

Allocation of Wind Power Plant Construction Using Adaptive Neuro-Fuzzy Inference System

by H Jasman, S M Said, I Nurtanio

Submission date: 09-Nov-2021 04:35PM (UTC+1100)

Submission ID: 1697509019

File name: ant_Construction_Using_Adaptive_Neuro-Fuzzy_Inference_System.pdf (727.65K)

Word count: 3725

Character count: 18704

PAPER • OPEN ACCESS

11
Allocation of Wind Power Plant Construction Using Adaptive Neuro-Fuzzy Inference System

To cite this article: H Jasman *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **875** 012035

12
View the [article online](#) for updates and enhancements.

You may also like

- 10
- [Short Term Load Forecasting for Weekends in Indonesia: Comparison of Three Methods](#)
F N Yaqin, A G Abdullah, D Chandra et al.
- 5
- [Separately Excited DC Motor Speed Tracking Control Using Adaptive Neuro-Fuzzy Inference System Based on Genetic Algorithm Particle Swarm Optimization and Fuzzy Auto-Tuning PID](#)
Mohamed Elhaj Ahmed Mohamed and Yanling Guo
- 8
- [Adaptive neuro-fuzzy inference system for forecasting rubber milk production](#)
R F Rahmat, Nurmawan, S Sembiring et al.



The Electrochemical Society
Advancing solid state & electrochemical science & technology

241st ECS Meeting

May 29 – June 2, 2022 Vancouver • BC • Canada
Abstract submission deadline: Dec 3, 2021

Connect. Engage. Champion. Empower. Accelerate.
We move science forward



Submit your abstract



11

Allocation of Wind Power Plant Construction Using Adaptive Neuro-Fuzzy Inference System

H Jasman^{1*}, S M Said¹, and I Nurtanio²

¹Electrical Engineering Department, Engineering Faculty, Hasanuddin University, Makassar, Indonesia

²Informatic Engineering Department, Engineering Faculty, Hasanuddin University, Makassar, Indonesia

*Email: henra.jasman.te10@gmail.com

Abstract. This research aims to determine the feasibility of a location to build Wind Power Plant (WPP). One of the challenges in wind energy development is to find area or location with high suitability for optimizing wind farm to allow the installation of as many wind turbines as possible within a limited area. To construct as many wind turbines as possible, the Adaptive Neuro Fuzzy Inference System (ANFIS) method is adopted using 7 parameters i.e wind potential, elevation, slope, type of land use, soil condition, access to roads, and populated areas and 2178 rules of fuzzy logic. The research was conducted in Kelara District, Jeneponto Regency, South Sulawesi, Indonesia. The most optimal result is obtained in the village of Tolo with a percentage of feasibility of 91% and error 0.48287. The output of this system can determine the feasibility of a location of wind turbine installation and can be used as a reference for determining wind farms in Indonesia and other countries.

1. Introduction

The increase in carbon dioxide (CO₂) emissions caused by the construction of fossil fuels has attracted worldwide attention because almost all of the world's gas emissions come from coal 44%, oil 36%, and natural gas 20%. One way to overcome the increase in CO₂ emissions is the use of renewable energy sources to reduce dependence on fuels [1].

Renewable energy is energy made from sources that will never run out, or that can be replenished. The use of renewable energy sources is a form of commitment from countries in the world to reduce carbon emissions and limit changes in global average temperature. One of the possible renewables is wind. The wind is everywhere, easily available, easily converted, and does not require high operational costs [2].

One of the challenges in developing wind energy is to find areas or locations with high compatibility because building wind power plants requires a long concept and research [3]. Therefore, it is necessary to make a location mapping to determine the potential of an area based on the eligibility criteria for installing wind turbine sites. The more wind fields installed, the higher the amount of wind energy lost due to the of the turbine-to-turbine interaction. Optimizing wind farms are needed to achieve the highest efficiency of the wind and allow the installation of as many wind turbines as possible within a limited area. Therefore, it is necessary to optimize the installation of wind turbine locations at wind power plants [4].

Previously, research on location determination used a combination of Boolean logic, fuzzy logic, and Weighted Product methods to determine suitable locations for the development of wind power plants in Palladam Taluk, Tamil Nadu. The location selection process uses ten criteria, namely wind source, slope, hospital distance, river distance and water source, air force base and settlement distance, distance from the road and transmission, and distance from the forest. The results showed that 2.99% of the study area was classified as the most suitable for the development of wind power plants, 10.2% were found to be quite suitable, 0.535% was the least suitable, and 86.267% were permanently unsuitable [5].

