75	37.35476	19.59
2.73	101.7	4	21	9.414893	90.45303	105	36.83655	18.95
2.73	101.7	5	21	18.79192	90.92968	135	35.27363	17.40
2.73	101.7	6	21	23.08591	91.16461	162	34.19731	16.50
2.73	101.7	7	21	21.18369	91.05887	198	34.53289	16.29
2.73	101.7	8	21	13.45496	90.65365	228	35.93741	17.73
2.73	101.7	9	21	2.216887	90.10576	258	36.91868	17.95
2.73	101.7	10	21	-9.5994	89.53793	288	36.47444	16.59
2.73	101.7	11	21	-18.912	89.06393	318	35.0443	17.27
2.73	101.7	12	21	-23.0496	88.83743	344	34.13998	13.67
2.73	101.7	1	21	-20.917	88.95574	17	34.79617	13.24
2.73	101.7	2	21	-12.9546	89.37152	47	36.41084	18.83
2.73	101.7	3	21	-2.41773	89.88465	75	37.35476	16.70
2.73	101.7	4	21	9.414893	90.45303	105	36.83655	18.03
2.73	101.7	5	21	18.79192	90.92968	135	35.27363	17.84
2.73	101.7	6	21	23.08591	91.16461	162	34.19731	17.36
2.73	101.7	7	21	21.18369	91.05887	198	34.53289	17.97
2.73	101.7	8	21	13.45496	90.65365	228	35.93741	17.54
2.73	101.7	9	21	2.216887	90.10576	258	36.91868	17.96
2.73	101.7	10	21	-9.5994	89.53793	288	36.47444	16.14
2.73	101.7	11	21	-18.912	89.06393	318	35.0443	15.15
2.73	101.7	12	21	-23.0496	88.83743	344	34.13998	13.64
2.73	101.7	1	21	-20.917	88.95574	17	34.79617	16.71
2.73	101.7	2	21	-12.9546	89.37152	47	36.41084	17.83
2.73	101.7	3	21	-2.41773	89.88465	75	37.35476	17.56
2.73	101.7	4	21	9.414893	90.45303	105	36.83655	22.30
2.73	101.7	5	21	18.79192	90.92968	135	35.27363	20.63
2.73	101.7	6	21	23.08591	91.16461	162	34.19731	21.29
2.73	101.7	7	21	21.18369	91.05887	198	34.53289	20.93
2.73	101.7	8	21	13.45496	90.65365	228	35.93741	20.99
2.73	101.7	9	21	2.216887	90.10576	258	36.91868	21.65
2.73	101.7	10	21	-9.5994	89.53793	288	36.47444	20.56
2.73	101.7	11	21	-18.912	89.06393	318	35.0443	18.18
2.73	101.7	12	21	-23.0496	88.83743	344	34.13998	16.91

Table A-4: Raw data for UTP Stations, Seri Iskandar, 2010-2012 (testing data)

Latitude:	Longitude:	Month of the year:	Altitude:	Solar Declination:	Sunrise Hour Angle:	Day Length:	Monthly Average Daily Extraterrestial Radiation (MJm-2):	Measured (MJ/m2):
4.4	100.98	1	24	-20.917	88.3186	17	34.11866	16.89
4.4	100.98	2	24	-12.9546	88.98812	47	35.96014	21.45
4.4	100.98	3	24	-2.41773	89.81428	75	37.21545	21.54
4.4	100.98	4	24	9.414893	90.72938	105	37.04716	19.08
4.4	100.98	5	24	18.79192	91.49689	135	35.75103	18.78
4.4	100.98	6	24	23.08591	91.87522	162	34.79069	17.65
4.4	100.98	7	24	21.18369	91.70492	198	35.07285	18.08
4.4	100.98	8	24	13.45496	91.05242	228	36.26153	18.47
4.4	100.98	9	24	2.216887	90.17028	258	36.91728	18.39
4.4	100.98	10	24	-9.5994	89.25606	288	36.12572	17.90
4.4	100.98	11	24	-18.912	88.49282	318	34.42689	16.81
4.4	100.98	12	24	-23.0496	88.12807	344	33.40586	14.56
4.4	100.98	1	24	-20.917	88.3186	17	34.11866	15.58
4.4	100.98	2	24	-12.9546	88.98812	47	35.96014	21.03
4.4	100.98	3	24	-2.41773	89.81428	75	37.21545	18.11
4.4	100.98	4	24	9.414893	90.72938	105	37.04716	18.49
4.4	100.98	5	24	18.79192	91.49689	135	35.75103	18.32
4.4	100.98	6	24	23.08591	91.87522	162	34.79069	18.88
4.4	100.98	7	24	21.18369	91.70492	198	35.07285	18.23
4.4	100.98	8	24	13.45496	91.05242	228	36.26153	17.54
4.4	100.98	9	24	2.216887	90.17028	258	36.91728	18.13
4.4	100.98	10	24	-9.5994	89.25606	288	36.12572	17.91
4.4	100.98	11	24	-18.912	88.49282	318	34.42689	16.19
4.4	100.98	12	24	-23.0496	88.12807	344	33.40586	15.92
4.4	100.98	1	24	-20.917	88.3186	17	34.11866	17.37
4.4	100.98	2	24	-12.9546	88.98812	47	35.96014	19.55
4.4	100.98	3	24	-2.41773	89.81428	75	37.21545	19.30
4.4	100.98	4	24	9.414893	90.72938	105	37.04716	19.48
4.4	100.98	5	24	18.79192	91.49689	135	35.75103	18.89
4.4	100.98	6	24	23.08591	91.87522	162	34.79069	19.51
4.4	100.98	7	24	21.18369	91.70492	198	35.07285	19.43
4.4	100.98	8	24	13.45496	91.05242	228	36.26153	18.92
4.4	100.98	9	24	2.216887	90.17028	258	36.91728	18.17
4.4	100.98	10	24	-9.5994	89.25606	288	36.12572	18.01
4.4	100.98	11	24	-18.912	88.49282	318	34.42689	18.13
4.4	100.98	12	24	-23.0496	88.12807	344	33.40586	16.46

