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Wind Resources Potential as a Wind Power Plant in Kulon Progo, Indonesia

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Abstract: This paper proposes the wind resources potential as a wind power plant in Kulon Progo, Indonesia. The location of this research is Congot Beach, Jangkaran Village, Temon District, Kulon Progo Regency, Yogyakarta Special Region Province, Indonesia. By considering that weather in the area is very conducive to the speed and strength of the wind, and the area is still full and extensive so that it is free to make a building for electric power plants using a windmill. The optimal configuration resulting from the Homer software analysis shows that this wind power plant is able to supply electricity needs without buying electricity from the grid. So that the wind turbine in Congot Beach has the potential to be built as a power plant, it's just that the construction costs are quite high and require a slightly longer return on investment, which is around 18.5 years..

Index Terms: Renewable energy, wind potential, wind energy.

I. INTRODUCTION

Indonesia is well-known as a country rich in potential natural resources, especially energy, both from mining, water, and air [1]-[5]. Based on the type of energy can be classified into two, namely renewable energy and non-renewable energy. Renewable energy sources such as wind energy, biomass, biogas, wood energy. While energy sources such as oil, coal, and natural gas are energy sources that are non-renewable or can be used up [6]-[8].

Non-renewable energy sources such as fossil energy sources, mainly fuel oil, will soon be exhausted, no later than the end of the 21st Century. Natural gas is predicted by experts to be used up in more or less 100 years, while coal reserves will be used up for approximately 200 to 300 years to come. This condition is very worrying, especially for the continuity of human life [9]-[13].

This energy scarcity occurs because it is triggered by irresponsible exploitation by both the government and private parties. The pattern of life of the community also contributes to a sizable proportion of the above phenomenon [14]. Humans are very dependent on energy derived from fossil fuels, ranging from personal consumption to a broader scope.

On the other hand, the level of human dependence on fossil fuels turned out to have contributed a significant role in increasing the temperature of the earth due to global warming. This condition will get worse if a better energy solution is not immediately found. In agriculture, fossil fuels are used as a source of energy to drive irrigation or drainage pumps. This irrigation pump is usually used on agricultural land, which is located far from the water source for irrigation [15]-[18].

Irrigation pumps are usually used for irrigation on rainfed lowland rice fields that do not have the potential of rivers for irrigation. There are solutions to these problems, but not all solutions are appropriate for use, one of which is the manufacture of waterwheels [19]. The disadvantage is that the rain-fed land does not have river currents that can move the wheels of the wind-wheels, and the distance between the paddy field and the water source is very far so that the physical building will be even higher. This fact will complicate the process and requires many costs [20]-[22].

Other energy sources that can be used to replace fossil fuels are renewable energy, especially wind energy. Wind energy contributes to improving people's lives, primarily rural areas or remote islands, better by fulfilling electricity.

It is meeting the needs of electrical energy with wind energy facing problems caused by fluctuations in wind speed and seasonal variations. In Indonesia, in general, electrical energy needs in remote areas are served by the Perangkanki Diesel Electric Power that uses diesel fuel. Delivery of diesel fuel to remote areas requires high costs and is greatly influenced by environmental conditions. This condition has resulted in high electricity production costs and delays in the supply of diesel fuel to the area [23]-[25].

Based on data from the Directorate General of Electricity and Energy Utilization, the potential for wind power in Indonesia with a speed of around 3-5 m/s. The total electric power that can be generated is approximately 9,287 MW, and the installed capacity is only around 0.5 MW [26]. The utilization of wind energy is usually by using a windmill conversion tool. Kinetic energy from the wind is captured by the blades with a specific area so that there is rotation on the blade. Blade rotation will produce mechanical energy that can rotate the centrifugal pump shaft, which will be used to raise irrigation water [27]. This fact means that wind energy can replace the function of fossil fuels as a source of power driving the irrigation pump.

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Wind energy can answer the problem of energy scarcity. It can reduce the impact of rising earth temperatures due to emissions of carbon dioxide (CO) from excessive human daily consumption in various fields, including agriculture. Meanwhile, windmills are a technology that is very rarely used by farmers — windmills, including technologies that are environmentally friendly, inexpensive, and simple to make.

The technology does not require fossil fuels as in pumping, and it is not affected by the location and flow of the river like a waterwheel. The essential factor in the utilization of this technology is the availability of wind (moving air). Also, windmill technology can be used as a solution to respond to national energy scarcity [28]-[29].

