Power Prediction Analysis using Artificial Neural Network in MS Excel

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Abstract: - In this study, an artificial neural network (ANN) based model for prediction of solar energy potential in Kuala Lumpur, Malaysia was developed. Standard multilayered, feed-forward, back-propagation neural networks were designed using Microsoft Excel (MS Excel). The meteorological data were acquired from Malaysia Meteorological Department. The data was consists of meteorological data from one station in Subang for period of 10 years (2003–2012) from were used for the training and testing the network. Parameter of month, sunshine duration, minimum temperature, maximum temperature, average temperature and relative humidity were used as inputs to the network, while the solar radiation was used as the output of the network. Simulation result shows that ANN potentially predicts solar radiation. Furthermore this prediction can contribute an enhancement of renewable energy development in Malaysia.

Key-Words: Artificial Neural Network, Backpropagation, Multilayer Perceptron, Power Prediction, Solar radiation

1 Introduction

In most systems, forecast or predictions of the future system condition or state are necessary to achieve optimal management and control. Power predictions for photovoltaic installations are playing bigger role since world get awareness on advantages of solar energy as sustainable energy. Thus, development and research on it has been rising year by year. It is used to optimize usage of the solar energy and provide plausibly accurate knowledge of the solar resource availability at any place it is required. According to the past literature, the general technique for prediction of power are ARIMA (Auto Regressive Integrated Moving Average), Bayesian and Markov [1].

Artificial Neural Network (ANN) models may be used as an alternative method analyzing data in engineering and predictions of solar energy. ANNs are a computing concept designed to mimic the human brain and nervous systems, which mainly function as neurons assembler. Like the human brain, the ANNs are intelligent with the ability to learn, memorize, and create relationships. The ANN captures this functionality because of their nonlinear and highly parallel information processing capability. This capability enables them to easily adapt to the change situations and sequential variations. Unlike the ANN, the classical statistics used in stochastic, analytic, and empirical methods do not cater for sequential variations [2]. The high interconnectivity in ANN makes them quite tolerant to errors or noise, in the input data. Neural networks have been used to perform complex functions in various fields. ANNs have been trained to overcome the limitations of the conventional approaches to solve complex problems and it can be trained to solve problems that are difficult to model analytically.

In recent years, solar energy studies have experienced an outstanding and rapid growth due to the environmental reasons. A number of conventional methods and neural network methods have been reviewed before this. The advantages of NN based simulation techniques are that they present an alternative approach to conventional physical modelling techniques, and they do not require the knowledge of internal system parameters, involve less computational effort and offer a compact solution for various problems.

A research done by T. Khatib *et. al* [3] presents a solar energy prediction model using ANN. This model predicts a clearness index that is used to calculate global and diffuse solar irradiations. The ANN model is based on the feed forward multilayer perception model with four inputs and one output. The input parameters are latitude, longitude, day number and In addition, the measured solar irradiations from the sites were used to derive an equation to calculate the diffused solar

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irradiation, a function of the global solar irradiation and the clearness index. The proposed equation has reduced the mean absolute percentage error (MAPE) in estimating the diffused solar irradiation compared with the conventional equation. Based on the results, the average MAPE, mean bias error and root mean square error for the predicted global solar irradiation are 5.92%, 1.46%, and 7.96% respectively. The MAPE in estimating the diffused solar irradiation is 9.8%.

Sozen *et al.* [4] have used the ANN predicted solar potential values to construct monthly radiation maps in Turkey. These maps are prime importance for different working disciplines like, scientists, architects, meteorologists and solar engineers. The predictions from the ANN models could enable scientists to locate and design solar energy systems and determine the best solar technology.

Mohandes, S. Rehman, and T. O. Halawani [5] used data from 41 collection stations in Saudi Arabia together with an ANN for the estimation of global solar radiation. From these data for 31 stations were used to train a neural network and the data for the other 10 for testing the network. The input values to the network are latitude, longitude, altitude and sunshine duration. The results for the testing stations obtained are within 16.4% and indicate the viability of this approach for spatial modelling of solar radiation.

