ESTIMATION OF POTENTIAL SOLAR ENERGY IN MTI REGION (MALAYSIA, THAILAND AND INDONESIA) BASED ON LINEAR, NONLINEAR AND ARTIFICIAL NEURAL NETWORK MODELS

HUDHAIFA MAZIN ABDULMAJEED

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by

HUDHAIFA MAZIN ABDULMAJEED

(1330810928)

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UNIVERSITI MALAYSIA PERLIS

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Author's full name : **Hudhaifa Mazin Abdul Majeed Al-Sammarrae……………………….**

Date of birth : **25/4/1980………………………………………………..………………….**

Title : **Estimation of Potential Solar Energy in MTI Region (Malaysia, Thailand and Indonesia) based on Linear, Nonlinear and Artificial Neural Network Models**

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بمسالله الرحمن الرحيم

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Hudhaifa Mazin Abdu-majeed
University Malaysia Perlis (UniMAP).
Email: hothyfa_mazen@yahoo.com

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PV	Photo voltage, [A].
$I_{\circ}$	Solar constant, = 1,367 [w/m^2].
N	Day Number.
α	Altitude Angel.
L	Latitude Angel.
ε	Incidence Angle.
Θ	Zenith Angle.
H_S	Hour Angle.
t_s	Solar time [s].
LMT	Instant time during calculation [s].
EOT	Equation of time [s].
L_{zt}	Local standard meridian[s].
Tm	Module temperature, [OC]
E_{extra}	whole solar energy before the atmosphere field
E_T	Global radiation [kWh].
E_D	Diffused solar radiation [kWh].
E_B	Beam (direct) solar radiation [kWh].
E_R	Reflected solar radiation [kWh].
E	Energy generated [kWh].
$S_{\circ}$	Number of shining hours.
δ	Angle of declination.
K_T	Clearness index.
$\frac{S}{S_{\circ}}$	Sun shine ratio.
S	Represents day length.[h].

C	Daily average cloud cover.
a, b, c, d	Model coefficients.
e	Error vector.
Y	Output Variable Vector.
X	Input Variable Matrix.
β	Coefficient Vector.
o_i	ith Hidden Node Output Value.
$w_{0,i}$	Weights.
k	Layer Index.
j	Neuron Index.
$f(net)$	Activation or Transfer Function.
μ	Mean of The Input Variable *x*.
σ^2	Variance of The Input Variable *x*.
$m_A(x)$	Membership Function.
c_i	Focus of The Membership Function.
c_1	Constant With a Positive Charge.
r_1, r_2	Random Numbers Which are Equally Distributed in [0, 1].
$\mathrm{x}_{\mathrm{kj}}(\mathrm{t})$	Location in Present Time of The Particle.
$\mathrm{x}_{\mathrm{k,j}}^{\mathrm{L}}(\mathrm{t})$	Best Location of The Particle.
$\mathrm{x}_{\mathrm{k,j}}^{\mathrm{G}}(\mathrm{t})$	Global Best Position.
$\mathrm{w}(\mathrm{t})\mathrm{v}_{\mathrm{k,j}}$	Paramount Term of The Velocity Update.
SR	Solar Radiation.
ANN	Artificial neural network.
MAPE	Mean Absolute Percentage Error.
RMSE	Root Mean Square Error.
MBE	Mean Bias Error.
MTI	Zone of Malaysia, Thailand and Indonesia.

UV	Ultraviolet.
LM	Linear Model.
NLM	Nonlinear Model.
FLM	Fuzzy Logic Model.
MLRM	Multiple Linear Regressions Model.
PSOM	Particle Swarm Optimization.
G_{extra}	Extraterrestrial Radiation.
G_T	Global Irradiation.
FFMLP	Feed Forward Multilayer Perceptron.
I	Real value.
I_{pi}	Predicted Value.
I_i	Measured Value.

