Prediction of electrical energy for solar cells based on the weather in the solo city and surrounding areas.

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Abstract. Electricity capacity in Indonesia is about 89% produced from fossil fuels and the remaining renewable energy. These reasons encourage the government to accelerate the fulfilled of electricity needs with the use of energy mix with the ratio of the use of renewable energy by 25% to meet the 100% electrification ratio in 2025. This study discusses the prediction of electrical energy generated by solar cells combined based on the weather in Solo and surrounding areas as part to encourage the realization renewable energy use. The Prediction system using Artificial Neural Network (ANN) with multi layer neural network based on maximum temperature, minimum temperature, precipitation, wind speed, relativity humidity and solar energy. The result of system is electrical power generated 1 solar cell. The solar cell with 0.35 m x 0.49 m of area generate electrical power 4.2865 x 10⁻² watt.

1. Introduction
The capacity of Indonesia's power plant in 2015 only meets the electricity needs of 87.88% of houses, lower than Singapore, Brunei, Thailand, Malaysia and Vietnam. The capacity of power plants in Indonesia is 54.488 MW in 2015 with about 89% produced from fossil fuels and the remaining renewable energy [1]. This reason is to encourage the government to accelerate the fulfillment of electricity demand by utilizing energy mix with 25% utilization ratio of renewable energy to meet 100% electrification ratio in 2025. Future challenges with the energy mix is the complexity of power grids, inter-network communication and network distribution to villages remote in Indonesia.

The solution to this problem is the smart grid capable of controlling the integration of renewable energy sources with fossil energy already installed [2] [3]. Smart grid technology is a technology that utilizes the advancement of communication technology, computer and cyber for the control and operation of electric power system in the distribution of electrical energy. Smart grid architecture consists of energy management, power management, power electronics management, and fault detection and recovery [4]. The management needs to be done everyday on an ongoing basis, therefore the use of Artificial Neural Network (ANN) can be a solution to optimize smart grid usage [5]. An important feature of smart grids is the use of information and communication technologies to collect and act on information in automatic mode to improve efficiency, reliability, economy and sustainability of electricity production, transmission and distribution [6].

The Artificial neural network (ANN) can be used for forecasting and prediction. Forecasting and prediction are important to classify and identify to data. Forecasting is generally made with linearity
assumptions, for example forecasting with linear models such as autoregressive (AR), Moving Averages (MA), Autoregressive moving averages (ARMA) and artificial neural network (ANN) [7]. Forecasting and prediction are widely used in energy mapping and its use [8], [9], [10]. This paper discusses this about the prediction of electrical energy generated by the combined solar cells based on the weather in solo raya as a part to encourage the realization of energy mix in Indonesia. Prediction using Artificial Neural Network (ANN) based on maximum temperature, minimum temperature, Precipitation, wind speed, relative humidity and solar radiation level with solar panel size 350 mm X 490 mm X 25 mm.

2. Experimental Methods
This research used method with steps as in figure 1 below:

![Figure 1](image1.png)

**Figure 1.** Research method consist data input, prediction process (normalization, training process and testing process) and output data.

The input data was then processed for prediction system. The prediction process used artificial neural network (ANN) by Rapidminer. In the prediction program, there were three steps: data normalization, training process and testing process. The input data consists of parameters: Maximum Temperature (°C), Minimum Temperature (°C), Precipitation (mm), Speed of Wind (m/s), Relative Humidity (fraction) and Solar Energy (MJ/m²). The process of training and testing the data used multi layer Neural network. The architecture of the multi layer neural network used as in figure 3 below:

![Figure 2](image2.png)

**Figure 2.** Architecture of Multi Layer Neural Network is composed input layer (5 node input plus 1 bias), hidden layer (4 node plus 1 bias) and 1 node output.
This study used data input from [http://globalweather.tamu.edu/data/cfsr/74558_2018-05-30-03-18-22.zip](http://globalweather.tamu.edu/data/cfsr/74558_2018-05-30-03-18-22.zip). Sample input data of 20 data, as in table 1, below:

| Max Temperature (°C) | Min Temperature (°C) | Precipitation (mm) | Wind (m/s) | Relative Humidity (fraction) | Solar (MJ/m²) |
|----------------------|----------------------|--------------------|------------|-----------------------------|---------------|
| 27.96                | 22.885               | 14.15348028        | 1.481733496| 0.90722777                  | 13.77792467   |
| 29.354               | 21.872               | 37.3869905         | 1.082391108| 0.905389682                 | 20.83496148   |
| 27.618               | 22.528               | 20.70064656        | 0.748224583| 0.922263839                 | 11.65789106   |
| 29.475               | 21.061               | 13.64708088        | 1.03468942 | 0.908858677                 | 23.70965332   |
| 29.263               | 22.132               | 10.89705982        | 0.983118345| 0.913161338                 | 18.78938432   |
| 26.833               | 21.301               | 2.48136521         | 1.582866495| 0.911576823                 | 15.6791197    |
| 28.032               | 20.876               | 0.779342724        | 3.215738919| 0.877186197                 | 24.97810384   |
| 27.269               | 21.065               | 1.262569406        | 3.106276469| 0.864451885                 | 20.31954687   |
| 28.241               | 20.975               | 2.818680617        | 3.232539071| 0.845207188                 | 25.07274014   |
| 27.503               | 20.442               | 1.419639732        | 2.591594799| 0.871882784                 | 23.7766779    |
| 28.455               | 20.433               | 10.91937928        | 1.230230036| 0.892076411                 | 22.52303606   |
| 28.937               | 21.895               | 13.5406507         | 1.561467387| 0.897736918                 | 23.47571162   |
| 28.429               | 21.96                | 33.22764401        | 1.522579249| 0.907283265                 | 22.52607139   |
| 27.547               | 22.752               | 62.36540532        | 1.108069158| 0.930770402                 | 19.1623617    |
| 26.497               | 22.372               | 56.7615384         | 1.115050896| 0.950531812                 | 9.687313342   |
| 26.704               | 21.838               | 31.22693136        | 0.860200984| 0.942829777                 | 11.44488097   |
| 28.224               | 20.919               | 19.13166504        | 0.718812274| 0.924971273                 | 21.27443984   |
| 28.376               | 21.389               | 13.09776029        | 0.960817989| 0.912163187                 | 19.78142625   |
| 27.784               | 21.625               | 8.748728892        | 1.180159415| 0.910338677                 | 21.66099314   |

