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Estimation Wind Energy Potential Using Artificial Neural Network Model in West Lampung Area

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Abstract. Wind energy is a famous green energy after solar energy realized. The highest potential green energy especially wind energy is depending from local characteristic study. However, survey and observation of local characteristic study it's very expensive to obtain wind potential energy. Thus, in this study aimed to estimate wind potential energy using Artificial Neural Network (ANN) over Krui, West Lampung, Sumatera, Indonesia. Here, the observation data such as wind speed, wind direction, and elevation taken from local survey while the wind potential energy taken from NASA LaRC POWER project. Here, all the data was processed using Levenberg Marquardt algorithm and ANN back propagation to estimate wind energy potential for Multilayer Perceptron (MLP) architecture with Root Mean Square Error (RMSE) and Variance Accounted For (VAF) wind energy potential energy value less than 0.04% and 95%, respectively. Based on the result, we have recommendation model to estimate wind energy potential for wind energy development over Krui, West Lampung in near future.

1. Introduction

Nowadays, green energy-based renewal energy concept has been developed by stakeholder e.g. government, private industry, and universities to minimize fossil fuel uses. The two types of famous green energy-based renewal energy concept are solar panel and wind turbine has developed since 2003 especially in Sumatera, Indonesia. Here, the green energy potential in Sumatera, Indonesia separated in two potential energy-based topography and resource energy, respectively. Mid Sumatera have solar resource energy while wind resource energy located over North and South Sumatera especially in Lampung area. The current study to assess wind resource energy using Geographic Information System (GIS) was successfully developed in Taiwan [1]. Here, the potential wind resource energy was analyzed based topology area with climate condition, land uses, and ecological environment. However, the meteorological parameter e.g. wind speed, wind direction, and elevation must be included in GIS with resolution 10-50 meters to obtain a good result of climate condition, land uses,



and ecological environment, respectively. To improve the lack of data measurement, Light Detection and Ranging (LiDAR) were proposed to assess wind resource energy in Cleveland, Ohio, USA [2]. Here, the LiDAR device is performed during evaluate wind potential energy with one-year data observation. However, the evaluation cost using LiDAR is very expensive to obtain the result by one-year data observation. In order to push budgetary from data observation, the statistical model is proposed to assess wind resource energy [3]. In addition, the statistic model cannot have performed to evaluate wind potential energy due to data variation. Thus, we propose soft sensor based Artificial Neural Network (ANN) to assess/evaluate wind potential energy at South Lampung, Sumatera, Indonesia. The current study of soft sensor-based ANN has applied to assess Galactic Cosmic Ray (GCR) to obtain highest energy correlated parameter from Neutron Monitor of University Delaware [4]. Here, soft sensor- based ANN with Multi-Layer Perceptron (MLP) has performed and have Root Mean Square Error (RMSE) less than 1%. Furthermore, ANN is capable to estimate wind turbine energy including a prior automatic filtering by using Gaussian Processes Model [5]. Here, ANN was used to evaluate wind performance. Thus, the capability and accuracy of ANN application it's very harmful to detect, measure, and monitor wind turbine, respectively. In order to evaluate and assess wind energy system, the ANN application was successfully performed in Chung Tung Wind Power Station [6]. Based on the previous study, we use ANN to estimate wind energy potential over Krui, West Lampung, Sumatera, Indonesia. Finally, we have recommendation model to estimate wind energy potential for wind energy development.

2. Methodology

2.1. Data and Location

In order to estimate wind energy potential using Artificial Neural Network (ANN), the meteorology parameters such as wind speed, wind direction, and elevation are used in this study. The three meteorology parameters taken from local observation in 4 July to 7 July 2018 with ten minutes resolution data while wind energy potential taken from NASA LaRC POWER forecasted by NASA was used in this study (see Figure 1).