Anggaran Potensi Tenaga Solar Di MTI Rantau (Malaysia, Thailand dan Indonesia) berdasarkan Linear, tak linear dan Neural Network Artificial Model

ABSTRAK

Data sinaran suria (SR) menawarkan maklumat tentang jumlah potensi matahari di bumi dalam tempoh masa yang tertentu. Data-data daripada sinaran suria sangat penting untuk merekabentuk sistem solar PV sistem. Disebabkan kos yang tinggi dan beberapa masalah, menyebabkan kekurangan data dalam membuat ketersediaan data amatlah sukar. Model ramalan untuk sinaran suria adalah penyelesaian utama untuk menggantikan data-data penting dan merangkumi daripada hilang. Oleh yang demikian, terdapat permintaan untuk membangunkan kaedah alternatif untuk meramalkan data ini. Zon seperti Malaysia, Thailand dan Indonesia (MTI), yang merupakan sebahagian daripada Asia Tenggara (SEA) merupakan sebuah kawasan yang besar, dengan model yang tidak meliputi segalanya. Di sisi lain, zon (MTI) telah mengaplikasikan banyak jenis pemodelan teknik ramalan sinaran suria dengan variasi dalam ramalan sikap dan keputusan ketepatannya; oleh itu ia adalah sangat penting untuk melaksanakan perbandingan antara model untuk menghasilkan satu model ramalan sinaran suri yang paling tepat. Model ramalan perlu mengikut ketepatan yang terbaik, perlu dibandingkan dengan lain-lain model dan berada dalam zon yang sama. Kajian ini membentangkan model MTI linear, MTI tak-linear dan artificial neural network (ANN) untuk membangunkan satu piawaian pemodelan di kawasan yang sama untuk meramalkan sinaran suria global dan tersebar. Model yang berbeza ini telah diuji di kawasan yang berbeza. Kawasan-kawasan yang dikelaskan sebagai Zion, rantau dan global. Sistem modela menunjukkan bahawa model zon dan wilayah adalah tepat dan boleh digunakan untuk meramalkan sinaran suria. Namun yang demikian, model global mempunyai peratusan ralat yang tinggi. Hasil kajian menunjukkan bahawa model ANN adalah tepat berbanding dengan tak linear dan model linear di mana min peratusan mutlak ralat (Mape) dalam pengiraan tenaga solar di Malaysia dengan model ANN ialah 5.3%, manakala Mape untuk tak linear MTI dan model linear adalah 6.4%, masing-masing 7.3%. Di samping itu punca min ralat kuasa dua (RMSE) menunjukkan keputusan yang memberangsangkan berikut, 7.2% bagi model ANN dan 8.1%, 8.5% bagi masing-masing tak linear MTI dan model linear. Akhir sekali min ralat berat sebelah (MBE) datang dengan hasil yang berikut model ANN ialah -1.3%, model tak linear MTI adalah -1.1% dan MTI model linear adalah -1.1%.

Estimation of Potential Solar Energy In MTI Region (Malaysia, Thailand and Indonesia) based on Linear, Nonlinear and Artificial Neural Network Models

ABSTRACT

Solar radiation (SR) data offer information on the amount of the sun potential at a location on the earth during a specific time. These data are very important for designing sizing solar photovoltaic (PV) systems. Due to the high cost of installation and fitting troubles, these barriers cause lack of data and make data availability difficult. Prediction models for solar radiation are the key solution to substitute these important data and cover the missing from it. Therefore, there is a demand to develop alternative ways of predicting these data. The zone of Malaysia, Thailand and Indonesia (MTI), which are part of southeast Asia (SEA), is a huge area Had no model can cover all regions but only individual models assigned to particular countries. On the other hand, the zone (MTI) had practiced many types of modeling techniques for solar radiation prediction, with variation in its prediction attitude and results accuracy; hence, it is very important to implement a comparison between models in order to find the most accurate one. Best prediction model according to accuracy, need to be compared with other similar neighbor models within the same zone. This study presents linear, non-linear models as MTI linear and MTI nonlinear models in order to develop a standardization modeling technique in this zone and Artificial neural network (ANN) models has been implemented also in the same area to predict its global and diffuse solar radiation. The different models have been tested in different areas. These areas are classified as zone, region and globally. It is found that the zone and region models are accurate and could be used to predict solar radiation, which is an interested achievement. Nevertheless, global models have a high error percentage. The results showed that the ANN models are accurate in comparison with the nonlinear and linear models in which the mean absolute percentage error (MAPE) in calculating the solar energy in Malaysia by the ANN model is 5.3%, while the MAPE for the MTI nonlinear and linear models is 6.4%, 7.3% respectively. In addition, the root mean square error (RMSE) shows the following promising results, 7.2% for ANN model and 8.1%, 8.5% for the MTI nonlinear and linear models respectively. Finally, the mean bias error (MBE) comes up with these next results ANN model is -1.3%, the MTI nonlinear model is -1.1% and MTI linear model is -1.1%.