The technology does not require fossil fuels as in pumping; it is not affected by the location and flow of the river like a waterwheel. The essential factor in the utilization of this technology is the availability of wind. Besides, windmill technology can be used as a solution to respond to national energy scarcity [30].

The technology can generally be divided into two types, namely; horizontal shaft windmills and vertical shaft windmills, namely savonius, darrieus, and H-type. One of the windmills that are very well developed is a vertical shaft type savonius. Savonius windmill does not depend on the direction of the wind so that we can put it at any height in the wind. Also, the manufacturing process is relatively simple because it does not use an electrical installation system (without a generator) as in wind turbines, and the production costs are still relatively inexpensive for farmers when compared to the use of pumps with fossil fuels [31]-[32].

The National Aeronautics and Space Agency (LAPAN) has developed this wind turbine technology since 1981 but is still focused on alternative lighting in helping to meet the national electricity needs of PLN. Meanwhile, the development of mechanical windmills for pumping is still infrequent.

Congot Beach in the Kulon Progo area of Yogyakarta is a strategic area for the construction of a power plant using wind resources. By considering that weather in the area is very conducive to the speed and strength of the wind, and the area is still full and extensive so that it is free to make a building for electric power plants using a windmill. Based on the background that has been explained, the writer will continue the research with the theme of the potential of wind resources as a wind power plant in Congot Beach, Kulonprogo, Indonesia [32].

The purpose of this study is to find out how effective the utilization of wind resources as power plants is, especially for residents around Congot Beach, Kulonprogo Regency, Indonesia. The next goal is to know and understand the best configuration of the wind turbine to supply the electricity in the area around Congot Beach, Kulonprogo Regency, Indonesia. The final goal is to analyze existing wind resources to find out whether they fit the criteria in their use and application by comparing them with the level of existing needs.

The benefit of this research is to provide information to stakeholders such as farmers, capital owners, academics, and the general public about new technologies that can be utilized as an alternative in utilizing the potential of natural resources, especially wind potential that can be utilized as a source of power plants that have various usability. Moreover, to find alternatives to preserve nature so that it does not quickly become extinct, especially in the case of coal and oil exploitation, which is often used to deliver power plants.

II. LITERATURE REVIEW

Wind Power Plants

Wind power electricity generation is an electrical technology that changes the potential of wind energy into electrical energy. The wind is moving air, so it has speed, power, and direction. The cause of this movement is the warming of the earth by solar radiation. The air above the surface of the earth, besides being directly heated by the sun also gets heating from solar radiation, the earth is not homogeneous, so the amount of solar energy that is absorbed and re-emitted by earth-based on place and time varies. This phenomenon causes differences in temperature in the atmosphere, which causes differences in density and atmospheric pressure. Air has the property always to achieve pressure equilibrium. Therefore this difference in atmospheric velocity and pressure causes air to move from an area of high pressure to an area of low pressure [33].

In a relatively hot region, air particles gain energy so that the air expands. As a result of the expansion, the air pressure in the area rises. However, the air density decreases, so that the specific gravity of the air in that place becomes relatively small, due to the air expanding upward and causing a decrease in pressure in the area left behind. This area is then filled with air from the surrounding area, which has higher air pressure and density. The air that expands upward, then experiences a decrease in temperature, so that shrinkage occurs and its density increases again. This air will drop back to another place that has lower pressure. This condition happens all the time continuously, so the air movement continues. Figure 1 shows the typical wind power plants.