APPENDIX B

NEURAL NETWORK MODEL

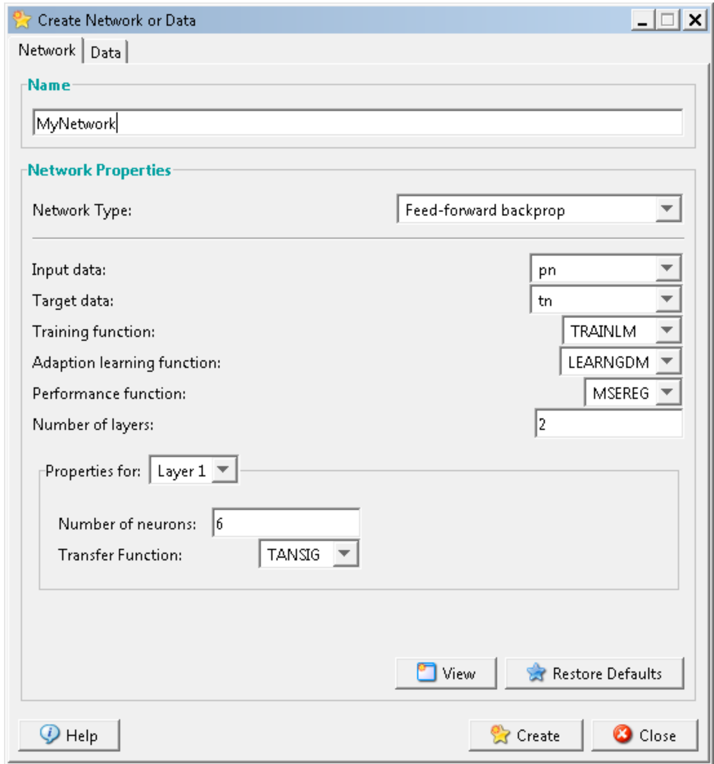


Figure B-1: Configuring network parameters

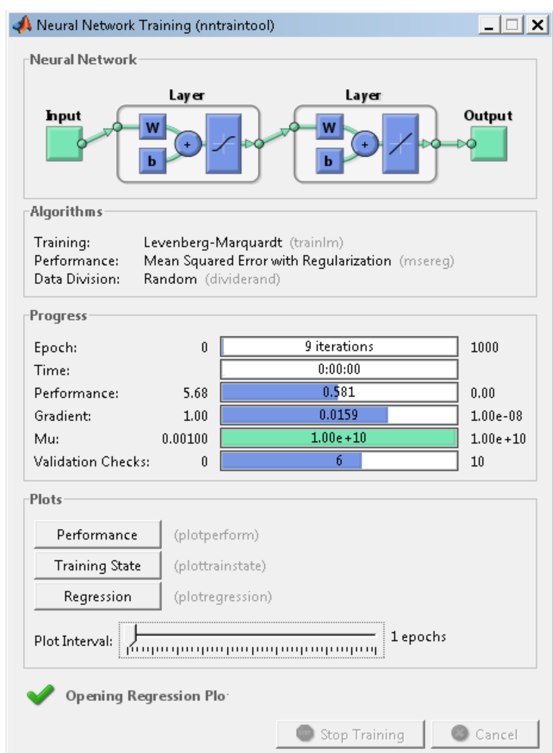
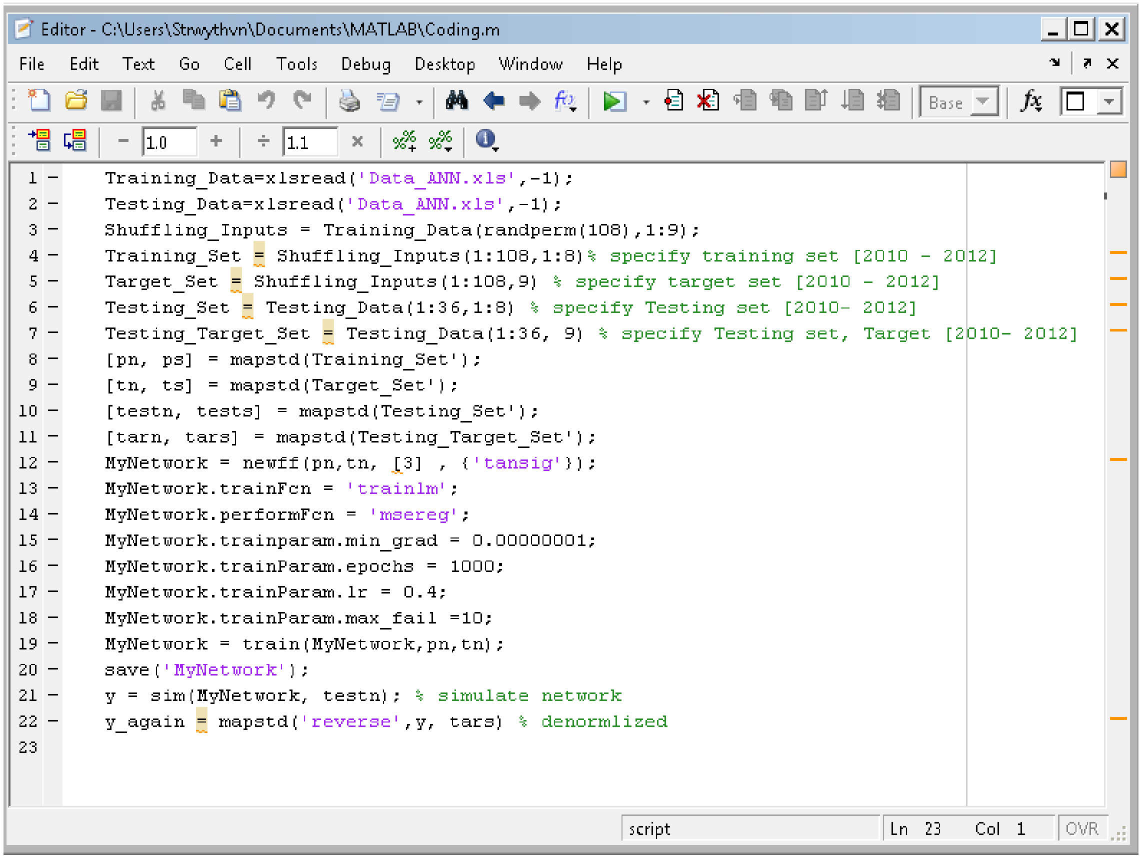


Figure B-2: Training of neural network (nntraintool)

APPENDIX C

CODING USED FOR DEVELOPING ANN



```
Training_Data=xlsread('Data_ANN.xls',-1);
Testing_Data=xlsread('Data_ANN.xls',-1);
Shuffling_Inputs = Training_Data(randperm(108),1:9);
Training_Set = Shuffling_Inputs(1:108,1:8)% specify training set [2010 - 2012]
Target_Set = Shuffling_Inputs(1:108,9) % specify target set [2010 - 2012]
Testing_Set = Testing_Data(1:36,1:8) % specify Testing set [2010- 2012]
Testing_Target_Set = Testing_Data(1:36, 9) % specify Testing set, Target [2010- 2012]
[pn, ps] = mapstd(Training_Set');
[tn, ts] = mapstd(Target_Set');
[testn, tests] = mapstd(Testing_Set');
[tarn, tars] = mapstd(Testing_Target_Set');
MyNetwork = newff(pn,tn, [3] , {'tansig'});
MyNetwork.trainFcn = 'trainlm';
MyNetwork.performFcn = 'msereg';
MyNetwork.trainparam.min_grad = 0.00000001;
MyNetwork.trainParam.epochs = 1000;
MyNetwork.trainParam.lr = 0.4;
MyNetwork.trainParam.max_fail =10;
MyNetwork = train(MyNetwork,pn,tn);
save('MyNetwork');
y = sim(MyNetwork, testn); % simulate network
y_again = mapstd('reverse',y, tars) % denormlized
```

Figure C-1: Code used for programming ANN