CHAPTER 1

INTRODUCTION

1.1 Background

Most of energy on earth is from the daily sunshine. This is called the solar energy. It takes the shape of rays when solar energy departs from the sun towards the earth, its possible to see some of them like light rays. Some rays are not visual to human, because they are beyond human vision capabilities like x-rays. These rays energy is called radiant energy (Hill, 1999). This energy comes from sun. The sun is a giant ball of gas. Majority of the rays are reflected back to space. With the exception of a small portion which finds its way to the earth. When the ray arrives and meets the earth's surface, some clusters of clouds reflect back the rays into aerospace. The majority of solar energy withdraws by the earth and turns it into heat. This heat increases the temperature of the earth and the air around the atmosphere as shown in Figure 1.1 where part of solar radiation is reflected and another part is absorbed. Without the solar energy, the earth will be very cold and human being cannot live on it.

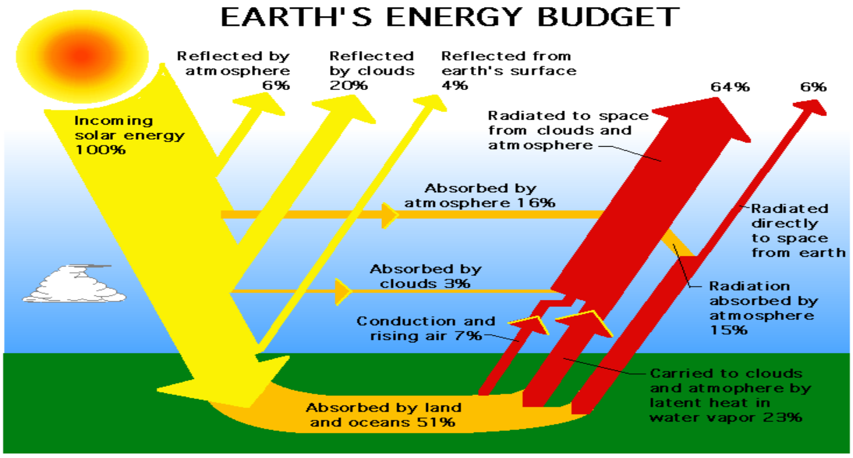

Figure 1.1: Solar energy stages (Hill R et al., 1999)

the energy which comes from sun (solar energy), considered as very smart and interesting solution for increasing global energy demand because this type of energy is basically considered as endless and available on a large scale (Aslani, 2014). Solar radiation is the main source of renewable energy in the earth. It's very important for solar energy engineers, designers, architects, and it is also a key factor to identify efficiently the needs of irrigation water and crop productivity potential, among other things (Aslani, 2014; Hudson, 2003). The sun produces electromagnetic radiation towards earth and the visible light is only one portion from that radiation .all along with the other invisible radiation like, infrared, Ultraviolet UV (A,B,C) , radio waves, micros, , X-rays (EUV or XUV) and gamma rays (Cai,2005), as shown in Figure 1.2. When sunlight reaches earth, it will be filtered over the Earth's atmosphere. When direct radiation is not prevented by the clouds, it will become the sunshine; it's a bright light and radiant heat mixture. It becomes a diffused light, if it has been blocked by the clouds or reflects off other things (Kreider, 2014; Tuller, 1976).

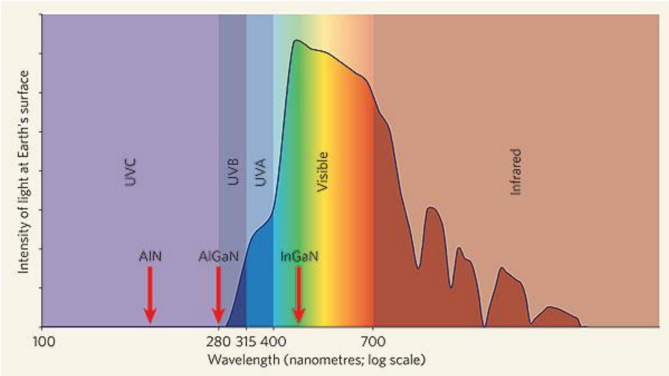

Figure 1.2: Solar irradiation as a function of wavelength (Kreider, J. F. et al., 2014).