There are five input neurons plus one bias on the input layer. These five neurons are Maximum Temperature, Minimal Temperature, Precipitation, Wind and Relative Humidity. In the hidden layer there are four neurons plus one bias. The output layer consists of one neuron which quantity solar energy with units of MJ / m². In this study used 450 training data. The stations used in this research data with locations that have Longitude: 110.938004, Latitude: -7.64961004 and Elevation: 174, in Solo City and Surrounding Areas.

3. Results and Discussion
The process of prediction the data using the parameters : number node of input layers: 5 node plus 1 node bias, number nodes of hidden layer nodes 4 nodes plus 1 node bias, Node of input layer are Max temperature, Min Temperature, Precipitation, Wind and Relative Humidity. The node of output is Solar Radiation (Solar Energy). The solar radiation was choosen because it will be used for calculation of energy for solar cell based on the weather. Training Cycles: 10,000, Learning Rate: 0.01, Momentum: 0.2 and Error Epsilon: 1.0E⁻⁵. The prediction process details are like figure 3 below:
Figure 3. Diagram of Prediction Process on the view design of Rapidminer, the data input consist training data and testing data, processing used multi layer neural network and the final result is output data.

In the prediction process used training data of 450 data and testing data of 127 data. The results of the 127 data test resulted in forecasting for the average solar energy per day per unit area (m\(^2\)). Forecasting results look like in figure 4, below:

Figure 4. Test results of data consist the result of prediction and data real of solar energy

According to figure 4 above there is a similar pattern between the original data and the prediction with root mean squared error: 2.787 ± 0.000. Based on the results of the next testing process will predict the daily solar energy value of some data that is dumped at a time in Solo region. The result of prediction is shown in table 2, below:

The average of Solar energy can be calculated based on the data in table 2 above. The average solar energy intensity is 21.59507092 MJ/m\(^2\). The value of solar energy can be changed to 0.249942951 J/m\(^2\).s or 0.249942951 watt/m\(^2\). The value of the Sun’s energy per unit area (m\(^2\)) and per unit of time (s) can be predicted the amount of electricity produced by a solar cell element with a certain area. In this research we used solar cell with 350 mm x 490 x mm x 25 mm of dimension, part number 53-065 sp 20, maximum voltage (Vmp) 17.4 V, current (Imp) 1.15 A, open circuit voltage (VOC) 22.4 V, short circuit current (Isc) 1.23 A, Maximum power at STV (P max) 20 W and Max System voltage
700 V. The calculation of output electrical power from solar system (P) is multiplication of solar energy intensity and the surface area of solar cell. If considered 100% efficiency and area of solar cell is 350 mm x 490 mm or 0.35 m x 0.49 m, then the value of electrical power output is 0.042865216 watt equal to 4.2865 x 10^{-2} watt for 1 solar cell.

**Table 2. The Result of Prediction Solar Energy**

| Max Temperature (°C) | Min Temperature (°C) | Precipitation (mm) | Wind (m/s) | Relative Humidity (fraction) | Solar Energy Prediction (MJ/m²) |
|---------------------|----------------------|--------------------|------------|----------------------------|-------------------------------|
| 30.379              | 20.097               | 2.40325956         | 0.945205   | 0.8513064                  | 24.69321406                  |
| 26.536              | 20.822               | 0.484085016        | 1.61266    | 0.89590926                 | 14.13307745                  |
| 29.989              | 21.541               | 7.264709482        | 1.37324    | 0.87957504                 | 23.74019969                  |
| 28.91               | 19.887               | 6.289675236        | 1.129832   | 0.88123739                 | 24.18173964                  |
| 30.747              | 21.207               | 7.374569184        | 1.066783   | 0.84625408                 | 24.03800787                  |
| 28.604              | 21.274               | 7.024389768        | 0.794336   | 0.88596358                 | 19.66666646                  |
| 26.801              | 20.637               | 0.243759197        | 1.756411   | 0.85511684                 | 15.29856165                  |
| 30.082              | 19.709               | 0.387954648        | 1.720409   | 0.80256682                 | 24.69993453                  |
| 28.985              | 18.518               | 0.147628937        | 1.945582   | 0.81343574                 | 23.90420303                  |

**4. Conclusion**

The forecasting system used to predict the value of electrical power output from solar cells. It used multi layer neural network. The neural network architecture consist the input layer with 5 input node plus 1 bias, the hidden layer with 4 nodes plus 1 bias and output layer with 1 node. The node of input layer are Maximum Temperature, Minimum Temperature, Precipitation, Wind and Relative Humidity. The output layer is Solar energy. The result of forecasting is electrical power produced the solar cell. The electrical power generated 1 solar cell with 0.35 m x 0.49 m area is 4.2865 x 10^{-2} watt.

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