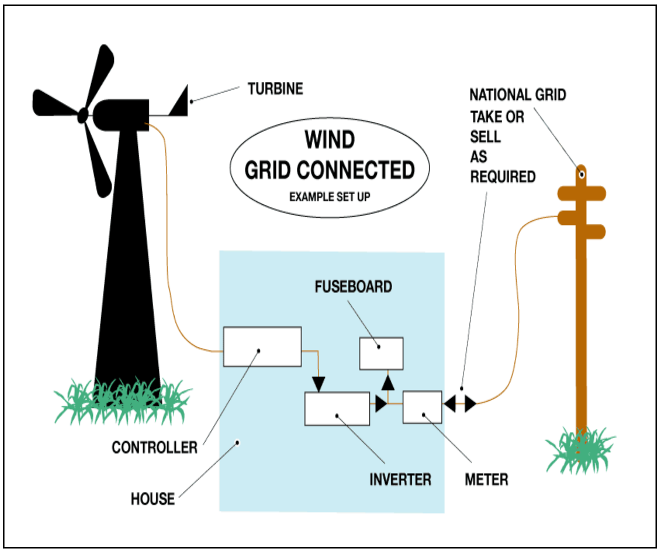

Figure 1. The typical wind power plants

Working Principle of Wind Power Plants

Wind power generation systems generally have power plants that have important parts as shown below, including wind turbines with the main component parts of the fan blades, connecting the fan blades to the engine shaft (hub), shaft rotation accelerator transmission (gearbox), a diverting guide for turning a tower (nacelle), a power plant, and a tower. Figure 2 shows the wind power plant components.

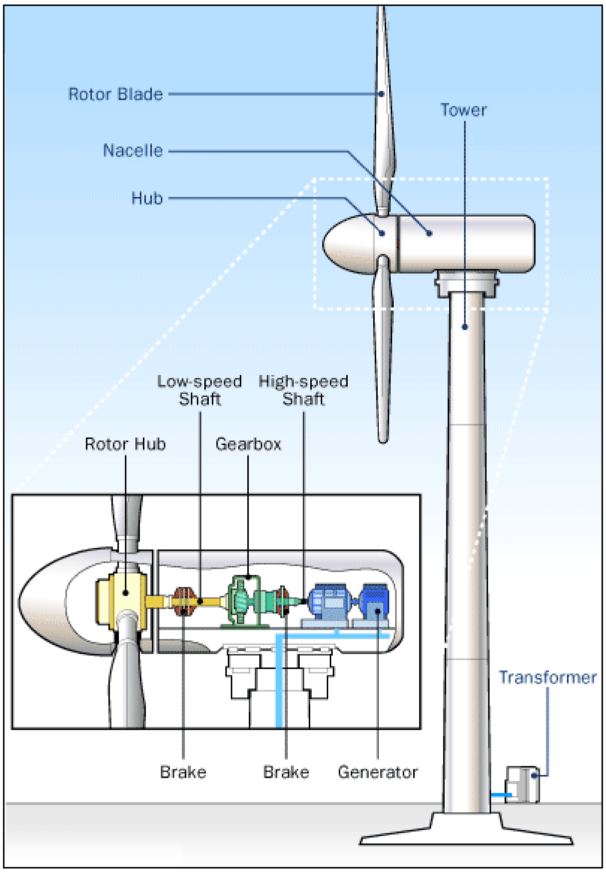

Figure 2. Wind power plant components

III. METHODOLOGY

In conducting this research, the authors will use the research method of an empirical approach. An empirical approach is an approach using objective facts, obtained from the field, namely data obtained from respondents and measurement data. The authors also conducted a literature study. The authors studied the literature on wind characteristics, wind turbines, generators, three-phase rectifier, standards from journals, books, and the internet.

This research was conducted by selecting a research location in Pancati Congot, Kulonprogo district, Indonesia. Congot Beach is a tourist beach that is best visited after visiting Glagah Beach. Both beaches are very close and connected by smooth paved roads that are even quite easy to reach by bicycle. Located in Jangkaran Village, Temon Subdistrict, Kulonprogo Regency, Congot Beach is the center of activities for residents who depend on fishing for their lives.

The beauty of the scenery can be found even while someone is still on the way to this beach. Along the road that connects Wates with Congot Beach, someone can see the green rice fields and the activities of villagers in Kulon Progo who are generally farmers. Like the plains near the beach in other areas, the roads to Congot Beach are also decorated by rows of coconut trees.

Congot Beach has its charm compared to other beaches because the nuances of fishers and fisheries are so strong. Along the coastline, someone can see the activities of residents and local tourists satisfying the hobby of fishing. In another corner, some fishermen are fishing fish by the beach, destroying crab shells attached to the nets, or cleaning the boat.

The hustle and bustle of the fishermen with a series of daily activities can be witnessed if someone visits at the right time. In the morning, fishers usually leave for the sea using motorized boats they have.

Not only the beauty that is owned by the beach, this beach is geologically supported by the situation of the beach, which has a lot of coconut plants, and the trees around it that have the potential to also have large wind waves.

Seeing this more natural potential and has not been exploited by anything else, the authors are eager to conduct an analysis of research on natural resources, namely the wind potential in the Congot Beach, to be used as a new energy resource for electricity generation, which will bring positive impact in meeting the daily needs of residents around and the community in general.