Research conducted by Said et al shows that Kelera Sub-District, Jeneponto Regency has a lot of potential location suitable for building a Wind Power Plant. The research succeeded in getting a feasibility value according to the criteria needed by an area with the help of Geographic Information System (GIS), which was then calculated by the weighting or scoring method. However, the result obtained by weighting or scoring methods are still done manually to determine the feasibility of an area and the determination of wind turbine installation points [6].

Based on the description from previous studies, the authors propose a method that can optimize the determination of locations for the construction of wind power plants using Fuzzy Logic and Adaptive Neuro-Fuzzy Inference System (ANFIS) with the help of GIS. The output of this system can determine the feasibility of the location of wind turbine installation. Therefore, it can be used as a reference for determining wind farms in Indonesia and other countries.

2. Literature Review

2.1. Fuzzy Logic

A very important aspect of fuzzy logic is the use of fuzzy if-then rules. Although in the field of artificial intelligence systems that rely on rules have long existed, but the system has a deficiency in connecting the gap between fuzzy antecedents and fuzzy consequences. Fuzzy logic removes these shortcomings by adopting calculus practices for fuzzy rules. The ability to strike a balance between important factors and accuracy has made fuzzy logic an interesting field of research. Humans have practiced this balance for a long time. Therefore, fuzzy logic is simultaneously new and old.

Fuzzy systems have two main characteristics to ensure increased performance for specific applications. The two characteristics are as follows:

- Fuzzy systems are suitable for uncertain or estimated analyzes. In particular, fuzzy systems are suitable for applications that have complex mathematical derivations.
- Fuzzy logic can make decisions that have approximate values below partial or temporary information.

Instead of giving a right or wrong answer, fuzzy logic tries to integrate the decision-making process followed by humans. Therefore, fuzzy logic provides an approximate but efficient method for explaining system performance, which is usually very difficult to accurately illustrate. Thus, fuzzy logic can be applied to intelligent decision-making systems in unpredictable and dynamic environments [7].

2.2. Adaptive Neuro-Fuzzy Inference System

Adaptive neuro-fuzzy inference system (ANFIS) is a hybrid rule-based learning system that is a combination of artificial neural networks and fuzzy logic for logical calculations and analysis. The ANFIS structure, as shown in Figure 1, consists of nodes and directional links that connect nodes.

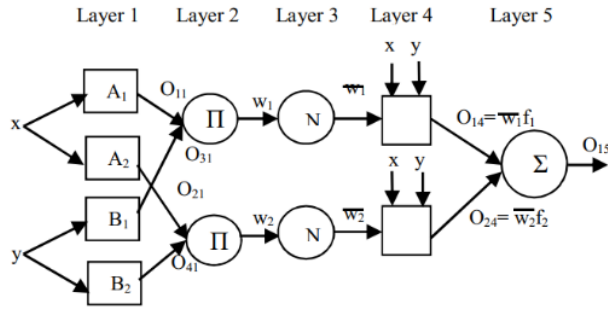


Figure 1. ANFIS architecture

These nodes may be adaptive when the output of the node depends on the parameters of the node i.e, the output of the node depends on the output of the previous layer. The purpose of directional links is to connect nodes of various layers and provide a path for signal flow without weight requirements for modifying signals.

ANFIS structure consists of five layers. Each layer has a fixed or adaptive node, connected by a directional link. Layer 1 has four nodes namely A1, A2, B1 and B2. Each node is a fuzzy set which output gives ownership level of input to the fuzzy set. Outputs Ok1 (k = 1 to 4), the output of node k from layer 1 is given by equations (1) to (4).

$$O_{11} = \mu_{A1}(x) \tag{1}$$

$$O_{21} = \mu_{A2}(x) \tag{2}$$

$$O_{31} = \mu_{B1}(x) \tag{3}$$

$$O_{41} = \mu_{B2}(x) \tag{4}$$

Layer 2 consists of a fixed node that performs the multiplication function for the incoming signal. Equations (5) and (6) give the output of layer 2.

$$\omega_1 = \mu_{A1}(x) \times \mu_{B1}(y) \tag{5}$$

$$\omega_2 = \mu_{A2}(x) \times \mu_{B2}(y) \tag{6}$$

Node on layer 3 used for normalizing layer 2 output using equations (7) and (8).