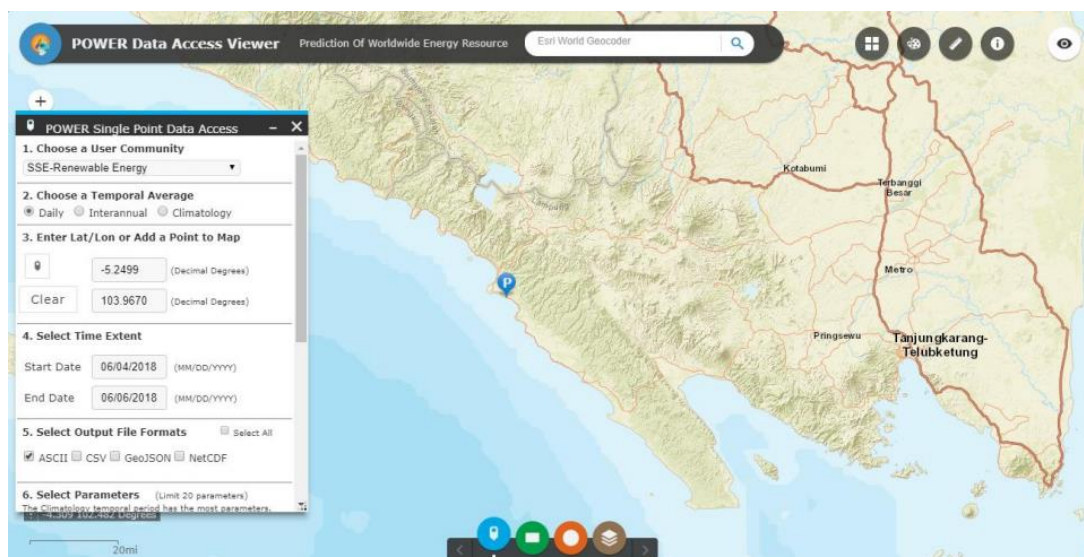


Figure 1. Local observation Krui, West Lampung, Sumatera, Indonesia

As can be seen in Figure 1, the local observation located in Krui, West Lampung, Sumatera, Indonesia with elevation 26 m (max). Here, the meteorological parameters and wind energy potential were

processed in preparation step to obtain correlation between input and output target parameters (see Figure 2).

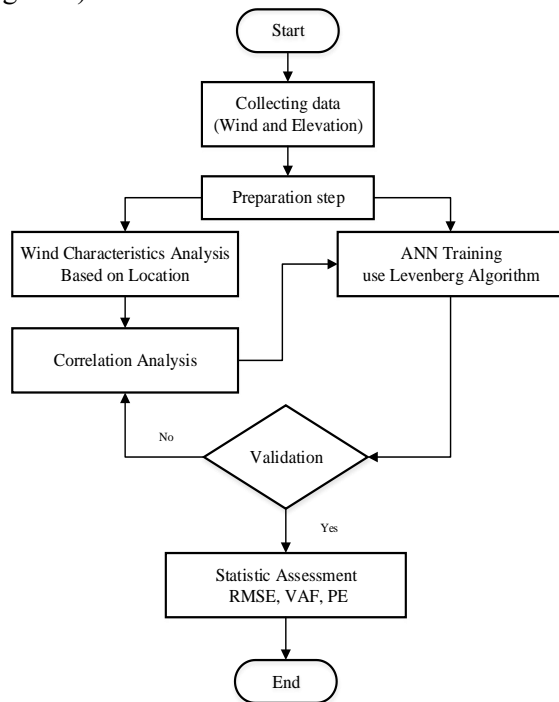


Figure 2. Flowchart estimation wind energy using ANN over Krui, West Lampung, Sumatera

As can be seen in Figure 2, ANN was designed in one session over preparation step (e.g. estimation model). Here, the estimation wind energy potential model based on ANN were developed using two input data such as elevation and wind speed. Here, wind direction parameter cannot included in training process over input parameter due to lack of R-sq value (negative correlation). In order to obtain estimation result, all the data was selected to train and testing data, respectively. After the estimation wind energy potential model has successful developed, the Root Mean Square Error (RMSE) and Variance Accounted For (VAF) are calculated to obtain performance model over statistic assesment to obtain model accuracy. Before the statistic assesment result obtained (RMSE and VAF), the estimation result must be validated by using data observation (observation). If the result status is invalid, all the data will be analyze to obtain good R-sq value. The estimation wind energy potential using ANN has worked over selected area.