IV. RESULTS AND DISCUSSION

This research was conducted at Congot Beach, Jangkaran Village, Temon District, Kulon Progo, D.I. Yogyakarta on 5 June 2019 to 20 July 2019. Observations were made to determine the condition of the beach and wind speed samples. The position of the beach is on the southern coastline, which has large ocean currents, and there are a lot of gently sloping and empty lands on Congot Beach. Figure 3 shows the Congot Beach condition with good wind potential.

Figure 3. The Congot Beach condition with good wind potential

In this study, the wind power generation system is used to provide electricity for the area around the power plant, namely in the area located around Congot Beach, Jangkaran Village, Temon District, Kulon Progo Regency, Yogyakarta Special Region Province, Indonesia.

The electrical equipment used in people's homes is generally relatively simple. Lighting lamps, 14 "TVs, water pumps, irons, magic jar, and radio/tape recorders are electrical appliances that are often found in homes in the area.

A one-day survey on the use of electrical equipment in households in Congot Beach, Jangkaran Village, Temon District, Kulon Progo Regency was conducted in June. For example, the lighting used for street lighting is used from sunset to dawn, or the sun will rise while the lighting in the house began to turn on when the sun sets until around 10 PM. This pattern of use of electrical equipment is used as a reference to produce the capacity of electrical energy used every hour of the day and the amount of electrical energy per day.

In this research, Homer software is used to analyze the potential of wind as a source of electrical energy and its relation to the electrical load to be served. Homer software can accommodate changes in the electric load profile for each month. Nevertheless, in this study, the electrical load profile for the tropics can be considered the same for each month. This condition is due to the absence of a very striking climate difference in one year. Thus, the electrical load profile is used to simulate the electricity load throughout the year.

Based on population data from BPS Kulon Progo, in Jangkaran Village, Temon District, Kulonprogo there are 459 electricity customers for households. In this study, the data is used as a reference to 459 houses whose electrical energy will be supplied by wind power plants.

Table 1. Load profile in Jangkaran Village, Temon District, Kulonprogo, Yogyakarta

Load Profile	
Average (kWh/d)	1.561
Average per hour (kW)	65
Peak (kW)	217
Load Factor	0.3

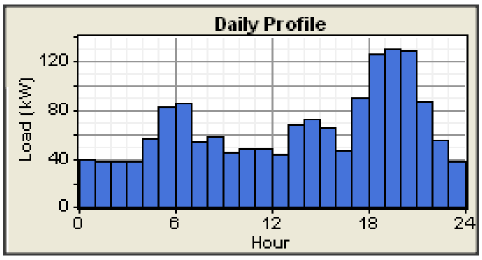

Figure 4. Daily load profile

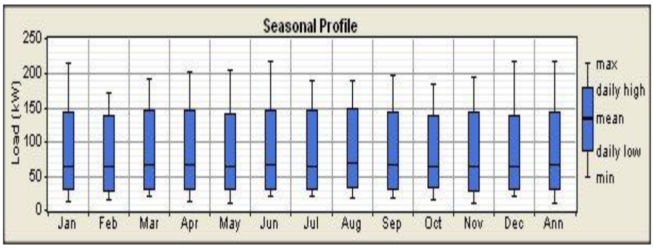

Figure 5. Annual load profile

Electricity load simulation used in this generating system is assumed to have a daily random variability of 15% with a time to step of 15%. It is thus resulting in the reasonable use of electrical energy of 1,561 kWh/day. The average electricity load per hour is 65 kW, with a peak load that can occur is 217 kW in 1 year, and the load factor that occurs is 0.3. Table 1 shows the load profile in Jangkaran Village, Temon District, Kulonprogo, Yogyakarta. Figure 4 shows the daily load profile while the annual load profile was shown in Figure 5. Detail of annual load profile in Jangkaran Village, Temon District, Kulonprogo, Yogyakarta was shown in Figure 6.