$$\varpi_1 = \omega_1 / (\omega_1 + \omega_2) \tag{7}$$

$$\varpi_2 = \omega_2 / (\omega_1 + \omega_2) \tag{8}$$

The output of the layer 4 adaptive nodes depends on the consequence parameters of the node. The output is obtained using equations (9) and (10).

$$O_{14} = \varpi_1 f_1 \tag{9}$$

$$O_{24} = \varpi_2 f_2 \tag{10}$$

Where ϖ_1 and ϖ_2 are normalized outputs from layer three, while f_1 and f_2 are determined by the Sugeno fuzzy system, using equations (11) and (12).

$$f_1 = p_1x + q_1y + r_1 \quad (11)$$

$$f_2 = p_2x + q_2y + r_2 \quad (12)$$

where, p, q, and r are the system parameter sets.

The function of layer 5 is to do the sum of the incoming O14 and O24 signals to give the total output (O₁₅) calculated by equation (13) [8].

$$O_{15} = (\omega_1f_1 + \omega_2f_2) / (\omega_1 + \omega_2) \quad (13)$$

3. Proposed System

The study area for the development of WPP in Indonesia is focused on Jeneponto, as shown in Figure 2. Jeneponto, which has eleven districts, is one of the districts in the province of South Sulawesi. It located in the northern boundary of Gowa and Takalar Regencies, the eastern border with Bantaeng Regency, the southern border with the Flores Sea, and the western border with Takalar District with an area of 749.79 km². Average wind speed is generally above 5 m/s. Thus, the area in Jeneponto has enough potential to develop WPP and interesting to be observed in more detail.

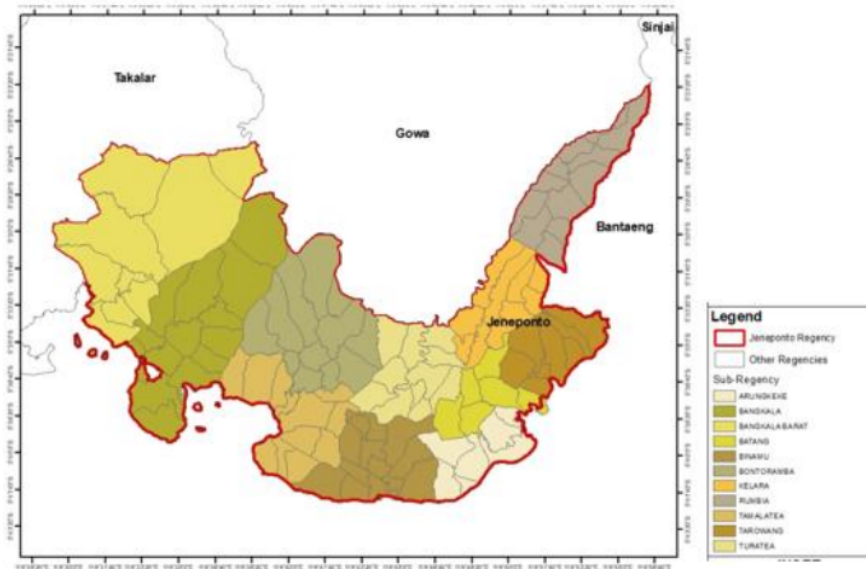


Figure 2. Location map of Jeneponto regency

Feasibility testing is done by the Fuzzy logic method shown in the flowchart in Figure 3.

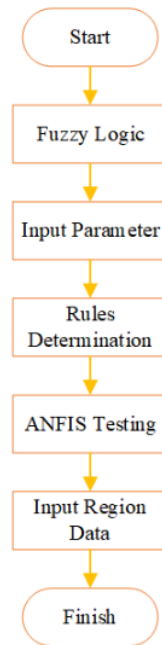


Figure 3. Flowchart of the research

The first step is input parameters, where the parameters used in this study are wind speed, elevation, slope, forest, land, road, and settlement with values, wind potential, elevation, slope, type of land use, soil conditions, access, and area populated.

Wind speed parameter is classified into 5 categories, namely very low (<2 m/s), low (2-3 m/s), medium (3-4 m/s), high (4-5 m/s), and very high (> 5 m/s). Elevation parameter (above sea level (ASL)), is categorized as high (> 100 m), medium (50-100 m), low (0-0 m). The slope is divided into five categories, which are very good (0–8°), good (9–15°), neutral (16–25°), bad (25–40°), and very bad (> 40°). Land use is divided into five categories, very good (non-forest (NFA)), good (protection forest (PF)), neutral (production forest (PRF)), poor (limited production forest (LPR)), and very poor (hunting park (HP)). Soil type is divided into very good (hap-ustalfs), good (haplustult), neutral (ustropepts), poor (ustipsamments), and very poor (dystrandeps).