C Chupong *et. al* [6] forecast power output of PV Grid Connected System by data from calculating the solar radiation in clear sky condition and weather forecast data as Input to the Elman neural network instead of using a solar radiation measurement. This research use MATLAB software to create network and training, data used to train the network come from the calculation weather forecast and hourly data of output PV 1 kWp Grid Connected System at roof-top of Building Faculty of Science and Technology, Rajamangala University of Technology Thanyaburi. In this experiment found that the forecast and actual values go in the same direction and the errors were 16.83%.

The aim of this study is to analyze, investigate and develop model of supervised learning network of photovoltaic power prediction for precise and accurate power prediction. To provide a comprehensive solar radiation data output Hence, the model can be used to predict the monthly solar radiation potential for specific locations in Malaysia where there are no records of solar radiation for certain places that not have meteorological stations. The predicted solar radiation values from the model were given in the form of monthly data in MS Excel from January to December, which can be used easily for design and assessment of solar application systems.

2 Problem Formulation

At present, the research on PV power technology is lacking in Malaysia. Referring authors in [3], they list several researches for power prediction using neural network has done in Malaysia. Thus, an ANN model for solar energy prediction should be developed to provide a comprehensive data of solar energy potential in Malaysia.

Generation of electricity from solar energy is gaining popularity as a solution to the growing energy demands. The most important parameter in renewable energy applications is solar radiation. Due to forceful power crisis, increasing of solar energy based solutions are being purchased. Weaknesses of these solutions are long payback period and comparatively less efficiency. Solar radiation data is considered as the most important parameter in the meteorology, solar conversion, and renewable energy application. Unfortunately, this parameter is not always available particularly in remote areas, where there are no meteorological stations installed in these locations. Thus, an ANN model for solar energy prediction should be developed to provide a comprehensive data for the solar energy potential in Malaysia. Usually the power prediction made using measurement and calculation method thus it is need much time and not practical.

2.1 Artificial Neural Network

Artificial Neural Networks attempt to model the functioning of the human brain. The human brain for example consists of billions of individual cells called neurones [7]. Neural networks are composed of simple elements operating in parallel [8]. These elements are inspired by biological nervous systems. As in biological nervous systems, the network function is determined largely by the connections between elements. A neural network can be trained to perform a particular function by adjusting the values of the connections (weights) between the elements. Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output. During the training process, the weights of the connections between neurons are adjusted to achieve a desired input/output. A multilayer feed forward network has its neurons organized into layers with no feedback

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or lateral connections. Layers of neurons other than the output layer are called hidden layers. Input signals propagate through the network in a forward direction, on a layer-by-layer basis until the output layer.

One of the major advantages of neural networks is their learning ability to perform specific tasks. Learning is accomplished by adjusting the weights of the connections between neurons. Weights are adjusted to allow the network to produce outputs as close as possible to the known correct answers of the training data

The back-propagation algorithm is a supervised iterative training method for multilayer feed forward networks [9]. A sample from the training data is chosen randomly and provided to the inputs of the network, which computes the outputs on a layer-by-layer basis until the output layer. The difference between the actual output of the network and the correct output that is provided in the training data is used to adjust the weights, so that the next time that same input is provided, the network output will be closer to the correct one. This process is repeated for all other input-output pairs in the training data. Thus, the back-propagation algorithm minimizes an error function defined by the average of the sum square difference between the output of each neuron in the output layer and the desired output.

Computational complexity refers to the time required for a learning algorithm to estimate a solution from training patterns. Many existing learning algorithms have high computational complexity. Designing efficient algorithms for neural network learning is a very active research topic. It is hoped that devices based on biological neural networks will possess some of these desirable characteristics.

2.2 Power Prediction

A prediction or forecast is a statement about the way things will happen in the future based on experience or knowledge. Solar radiation data provide information on how much of the sun's energy strikes a surface at a location on the earth during a particular time period. These data are needed for effective research into solar energy utilization. It is an opportunity to use this source to generate clean energy. This energy is free of charge, clean, and abundant in most places throughout the year. The ability to estimate solar radiation using surrogate measures would provide better analysis of expected performance of technologies. The validation of the average meteorological data for the region will also have applications especially when sizing and deploying solar technology systems.