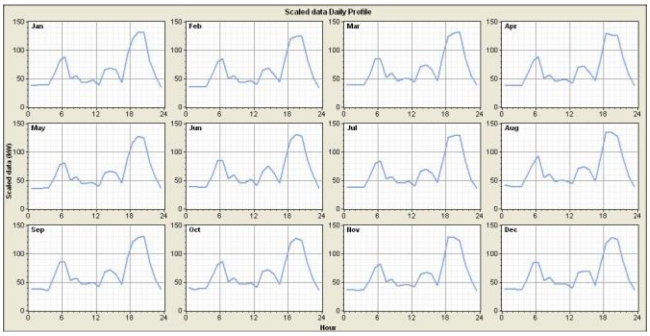

Figure 6. Detail of annual load profile

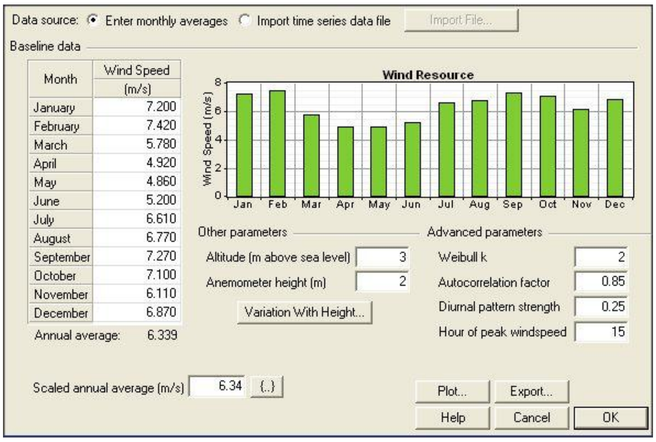

Figure 7. Wind speed data in Homer software

Input for Homer software can be seen in Figure 7. On the capital cost side, the price is $ 26,870 obtained from the website http://www.criticaltowers.com/ for one wind turbine type BWC Excel-R 7.5 kW DC. They are assuming an estimated replacement cost of 70% of the initial investment cost. Due to the wind turbine system, the cost of replacing components is not carried out thoroughly. There are still some components that can still be reused. Replacement costs are charged after the project has been running for 15 years.

On a small scale wind turbine, which is <10 kW generally does not require Operational & Maintenance (O&M) costs. It is just that the writer assumes an O&M cost of 4% of the initial investment costs mimicking micro-hydro O&M contained in the Layman's Guidebook Hydropower. These costs are used for operational costs and maintenance costs, such as the replacement of worn or damaged components, checking for dust or dirt attached, especially in moving parts, rust inspection, tail guide inspection, and so forth. So, the estimated O&M cost of a BWC Excel-R wind turbine is: 4% x $ 26,870 = $ 1,074.80. With an estimated lifetime of the project for 25 years. Based on the data that the authors get from the results of a direct survey in the field, it is obtained that the data potential of an average wind speed of 5.895 m / s.

By comparing the average wind speed data for 2018 from BMKG Maritime Cilacap, the most significant wind energy occurred in February and September at values of 7.42 m/s and 7.27 m/s. and the average wind speed in a year is 6,339 m/s.

The design of the battery system consists of 3 main parts, namely Unit size, cost, and size to consider. With a nominal voltage of 4 volts and a nominal capacity of 1,900 Ah, the price of a battery with the Surrette 4KS25P brand is $ 1,444. For many purchases only for $ 1,299.

The author assumes that if there is damage to the battery, then the battery must be replaced by all its components. Thus, the cost of replacement is the same as the cost of the capital. With a battery per string is one piece, and on the side, the number of batteries considered is 368 to 376, and the cycle charging system and set charge points are 80%. Figure 8 shows the battery system in Homer software.

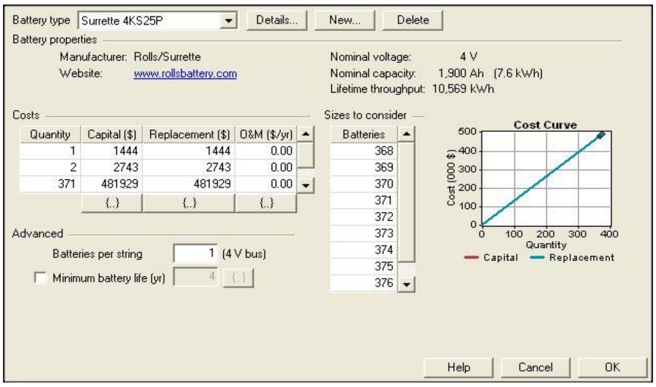

Figure 8. Battery system in Homer software

An inverter is an electronic device that serves to change the DC from a wind turbine or from a battery to an AC. The choice of the right inverter for a particular application depends on the load requirements. The efficiency of the inverter during operation is around 90%.