In addition, the output target in this study is a wind energy potential (watt/m^2) over Krui, West Lampung, Sumatera, Indonesia. Here, we use five to six layer with Levenberg Marquardt algorithm to obtain wind energy potential while in validation process we used 25% of data observation. The advantages in this application for support equipment in wind energy potential survey due to budget limitation.

2.2. Artificial Neural Network (ANN)

In this study, Artificial Neural Network (ANN) is selected due to have capability to assess wind energy potential from wind speed, wind direction, and elevation parameter. In order to obtain a good result estimation wind energy potential, the Root Mean Square Error (RMSE) and Variance Accounted For (VAF) has calculated in this study. The common equation to calculate VAF expressed as follow [7]:

$$VAF = \left\{ 1 - \frac{\text{var}[y(t) - y'(t)]}{\text{var}[y(t)]} \right\} \quad (1)$$

where, $y(t)$ and $y'(t)$ are output parameter and estimation result, respectively. In order to design ANN architecture using Multilayer Perceptron (MLP), input and output target must be normalized due to training and testing time. Here, the Levenberg Marquardt algorithm was proposed to obtain estimation wind energy potential over MLP architecture. The estimation result obtained from input parameter expressed as follow [7]:

$$y(t) = y'[t, \theta] + e(t) \quad (2)$$

where, θ and $e(t)$ are candidate model and error training, respectively. The detailed combination of varying input (u) and output $y(t)$ by Laurence to obtain ANN architecture expressed as follow [8]:

$$Z^n = \{[u(t), y(t)], T = 1, \dots, n\} \quad (3)$$

where, Z^n and T are model training candidate and ANN variation node, respectively.

3. Result and Discussion

In order to estimate wind energy potential over Krui, the input parameter such as elevation and wind speed has been processed. By using four days data observation, the wind energy potential was assessed using correlation analysis to obtain R-sq between input and output target. Here, input and output target are normalized due to scale of input and output parameter are difference. In addition, the correlation analysis between wind energy potential with wind speed was successful obtained. The positive correlation with R-sq 0.73 and 0.78 from output target and input parameter (predictor) has performed in this study. Based on correlation result, we obtain strong correlation from both parameters to develop estimation model using Artificial Neural Network (ANN). In addition, the observation of wind speed and wind direction are presented in Figure 3.

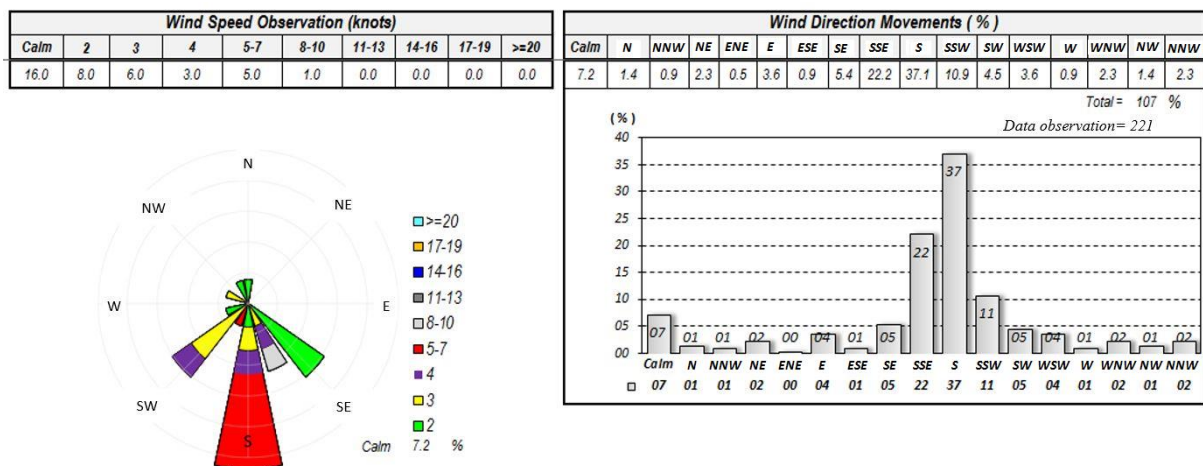


Figure 3. Distribution wind speed and wind direction over local observation at Krui, Sumatera

As can be seen in figure 3, the maximum wind speed reached 5 to 7 knots from south area while the minimum wind speed reached 0 to 2 knots over southeast area, respectively. In addition, the Levenberg Marquardt algorithm with Back propagation network architecture was used in ANN method to estimate wind energy potential. In this study, the variation five to six layers are applied to estimate wind energy potential using ANN architecture. Furthermore, the observation using LaRC POWER forecasted by NASA was used in this study. Here, the accumulated observation of wind energy potential are presented in time series (see Figure 4a and 4b) where the elevation 195.5m from surface.

