Modeling Of Solar Radiation Using Artificial Neural Network for Renewable Energy Application

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Abstract: For Solar Energy Utilization And Installation Of Any Solar Devices, The Accurate Measurement And Knowledge Of Global Solar Radiation Of A Particular Location Is Very Essential For Effective And Efficient Usage Of Solar Devices In That Particular Area. However, The Number Of Radiation Stations Are Not Many When Compared To The Stations That Collecting Atmospheric Parameters Like Ambient Temperature, Relative Humidity, Rainfall E.T.C., The Modeling Of Global Solar Radiation With An Atmospheric Parameter Using Artificial Neural Networks (ANN) At Subang Selangor Malaysia (Latitude 7°n, Longitude 103°e) Was Carried Out In This Study In A Simpler Way. The ANN Was Used To Develop A Model Based On Multi-Layer Perceptron (MLP) Of ANN Which Trained And Tested Using A Period Of Eleven Years (2000-2010) Meteorological Data. The Estimated Result That Generated From The Artificial Neural Network Was Validated Using Mean Bias Error (MBE), Root Mean Square Error (RMSE), And Mean Percentage Error (MPE). Based On Analysis And The Result Obtained From The Proposed Model Using ANN, A Close Agreement Is Obtainedbetween The Measured Values Of Annual Global Solar Radiation And The Predicted Values By The Proposed Model And The Correlation Coefficient Estimated To Be 0.972. The Value Of Mean Bias Error, Root Mean Square Error And Mean Percentage Error Are 0.00422, 0.00312 And -0.0811 Respectively. This Confirms That The Model Can Be Used Successfully For Estimating Global Solar Radiation In The Study Area For Solar Energy Devices Applications.

Key Words: Global Solar Radiation, Artificial Neural Networks, Solar Energy, Atmospheric Parameters.

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I. Introduction


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The Neural Network Is A Software Application That Can Be Used To Predict A Value Of Data Such As Solar Radiation. Artificial Neural Networks (ANNs) Are Information Processing Systems That Are Non-Algorithmic, Non-Digital And Intensely Parallel [8, 9,10]. A Neural Network Learns The Relationship Between The Input And Output Variables Through Studying Previously Recorded Data By A Procedure Called Learning (Or Training). The Neural Network Employed Is A Multi-Layer Feed Forward Perceptron Which Is One Of The Most Commonly Used Neural Network Models That Learn From Examples [11, 12]. The Neural Network Can Be Used In Modelling An Equation For Predicting The Value Of Solar Radiation Where There Is No Equipment To Measure The Solar Parameters Especially In The Rural Areas As A Result Of High Expensive Of The Weather Station EQUIPMENT. The Prediction Of The Solar Radiation By Application Neural Network Will Be Useful In Any Utilization Solar Energy Particularly In Design And Manufacture Of Any Solar Devices For High Performance Efficiency. Artificial Neural Networks Are Generally Accepted As A Technology Involvement To Encounter Multifaceted And Ill-Defined Problems. They Have Been Used In Different Applications Device, Weather Forecasting, Power System, Robotics, Medicine, Industrialization And Optimization, Signal Processing And Social/Psychological Sciences [13, 14, 15].

II. Materials And Method

2.1 Data Acquisition


2.2 Development Of The ANNs For Solar Radiation Models


The Data Collected Is Randomly Divided And 60% Was Used For Training, 20% For Testing And 20% For Validation. Testing Data Does Not Have Any Effect On Training. It Provides Independent Measure Of Network Performance During And After Training. The Following Is An Outline Of The Procedure To Use In The Development Of The ANN Model: Input And Target Values Were Normalized, In The Range -1 To 1, Matrix Size Of The Dataset Was Defined, Partition; Create Training, Test And Validation Sub-Datasets, The MLP Neural Network Will Be Created, The MLP Neural Network Will Be Trained, Automatic Architecture Will Be Selected, Output Values Will Be Generated, Un-Normalize The Output Values, The Performance Of The Neural Network Will Be Checked By Comparing The Output Values With Measured Values.

2.3 The Model

The Armstrong-Type Regression Model Equation Has Been Used To Determine Its Applicability For This Work.

The Equation Is Expressed As; \[ \frac{H}{H_0} = K = a + b1 \]

Where T Is Mean Ambient Temperature Of The Study Station. ‘A’ And ‘B’ Are Constants For A Particular Station Been Considered Which Are Dependent On Latitude And Other Meteorological Parameters.