The design of the converter system consists of 3 main parts, namely: unit size cost, efficiency, and size to consider. Based on http://www.alibaba.com/, the price of an inverter of 4kW is $ 100 - $ 500 under the pure sine wave brand. Assuming there is an increase in price, the author's input value of $ 600 on the converter input in Homer software at a 10% discount for large capacity purchases. If there is damage to the converter, then all the components must be replaced so that the replacement costs equal to the capital costs. Then on the side of the size of the converter considered starting at 200 kW to 1550 kW. Figure 9 shows the inverter system in Homer software.

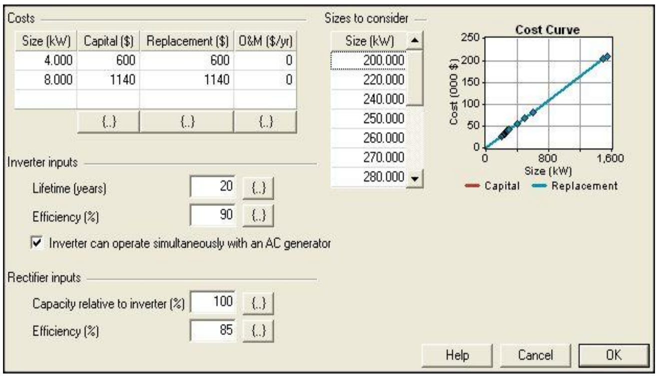

Figure 9. Inverter system in Homer software

This system design simulation uses a connection to the grid so that that excess electrical energy can be sold directly to PLN. Based on the Minister of Energy and Mineral Resources Regulation No. 4 of 2012 that PLN is required to use small to medium scale renewable energy with a capacity of up to 10MW or excess power from state-owned enterprises, regionally-owned enterprises, private businesses, cooperatives, and community self-help in order to strengthen the local electricity supply system. The purchase price of electricity by PLN is set at Rp 1,004 kWh.

Homer Software has simulated more than 1,000 system configurations that may occur with two sensitivity. The best configuration is the configuration that has the smallest Net Present Cost (NPC). The NPC is the present value of all costs incurred during the service life minus all revenue earned during the service life. In contrast, the Cost of Energy (COE) is the average per kWh of electrical energy produced by the system.

The best generating system design for Jangkaran village, Temon sub-district, Kulon Progo district, Yogyakarta Special Province, is a combination of 150 wind turbines, 371 batteries, and a converter of 1500 kW. Figure 10 shows the results of the calculations by Homer software.

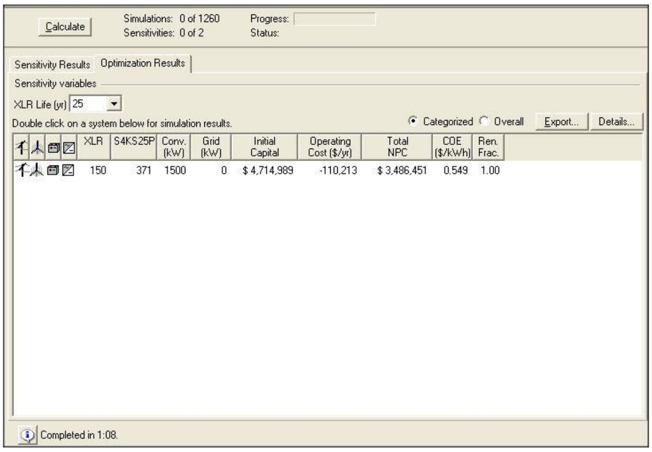

Figure 10. Results of the calculations by Homer software

From the results of simulations carried out by providing input system configuration and component data used in it, it can be seen the total capital cost in the planning of the construction of wind power plants. Total capital cost is the overall cost of doing a power plant construction project. For the simulation results of the calculation of the cost of developing a wind power plant in Jangkaran Village, the total capital cost is $ 4,714,989.00. The more configurations, the higher the total capital cost generated. The greater the converter capacity, the higher the investment costs.

V. CONCLUSION

The most optimal system configuration to be implemented in Jangkaran Village, Temon District, Kulonprogro Regency, is a combination of 150 wind turbines, 371 batteries, and a converter of 1500 kW.

This combination produces 4,419,966 kWh of electricity per year with electricity consumption from the residents of Jangkaran Village at 569,392 kWh per year or equivalent to 14% of the total power generated by the power plant. The wind power plant is effectively implemented in Congot Beach because it can supply the needs of the community and can provide an appropriate economic value.