As for the distance to the road (access), the road is classified into very suitable (> 300 m, fine asphalt), suitable (250-300 m, asphalt), neutral (150-250 m, fine soil), unsuitable (50- 150 m, non-smooth land), and very unsuitable (0–50 m, rocky land). Meanwhile for populated areas, it is divided into very suitable (> 300 m, very not crowded), suitable (250-300 m, not crowded), neutral (150-250 m, medium), unsuitable (50-150 m, busy), and very unsuitable (0–50 m, very crowded) [6].

After giving criteria, the next step is to set rules with all possible combinations of a total of 2178 combinations shown in Table 1 with the combination rules as follows:

- If the A1 wind combined with the others, it will produce a low value unless A1 is combined with C2 C3 C4 C5 C6 C7, then it will be of an average value.
- If the wind B1 combined with the others, it will produce an average value. But if B1 combined with B2 B3 B4 B5 B6 B7, it will be of high value.
- If the C1 wind combined with the others, it will produce high values unless it combined with C2 C3 C4 C5 C6 C7, then it will be very high.

Table 1. Rules table

Wind Speed	Elevation	Slope	Land Use	Soil Type	Access	Populated Area	Result
7	A2	A3	A4	A5	A6	A7	Low < 30%
7	B2	B3	B4	B5	B6	B7	Medium 30 - 60 %
7	C2	C3	C4	C5	C6	C7	High 60 - 90%
							Very High 90 - 100 %

Code A represents the low parameter condition, code B represents the medium parameter condition, and code C represents the high parameter condition. The results have 4 conditions, namely low if below 30%, medium between 30 - 60%, high between 60 - 90%, very high above 90%. The number 1 represents wind speed parameter, number 2 represents elevation parameter, number 3 represents slope parameter, number 4 represents land use parameter, number 5 represents soil type parameter, number 6 represents access parameter, and number 7 represents populated area parameter.

Furthermore, these rules are tested using the ANFIS method by taking samples to test errors based on the rules that have been made and determine the suitability of the rules with parameters to get the feasibility of a location. The rules of all the parameters that have been set are:

- Wind area between 0 to 8
- The elevation from sea level is 0 to 200
- Slope type 0 to 50
- Forest or land use 0 to 100
- Soil types 0 to 100
- Access roads from 0 to 350
- Populated area from 0 to 350

After that, the minimum to a maximum range of each parameter is divided by 100 to equalize the conditions so that there are 100 consecutive samples of each parameter for the ANFIS test data, then the data are trained as shown in Figure 4.

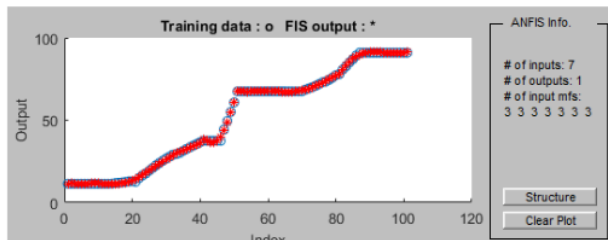


Figure 4. Training chart with ANFIS testing

Figure 4 illustrates the simulation of the data provided by the method, where blue color is the rule of testing data while red color is a simulation designed by the ANFIS method to mimic the obtained data. Furthermore, the two data trained with the results of the training test in Figure 5 shows that the rules made by the ANFIS method approach get an error value of 0.4287 in the second iteration as in Figure 3.

```

ANFIS info:
  Number of nodes: 4426
  Number of linear parameters: 2187
  Number of nonlinear parameters: 63
  Total number of parameters: 2250
  Number of training data pairs: 101
  Number of checking data pairs: 0
  Number of fuzzy rules: 2187

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

 1   0.490977
 2   0.48287

Designated epoch number reached --> ANFIS training completed at epoch 2.
    
```

Figure 5. Training result with ANFIS testing

Then, the testing is done by trying each region data with the input of each village, according to the data taken. Village selection is focused on Kelara sub-district because the area is considered as a potential WPP development area [6].

The assignment of values for land/forest use conditions and soil types is only sorted according to the highest to lowest order and is given a range between 0 to 100 as shown in Tables 2 and 3.