Another reason focusing on solar energy is Feed-in Tariff. The FiT is Malaysia's new mechanism under the Renewable Policy and Action Plan to catalyse generation of RE. This mechanism allows electricity produced from indigenous renewable energy resources to be sold to power utilities at a fixed premium price for a specific duration [10].

3 Problem Solution

3.1 Artificial Neural Network for Power Prediction

An ANN resembles a biological neural system, composed of layers of parallel elemental units called neurons. The neurons are connected by a large number of weighted links, over which signals or information can pass. A neuron receives inputs over its incoming connections, combines the inputs, generally performs a nonlinear operation, and outputs the final results. MS Excel was used for develop the ANNs for solar radiation prediction. The neural network adopted was a feed- forward multilayer perception (FFMLP) network, among the most commonly used neural networks that learn from examples.

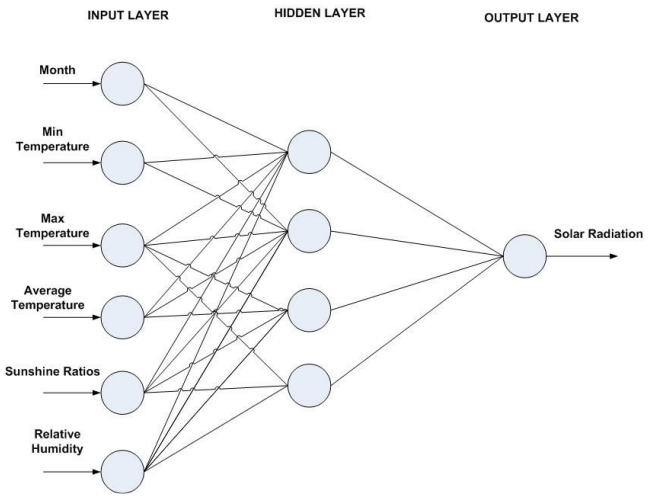

Fig. 1 Network Topology

A schematic diagram of the basic architecture is shown in Fig. 1. The network has three layers: the input, hidden, and output layers. Each layer is interconnected by connection strengths, called weights. MLP network developed using MS Excel, it is easy to use and better understanding on neural network. A spreadsheet was designed that would hold all of the information that was necessary for the network to operate. Code was written that would

take an input file in any standard Excel format, and use the data there to construct an ANN automatically. Following the expected format, the input file must have the actual data in the first columns, while the final column must always contain the desired output for the previous columns' input data. MS Excel has an excellent graphing capability; this can be used to the user's advantage. It is often useful to graph the entire node activation area of the spreadsheet.

Six meteorological variables were used as input parameters for the input nodes of the input layer. These variables were month, minimum temperature, maximum temperature, average temperature, relative humidity, and sunshine hour's ratio which is measured sunshine duration over daily maximum possible sunshine duration. A single node was at the output layer with the estimated solar radiation as the output.

An Artificial Neural Network (ANN) consists of many interconnected identical processing units called neurons. Each neuron computes a weighted sum of its z input signals. The activation function for neurons is sigmoid function. The learning algorithm used was the standard back propagation. The sigmoid function, S defined as follows:

$$S(z) = \frac{1}{1 + e^{-z}} \quad (1)$$

where z is the weighted sum of the inputs. The weights of the interconnections between neurons are adjusted during the training process to achieve a desired input/output mapping.