The optimal configuration resulting from the Homer software analysis shows that this wind power plant is able to supply electricity needs without buying electricity from the grid or PLN. So that the wind turbine in Congot Beach has the potential to be built as a power plant, it's just that the construction costs are quite high and require a slightly longer return on investment, which is around 18.5 years. The reason for the expensive construction costs is because parts of the wind turbine must be imported from abroad, and costs must be spent using the US dollar. The exchange rate of the rupiah against the US dollar is very low, which results in high project costs.

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REFERENCES

1. Syahputra, R., Soesanti, I. (2017). Modeling of Wind Power Plant with Doubly-Fed Induction Generator. Jurnal Teknologi, Journal of Electrical Technology UMY (JET-UMY), 1(3), pp. 126-134.
2. Syahputra, R., Soesanti, I. (2016). DFIG Control Scheme of Wind Power Using ANFIS Method in Electrical Power Grid System. International Journal of Applied Engineering Research (IJAER), 11(7), pp. 5256-5262.
3. Syahputra, R., Wiyagi, R.O., Sudarisman. (2017). Performance Analysis of a Wind Turbine with Permanent Magnet Synchronous Generator. Journal of Theoretical and Applied Information Technology (JATIT), 95(9), pp. 1950-1957.
4. Syahputra, R., Soesanti, I., Ashari, M. (2016). Performance Enhancement of Distribution Network with DG Integration Using Modified PSO Algorithm. Journal of Electrical Systems (JES), 12(1), pp. 1-19.
5. Syahputra, R., Robandi, I., Ashari, M. (2015). Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm. International Review of Electrical Engineering (IREE), 10(2). pp. 293-304.
6. Brusco, G., A. Burgio, D. Menniti, A. Pinnarelli, N. Sorrentino. (2014). Optimal Sizing of DGs for a CHP-Based Agro-Industrial Microgrid with a Priority Criteria Operational Strategy, International Review of Electrical Engineering (IREE), 9(2), pp. 351-362.
7. Syahputra, R. (2017). Distribution Network Optimization Based on Genetic Algorithm. Jurnal Teknologi, Journal of Electrical Technology UMY (JET-UMY), 1(1), pp. 1-9.
8. Mujaahid, F., Fauzi, A.M., Syahputra, R., Putra, K.T., Purwanto, K. Potentials of Organic Waste Conversion in a Green Campus Concept. Journal of Electrical Technology UMY (JET-UMY), 1(4), pp. 183-188.
9. Ahmed, J., Salam, Z. (2018). An Enhanced Adaptive P&O MPPT for Fast and Efficient Tracking Under Varying Environmental Conditions, IEEE Transactions on Sustainable Energy, 9(3), pp. 1487 – 1496.
10. Hui, J.C.y., Bakhshai, A., Jain, P.K. (2016). An Energy Management Scheme With Power Limit Capability and an Adaptive Maximum Power Point Tracking for Small Standalone PMSG Wind Energy Systems, IEEE Transactions on Power Electronics, 31(7), pp. 4861 - 4875.
11. Hui, J.C.y., Bakhshai, A., Jain, P.K. (2015). A Sensorless Adaptive Maximum Power Point Extraction Method With Voltage Feedback Control for Small Wind Turbines in Off-Grid Applications, IEEE Journal of Emerging and Selected Topics in Power Electronics, 3(3), pp. 817 - 828.
12. Syahputra, R., Robandi, I., Ashari, M., (2012), "Reconfiguration of Distribution Network with DG Using Fuzzy Multi-objective Method", International Conference on Innovation, Management and Technology Research (ICIMTR), May 21-22, 2012, Melacca, Malaysia.
13. Syahputra, R., Robandi, I., Ashari, M. (2014). Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-objective Method. International Review of Electrical Engineering (IREE), 9(3), pp. 629-639.
14. Jiang, R., Han, Y., Zhang, S. (2017). Wide-range, high-precision and low-complexity MPPT circuit based on perturb and observe algorithm, Electronics Letters, 53(16), pp. 1141 - 1142.
15. Peng, B.R., Che, K., Liu, Y.H. (2018). A Novel and Fast MPPT Method Suitable for Both Fast Changing and Partially Shaded Conditions, IEEE Transactions on Industrial Electronics, 65(4), pp. 3240 - 3251.