The Ratio Of Mean Monthly Global Solar Radiation (H) To The Mean Monthly Extraterrestrial Solar Radiation (Ho) I.E Average Clearness Index Was Correlated With Monthly Average Ambient Temperature, Transforming Equation 1 Into Equation 2

Where’s Y = 0.0314x - 0.77682

Y Is Equivalent To H/Ho = K,

X Is Equivalent To T

A = 0.7768 And B = 0.0314

Where H Is The Global Solar Radiation, Extraterrestrial Solar Radiation, K Is The Clearness Index And T Is Mean Ambient Temperature Of The Study Station. ‘A’ And ‘B’ Are Constants For A Particular Station Been Considered Which Are Dependent On Latitude And Other Meteorological Parameters. ANN Predicted Values Of Monthly Average Global Solar Radiation As Well As Average Monthly Clearness Index Were Computed Using Equation 8 And Then Compared With The Measured Values.
2.4 Validation Of Model

The Estimated Results That Will Be Given By The Artificial Neural Network Will Validated Using The Following Errors Analysis: Mean Bias Error (MBE), Root Mean Square Error (RMSE) And Mean Percentage Error (MPE). The Statistical Expressions For The Estimators Are Expressed As Follows:

\[
\text{MBE} = \frac{\sum_{i=1}^{n} (K_{tp} - K_{tm})}{n}
\]
\[
\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (K_{tp} - K_{tm})^2}{n}}
\]
\[
\text{MPE} = \frac{\sum_{i=1}^{n} (K_{tp} - K_{tm})}{K_{tm}} \times 10^5
\]

III. Results And Discussion

3.1 Distribution Of Global Solar Radiation In The Study Area.

Table 1 Shows The Measured Global Solar Radiation (Hm) Of The Study Station. From The Table, It Is Seen Clearly That The Highest Magnitude Of Solar Radiation Was Received On The Earth Surface In The Year 2004 And The Lowest Magnitude Of Solar Radiation Was Received In The Year 2003 At The Study Area. Also, It Is Observed From The Table That Year 2007, 2008, 2009 And 2010 Have A Close Range Of Magnitude Of Solar Radiation, This Implies That In These Years, At The Area Of Study, Approximately, The Same Values Of Solar Radiation Were Received On The Earth Surface From The Sun. Hence, The Effect Of Solar Radiation Characteristic Will Also Be In Close Range In These Years, Thus, This Could Also Be Attributed To Stable Climate Characteristics In The Study Area. This Is Evidence And Ascertained That The Area Of Study And Its Environ Actually Have High Potential For The Solar Energy Applications, Especially For The Photovoltaic Solar System To Sustain Both Long Term And Less Expensive Power Supply Compared To Conventional Power System Currently Using In The Area.

The Reports Of Figure 2, Shown That The Minimum Value Of Global Solar Radiation Is 19.86 MJm-2day-1. It Occurs In The Month Of March. This Result Is Expected Because The Month Of March Is Dry Period In The Study Station, The Southern Part Of The Country. The High Values Of Solar Radiation From Figure 2 Occur In February To May When Most Part Of The Station Area Experiences High Intensity Of Sunshine.

3.2 Variation Of Annual Mean Ambient Temperature

Global Solar Radiation Depends Upon The Location And Has Many Effects On The Type And Rate Of Chemical Reaction In The Atmosphere. It Affects The Air Convection And Mixing And Thus, The Ambient Temperature Of The Day. However, It Is Observed From Figure 1 That The Maximum Temperature Obtained In The Months Of April, May And June Is Around Approximately 28°C, While The Minimum Temperature Recorded Is Round 27°C In The Months Of August To December And January. Generally, The Trend Of Temperature Variation Expected To Be Similar To All The Studied Years In The Area, Since The Ambient Temperature Is The Function Of The Global Solar Radiation Reaching The Surface Of The Earth.

It Was Observed From Table 3 That There Were Consistent Decreases In Mean Values Of Ambient Temperature, Measured Global Solar Radiation, Extraterrestrial Solar Radiation On The Horizontal Surface As Well As The ANN Predicted Global Solar Radiation From July To December And January To February. The Low Values Are Attributed To Rainy Season In The Station When Temperature Is Expected To Be Low. The High Value Of Temperature In The Month Of March, April, May And June Explain While The Great Landmasses Of The Station Hemisphere Are Much Hotter At The Same Latitude, And Low Value In The July To December Confirmed The Reversed Situation. This Indicates That Temperature Of The Atmosphere Is Greatly Influenced By Both The Land And The Sea Areas.