Table 2. Soil type parameter

Criteria	Description Slope	Value
Very Poor	Dystrandepts (Andisol)	0-20
Poor	Ustipsamment (Entisol)	20-40
Neutral	Ustropepts (Inceptisol)	40-60
Good	Haplustults (Aluvial)	60-80
Very Good	Haplustalfs (Alfisol)	80-100

Table 3. Land use parameter

Criteria	Land Use	Value
Very Poor	Hunting Park	0-20
Poor	Limited Production Forest	20-40
Neutral	Production Forest	40-60
Good	Protection Forest	60-80
Very Good	Non-Forest	80-100

The data of each area are shown in Table 4

Table 4. Data of each village

Village	Wind Speed	Elevation	Slope	Land Use	Soil Type	Access	Populated Area
Tolo	7.39	170	4	90	90	301	301
Tolo Barat	7.39	145	4	90	90	301	275
Tolo Selatan	7.39	150	4	90	90	301	275
Tolo Timur	7.39	255	12	50	80	301	275
Tolo Utara	7.39	365	32.5	70	80	301	275

Village	Wind Speed	Elevation	Slope	Land Use	Soil Type	Access	Populated Area
Bonto Lebang	7.39	170	12	50	80	301	275
Samataring	7.39	215	32.5	50	80	301	301
Bonto Nompo	7.39	240	32.5	50	80	301	75
Gantarang	7.39	180	32.5	50	80	301	75
Tombolo	7.39	275	32.5	50	80	301	75

Data are obtained by direct acquisition, such as wind data are obtained by measuring wind conditions for 2 months using anemometer measurement, soil type data by taking soil samples, road access data by observing the state of the village area, land use data by observing forests in the area, data settlements by directly observing the state of the number of houses in each village while data on sea level and slope obtained from the Geographic Information System (GIS) software shown in Figures 6 and 7.

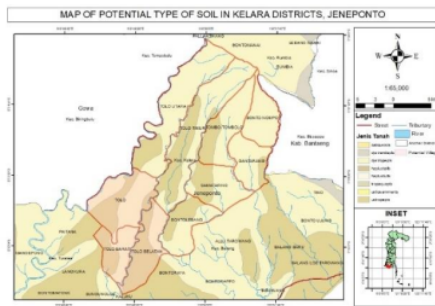


Figure 6. Map of potential type of soil in Kelara

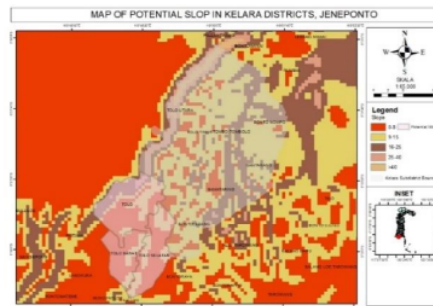


Figure 7. Map of potential slop in Kelara

4. Result and Discussion

The testing carried out in each village in the Kelara sub-district of Jenepono using the mentioned parameter values produced the results as shown in Table 5.

Table 5. Test result

Village	Feasibility (%)
Tolo	91
Tolo Barat	78,4
Tolo Selatan	78,4
Tolo Timur	69,3
Tolo Utara	60,8
Bonto Lebang	65
Samataring	68,4
Bonto Nompo	55
Gantarang	55
Tombolo	55

Table 5 shows that the percentage of the feasibility values obtained is different, the highest value in the village of Tolo with a percentage value of 91%, then the villages of West and South Tolo get the second-highest value with a percentage of 78.4%, in the third place in the village of East Tolo with a percentage of 69.3%, in order fourth in the village of Samatarang with a percentage of 68.4%, ranked fifth in the village of North Tolo with a percentage of 60.8%, and then in the last three positions with a percentage of 55% are the villages of Bonto Nempo, Gantarang and Tombolo. This allows that the feasibility of a location determined with the highest value.



Figure 8. Map of Tolo village

The Tolo village area, as shown in Figure 8, is the best location to place the WPP with the highest percentage value using the ANFIS method. The area of Tolo village is 568 hectares. Based on the existing conditions, the potential location for placing wind turbines in Tolo is around 127 hectares for the optimal location of WPP.

The proposed method can be used to help determine the feasibility of a location of the wind turbine installation. Utilization of wind energy for WPP in Tolo Village, Jeneponto Regency, could be one of the solutions for the Indonesian government to increase the use of electricity generation by using renewable energy sources. Hence, the use of alternative energy to meet electricity needs in South Sulawesi in addition to the Sidrap WPP, and WPP in Kayuloe village, Jeneponto district in the next few years can be increased.