Photovoltaic (PV), also called solar cell, is a device that creates electricity by transforming directly light which comes from the sun based on solar energy. Without consuming fossil fuels with clean, reliable energy, PV system can be utilized in wide different applications (IEEE Standard 1262, 1995). PV technology provides power for many applications such as lights, TV and calculators. and these are some of the advantages for using PV technology (Godfray, 2010). PV has been available for more than a hundred years ago (Green, 2004). It has been noticed in 1873, that selenium is sensitive to light, by British scientist Willoughby Smith. He concluded that after exposing selenium to light, it will have the capability to conduct electricity increase in direct proportion to the degree of light (Green, 2004).

This conclusive statement of photovoltaic directed many scientists to research with this comparatively exceptional element with the optimism of using the material to create electricity. More widely, one of the PV benefits is that many countries have installed large PV arrays recently to provide consumers with solar energy to generate electricity. PV technology began using backup systems to provide critical equipment and tasks. About 175,000 villages in over 140 countries worldwide use power that is supported from PV modules, as a result, thousands of jobs have been produced and sustainable economic prospects have been created (Al-Badi, 2011).

Over 350 megawatts of international sales for PV products amounted over USD 2 billion in the global market in 2001. PV applications can be involved in communications, different electrical devices for health care, crop irrigation, water purification, lighting, cathode protection, environmental monitoring, marine and air navigation, utility power, and other residential and commercial applications (Al-Badi, 2011). The intense generated by current PV applications provides promise for this rapidly developing technology (Godfray, 2010).

There are two main sources of energy, they are renewable source and nonrenewable source. In fact, renewable energies are the armature to fight climate change and resource depletion. Solar radiation is the most significant source of renewable energy in the globe (Aslani, 2014; Khatib, 2013). But, the nonexistence situation of measured solar radiation data, several studies had been done to evaluation and prediction the amount of solar radiations.

Solar radiation data should always be measured and precisely over the longstanding, for an effectual transformation and deployment of solar power. Though, due to some technical and fiscal limitations, the measurement of solar radiation is not obtainable for all countries in the world. For this reason, numerous studies were proposed in the publications and researches in worldwide to find scientific ways to estimate and forecast the amount of solar radiations such as stochastic prediction models which based on time series methods (Huang, 2009; Knight, 1991) and artificial neural network approaches (Khatib, 2012; Mubiru, 2008).

Models which have been developed to simulate solar energy are many which include the linear, nonlinear, ANN (Artificial neural networks), FL (Fuzzy Logic) modeling, MLR (Multiple Linear Regressions) modeling and PSO (Particle Swarm Optimization) models. Then after, a truthful model for solar energy should be established to provide a comprehensive database for the solar energy prospective (prediction). Nevertheless, various reviewing effort in respects to solar energy models can be referred in literature and will be discussed in this thesis.

1.2 Problem Statement

The data of solar radiation offer information and facts on how much of the sun's energy that been applied on a surface at a location on the earth throughout a precise time period. It is very important to use these data for effective research in solar energy application. Hence, there are compulsory needs to substitute and generate the missing data in order to cover the lack of required informations, as much the cost and difficulty in solar radiation measurements, in addition, these data are not readily available (Aslani, 2014). Because of this lack of measured solar radiation data, many different models arise to estimate it, These models have been developed using more readily available data. Some are the Angstrom Prescott equation and its variations and others are linear, polynomial, neural networks, exponential and logarithmic models; also stochastic and genetic algorithm models, among others (Ji, 2011; Boland, 2008; Kreider, 2014).

Absences of a standard model of solar energy prediction that point on particular area, make the prediction process more complex and increases the cost of time and efforts, On other hand, the majority of the researches and approaches were focusing on applying new parameters and coefficients to the prediction models or estimating solar energy for specific location Malaysia, Thailand...etc. Because of this problem which is (location boundary), it is not possible to predict solar energy for huge area which covers the Malaysia, Thailand and Indonesia MTI region. Even with country that had the chance to find their prediction model, their model operated in specific metrological locations and didn't cover all country zone. whether there is chance to find a good solar energy spot within the same region that worth to be invested, but the lack of information is prevented. For these reasona a common models are purposed in this thesis, which compatible with MTI region based on linear, nonlinear and ANN models. The proposed model has been analyzed and compared with the other models.