Comparison Of The Results Predicted By The Proposed Model And Measured Values Of Annual Global Solar Radiation Is Presented Graphically In Figure 3. Figure 3 Displays The Variation Of The Measured Values Of Global Solar Radiation Obtained In The Study Area And Predicted Results Of Global Solar Radiation By The Proposed Model Using ANN With Number Of Years. It Could Be Deduced From This Graphical Analysis That Result Obtained From The Model Has A Closer Agreement With The Measured Values Of Annual Global Solar Radiation In The Study Area. This Confirms That Predictive Value By The Proposed Model Using ANN And Measured Values Are Of The Same Values. Hence, The Model Can Serve As
A Baseline Tool That Will Use In Designing And Sizing Solar Devices Application In Subang Area Of Malaysia And Its Environs For Solar Installers And Users.

3.2. Model Validation

From The Table 2 Validation Of The Results Estimated By The Model Using Error Analysis Gives The Values Of Mean Bias Error (MBE) As 0.00422, Root Mean Square Error (RMSE) As 0.00312 And Mean Percentage Error (MPE) As -0.0811. It Can Be Concluded From The Errors Analysis Results That Low Values Of Both MBE And RMSE Attributes To The Good Performance Of The Proposed Model. It Is Also Important To Note From The Results That The Value Of MPE From The Model Is Less Than 1%. From Table 3, Even When The Model Was Subjected To Further Statistical Analyses; Percentage Error And Coefficient Of Determination, $R^2$, The Model Stood Out Uniquely, Correlation Coefficient (0.982) Is High For The Studied Area. This Implies That, There Are Statistical Significant Relationships Between The Global Solar Radiation And Ambient Temperature ($T$) In The Location Considered.

IV. Conclusion


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<table>
<thead>
<tr>
<th>Table 1</th>
<th>Meteorological Data Of The Study Location</th>
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<tbody>
<tr>
<td>Year</td>
<td>Month</td>
</tr>
<tr>
<td>2000</td>
<td></td>
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<tr>
<td>2005</td>
<td></td>
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<tr>
<td>2006</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
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<tr>
<td>Average</td>
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<table>
<thead>
<tr>
<th>Table 2</th>
<th>The Values Of Statistical Indicators For The Error Analysis</th>
</tr>
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<tbody>
<tr>
<td>R²</td>
<td>MBE</td>
</tr>
<tr>
<td>0.972</td>
<td>0.00422</td>
</tr>
</tbody>
</table>

| Table 3 | Meteorological Data Of Measured And Predicted ANN Solar Radiation, And Maximum Temperature Of Study Area |

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<table>
<thead>
<tr>
<th>Month Of The Year</th>
<th>Ho (MJ/M²/Month)</th>
<th>Hm (MJ/M²/Month)</th>
<th>Hp (MJ/M²/Month)</th>
<th>Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>284.584</td>
<td>16.93</td>
<td>17.01</td>
<td>27.23</td>
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<tr>
<td>Feb</td>
<td>138.583</td>
<td>19.63</td>
<td>18.38</td>
<td>27.59</td>
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<tr>
<td>Mar</td>
<td>179.798</td>
<td>19.86</td>
<td>19.00</td>
<td>27.94</td>
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<tr>
<td>Apr</td>
<td>139.038</td>
<td>19.18</td>
<td>18.68</td>
<td>27.86</td>
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<tr>
<td>May</td>
<td>149.603</td>
<td>19.57</td>
<td>18.70</td>
<td>28.57</td>
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<tr>
<td>Jun</td>
<td>243.685</td>
<td>17.96</td>
<td>18.06</td>
<td>28.16</td>
</tr>
<tr>
<td>Jul</td>
<td>269.253</td>
<td>17.42</td>
<td>18.68</td>
<td>27.85</td>
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<tr>
<td>Aug</td>
<td>203.910</td>
<td>17.54</td>
<td>17.54</td>
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<tr>
<td>Sep</td>
<td>192.056</td>
<td>18.69</td>
<td>18.01</td>
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<tr>
<td>Oct</td>
<td>185.346</td>
<td>18.85</td>
<td>18.18</td>
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<tr>
<td>Nov</td>
<td>281.763</td>
<td>17.19</td>
<td>18.70</td>
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<tr>
<td>Dec</td>
<td>228.756</td>
<td>15.89</td>
<td>16.84</td>
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</tbody>
</table>

Figure 1: Accumulated Mean Variation of Ambient Temperature Of The Station

Figure 2: Accumulated Mean Variation of Measured Global Solar Radiation Of The Station
References

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