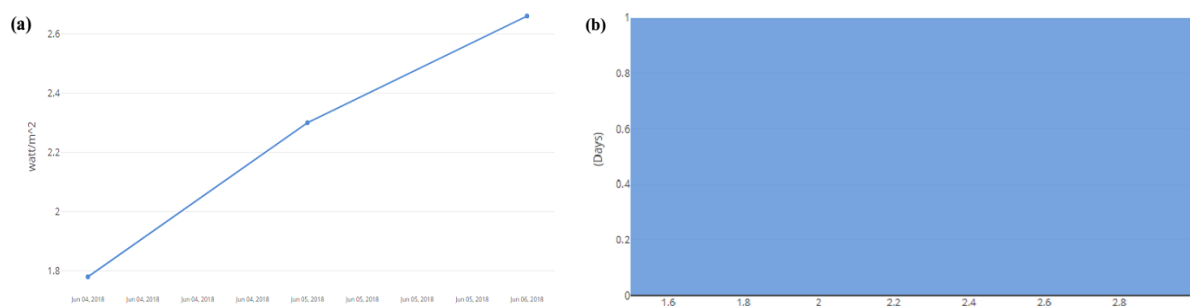


Figure 4. Observation using LaRC POWER by NASA for (a) wind energy potential and (b) wind speed averages at Krui, West Lampung, Sumatera

As can be seen in Figure 4b, the wind speed averages forecast by NASA and local observation is difference due to elevation value both of observation. The investigation of elevation value using LaRC POWER by NASA cannot be adjustment due to default setting by sistem. Thus, we proposed ANN to estimate wind potential energy and wind speed averages (See Table 1).

Table 1. The estimation result using ANN compared by investigation from LaRC POWER by NASA

Parameter	Estimation using ANN	LaRC POWER by NASA
Min Wind Speed	1.68 m/s	1.60 m/s
Max Wind Speed	3.3 m/s	3.00 m/s
Wind Speed Avg.	2.27 m/s	2.25 m/s
Wind Energy potential.	2.71 watt/m ²	2.60 watt/m ²

Table 1 shows the estimation result from ANN compared investigation from LaRC POWER by NASA result is significant and not different of each other. In addition, the statistical analysis Root Mean Square Error (RMSE) and Variance Accounted For (VAF) has been calculated to obtain error calculation between estimation using ANN and LaRC POWER by NASA (see Table 2).

Table 2. The stastical calculation estimation using ANN and investigation from LaRC POWER by NASA compared observation data

Parameter	Estimation using ANN	LaRC POWER by NASA
RMSE (%)	1.893	2.060
VAF (%)	96.543	93.367

Table 2 shows stastical calculation from estimation using ANN model and investigation from LaRC POWER by NASA compared by observation data has successfully obtained in this study. Here, the estimation result using ANN is good compared investigation from LaRC POWER by NASA. Based our study, we obtained recommendation wind speed 3.3 m/s with elevation 7 m to 10 m to obtain 2.71 watt/m² of wind energy potential. Finally, the estimation model using ANN was successfully developed to support wind energy development over Krui, West Lampung in near future.

4. Conclusion

The development estimation model for wind energy potential model using ANN successful developed in this study. The correlation analysis shows wind speed and wind potential energy have positive corelation with R-sq value 0.73 and 0.78 from output target and input parameter (predictor). Furthermore, The stastical calculation showed estimation model using ANN is very taft compared observation data while the investigation LaRC POWER forecasted by NASA due to elevation value. Thus, based on the result we were successful developed wind energy potential model using ANN.

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