5. Conclusion

This study presents an analysis of location suitability for WPP placement using the Fuzzy Logic method and the Adaptive Neuro-Fuzzy Inference System (ANFIS) to find the feasibility value using seven parameters and 2178 rule sets. The obtained results are the Tolo village gets a percentage of the feasibility of 91% with an error of 0.48287. The proposed system can be used to determine locations in other areas by looking for values by adjusting the parameters that exist in that region.

References

- [1] M. D. C. Koengkan and J. A. Fuinhas, "The Impact of Renewable Energy Consumption on Carbon Dioxide Emissions - The Case of South American Countries," *Rev. Bras. Energ. Renov.*, vol. 7, no. 2, Mar. 2018.
- [2] M. M. Rifadil, E. Purwanto, A. Jaya, and G. Prabowo, "Wind Power Generation Systems Using Vertical Axis Windmills for Residential Loads," *14th Semin. Intell. Technol. Its Appl.*, p. 5, May 2013.
- [3] A. Miller and R. Li, "A Geospatial Approach for Prioritizing Wind Farm Development in Northeast Nebraska, USA," *ISPRS Int. J. Geo-Inf.*, vol. 3, no. 3, pp. 968–979, Jul. 2014.

- [4] A. M. Abdelsalam and M. A. El-Shorbagy, "Optimization of wind turbines siting in a wind farm using genetic algorithm based local search," *Renew. Energy*, vol. 123, pp. 748–755, Aug. 2018.
- [5] L. Iyappan and P. Kasinatha Pandian, "Geoprocessing model for identifying potential wind farm locations," *IET Renew. Power Gener.*, vol. 10, no. 9, pp. 1287–1297, Oct. 2016.
- [6] S. M. Said, Y. S. Akil, and M. H. Muzakir, "GIS approach for wind power plant development in South Sulawesi, Indonesia: A location suitability analysis," presented at the The 4th International Conference on Industrial, Mechanical, Electrical, and Chemical Engineering, Surakarta, Indonesia, 2019, p. 030085.
- [7] R. Hossain, A. Maung, A. Than Oo, and A. Shawkat Ali, "A hybrid machine learning using Mamdani type fuzzy inference system (FIS) for solar power prediction," *Ann. Fuzzy Sets Fuzzy Log. Fuzzy Syst.*, May 2013.
- [8] S. A. Khan, M. D. Eqbal, and T. Islam, "ANFIS based identification and location of paper insulation faults of an oil immersed transformer," in *2014 6th IEEE Power India International Conference (PIICON)*, 2014, pp. 1–6.

Allocation of Wind Power Plant Construction Using Adaptive Neuro-Fuzzy Inference System

ORIGINALITY REPORT

19%

SIMILARITY INDEX

10%

INTERNET SOURCES

13%

PUBLICATIONS

12%

STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Institut Teknologi Kalimantan Student Paper	6%
2	Submitted to Central Queensland University Student Paper	4%
3	opinvisindi.is Internet Source	2%
4	L. Iyappan, P. Kasinatha Pandian. "Geoprocessing model for identifying potential wind farm locations", IET Renewable Power Generation, 2016 Publication	1%
5	Sumika Chauhan, Bhawana Singh, Manmohan Singh. "Modified ant colony optimization based PID controller design for coupled tank system", Engineering Research Express, 2021 Publication	1%
6	Ali M. Abdelsalam, M.A. El-Shorbagy. "Optimization of wind turbines siting in a wind	1%

farm using genetic algorithm based local search", Renewable Energy, 2018

Publication

7 Carla Longo de Freitas. "Propriedades imunomoduladoras de células tronco mesenquimais estromais no modelo de encefalomielite experimental autoimune", Universidade de Sao Paulo, Agencia USP de Gestao da Informacao Academica (AGUIA), 2019

1 %

Publication

8 San Aung Myat, Win Wut Yi, Pyone Saint Saint. "Trajectory tracking with ANFIS and uncalibrated vision system for uncertain robotic manipulators", IOP Conference Series: Materials Science and Engineering, 2018

1 %

Publication

9 www.mdpi.com

Internet Source

1 %

10 repository.uib.ac.id

Internet Source

1 %

11 Submitted to De Montfort University

Student Paper

1 %

12 repository.unhas.ac.id

Internet Source

1 %

13 revistas.ufpr.br

Internet Source

1 %

Exclude quotes On

Exclude matches < 1%

Exclude bibliography On