16. Hossain, M.K., Ali, M.H. (2013). Overview on Maximum Power Point Tracking (MPPT) Techniques for Photovoltaic Power Systems. International Review of Electrical Engineering (IREE), 8(4). pp. 1363-1378.
17. Tang, L., Xu, W., Mu, C. (2017). Analysis for step-size optimisation on MPPT algorithm for photovoltaic systems, IET Power Electronics, 10(13), pp. 1647 - 1654.
18. Ghasemi, M.A., Ramyar, A., Eini, H.I. (2018). MPPT Method for PV Systems Under Partially Shaded Conditions by Approximating I–V Curve, IEEE Transactions on Industrial Electronics, 65(5), pp. 3966 - 3975.
19. Farhat, S., Alaoui, R., Kahaji, A., Bouhouch, L., Ihlal, A. (2015). P&O and Incremental Conductance MPPT Implementation. International Review of Electrical Engineering (IREE), 10(1). pp. 116-122.
20. Soesanti, I., Syahputra, R. (2016). Batik Production Process Optimization Using Particle Swarm Optimization Method. Journal of Theoretical and Applied Information Technology (JATIT), 86(2), pp. 272-278.
21. Syahputra, R., Robandi, I., Ashari, M. (2015). PSO Based Multi-objective Optimization for Reconfiguration of Radial Distribution Network. International Journal of Applied Engineering Research (IJAER), 10(6), pp. 14573-14586.
22. Metry, M., Shadmand, M.B., Balog, R.S., Abu-Rub, H. (2017). MPPT of Photovoltaic Systems Using Sensorless Current-Based Model Predictive Control, IEEE Transactions on Industry Applications, 53(2), pp. 1157 - 1167.
23. Jamal, A., Syahputra, R. (2016). Heat Exchanger Control Based on Artificial Intelligence Approach. International Journal of Applied Engineering Research (IJAER), 11(16), pp. 9063-9069.
24. Kebede, M.H., Beyene, G.B. (2018). Feasibility Study of PV-Wind-Fuel Cell Hybrid Power System for Electrification of a Rural Village in Ethiopia. Journal of Electrical and Computer Engineering, 2018.
25. Soedibyo, Ashari, M., Syahputra, R. (2014). "Power loss reduction strategy of distribution network with distributed generator integration", Proceeding of 2014 1st International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE) 2014, UNDIP Semarang, pp. 404 - 408.
26. Jamal, A., Suripto, S., Syahputra, R. (2015). Multi-Band Power System Stabilizer Model for Power Flow Optimization in Order to Improve Power System Stability. Journal of Theoretical and Applied Information Technology (JATIT), 80(1), pp. 116-123.
27. Syahputra, R., Soesanti, I. (2015). Power System Stabilizer model based on Fuzzy-PSO for improving power system stability. 2015 International Conference on Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation (ICAMIMIA), Surabaya, 15-17 Oct. 2015 pp. 121 - 126.
28. J. Ahmed, Z. Salam. (2018), "An Enhanced Adaptive P&O MPPT for Fast and Efficient Tracking Under Varying Environmental Conditions", IEEE Transactions on Sustainable Energy, Vol. 9, No. 3, pp. 1487 – 1496.
29. Syahputra, R., Soesanti, I. (2016). Application of Green Energy for Batik Production Process. Journal of Theoretical and Applied Information Technology (JATIT), 91(2), pp. 249-256.

30. L. Tang, W. Xu, C. Mu, “Analysis for step-size optimisation on MPPT algorithm for photovoltaic systems”, IET Power Electronics, Vol. 10, No. 13, pp. 1647 – 1654, 2017.
31. Sher, H.A., Addoweesh, K.E., Al-Haddad, K. (2018). An Efficient and Cost-Effective Hybrid MPPT Method for a Photovoltaic Flyback Microinverter, IEEE Transactions on Sustainable Energy, 9(3), pp. 1137 - 1144.
32. Syahputra, R., Soesanti, I. (2016). An Optimal Tuning of PSS Using AIS Algorithm for Damping Oscillation of Multi-machine Power System. Journal of Theoretical and Applied Information Technology (JATIT), 94(2), pp. 312-326.
33. Zhang, Y., Zhang, L., and Liu, Y. (2019). Implementation of Maximum Power Point Tracking Based on Variable Speed Forecasting for Wind Energy Systems. Processes. 7. 158. 10.3390/pr7030158.

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