1.3 Research Objectives

The developed models for solar energy prediction are many which contain the linear, nonlinear, ANN, FL, MLR and PSO models. Moreover, a truthful model for solar energy should be established to make available a broad database for the solar energy possible.

The objectives of this study are to investigate the following issues:

1. To develop linear, nonlinear, and ANN modeling techniques used to pridict solar radiation.

2. To analysis and evaluate the solar radiation using the previous modeling techniques and compare to previous work.

3. To verify the mentioned models based on data measurement and compare proposed model with regional MIT models.

In this study the three types of prediction models have been proposed based on previous model in different zones, regains and global. MATLAB 9 software has been used to design and analysis linear, non-linear and ANN models.

1.4 Scope of Research Works

Limitation of solar energy data is a big barrier for a good estimation. Owing to such, prediction models are required to compensate the lack of data. This study focuses on development for linear and non-linear models to be compatible to all MTI regions also compare them with many similar models from the same region. Nevertheless an ANN model has been applied, so to be compared with the rest of the models. In addition, with the help of ANN comparison, diagnosis between similar and different model is possible.

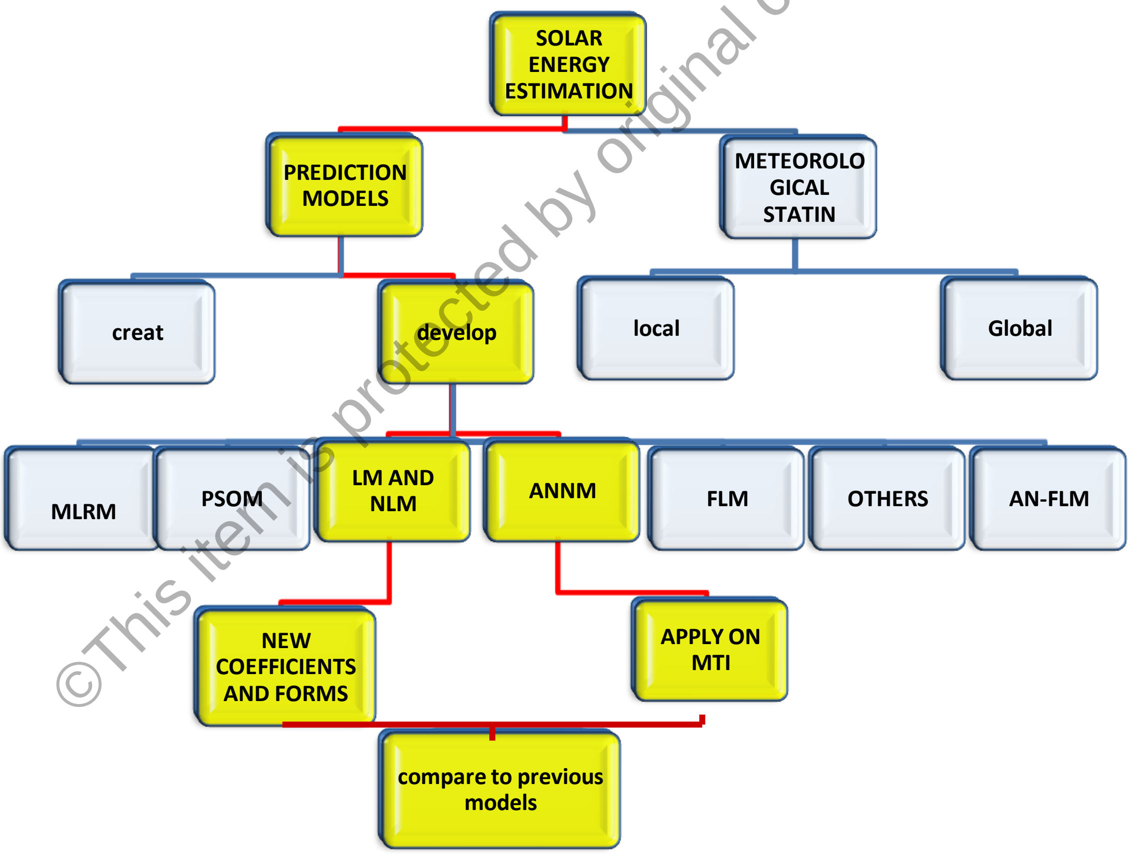

Figure 1.3: scope of research works