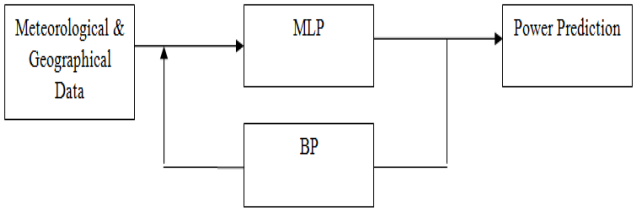

Fig. 2 Model Architecture

The data from 1 station which is Subang Meteorological Station contains five parameter data for 10 years which is for 120 months. 7 years was used for training the neural network. This provided 504 input-output pairs for training. The training process continues until approaches a precise minimum value. After the training is completed, the developed model is used for testing using remaining 2 years data. Lastly, one year data was used for prediction.

Fig. 2 shows the model architecture. Meteorological data was the input and these inputs are feed into the MLP network. The network use BP algorithm as learning method and the data are trained until satisfying the desired output. This network will then produce output which is solar radiation.

3.2 Result and Discussion

An expected outcome was solar radiation for specific area in unit MJ/m^2. This output then used to evaluate the performance of the network such as mean absolute percentage error (MAPE). MAPE is ccomparison result between proposed and existing model. The model's evaluation method can guarantee the stability of model prediction error. This research will produce analysis on solar radiation as output of the network.

Fig. 3 shows result from developed network for testing stage. The result shows the network still not stable since simulation for certain months produce big different between predicted and measured.

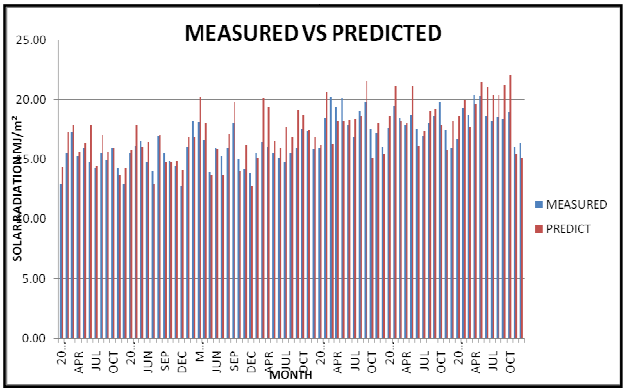

Fig. 3 Measured vs Predicted Result (Testing Stage)

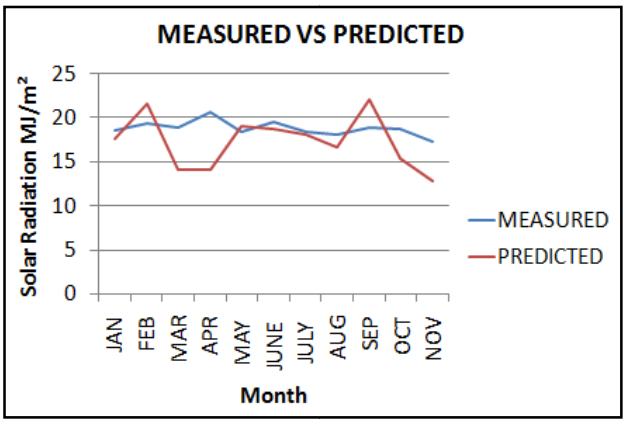

Fig.4 Measured vs Predicted Result (Prediction Stage)

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Fig. 4 shows result on prediction using input data for one year which is for 2012. MAPE average for 2012 is 13.56%. Mean Square Error (MSE) is the average of the weighted sum of the error for N training sample, and the result is 0.014285. This study proves that power prediction using network can be develop using MS Excel.

4 Conclusion

The results of this study indicate that the ANN based model for solar radiation is accurate for prediction of solar radiation in Kuala Lumpur, Malaysia. The ANN model is capable and can be used to predict solar radiation for any region with provided comprehensive meteorological data. However the result produce from this research is still not appropriate and still needs further improvement on the network mechanism. One of the important aspects in our future research is to look into and analyze the network architecture for the Mean Square Error (MSE) optimization.

This study can give significant knowledge on power prediction and the accuracy of the forecast power can provide necessary basis data for the dispatcher or end user. Moreover it is extremely important to the planning and operation of photovoltaic system since a reasonably accurate knowledge of the solar resource availability at any place is required by solar engineers, architects and meteorologists in many application areas of solar energy.

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