Journal of Applied Engineering and Technological Science
Vol 3(2) 2022 : 190-197

APPLICATION OF SAVONIUS TYPE TURBINE TECHNOLOGY FOR THE CONVERSION OF LOW SPEED WIND INTO SMALL ELECTRICAL ENERGY SOURCE

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Received : 01 May 2022, Revised: 30 June 2022, Accepted : 30 June 2022
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ABSTRACT
Utilization of the potential that exists in tourist attractions aims to increase the savings in expenses that must be borne by the community to manage tourism. The beach is a place that is rich and abundant in wind potential that can be used to drive wind turbines. To take advantage of the existing wind potential, of course, we must know how the wind potential is in the form of wind speed and locations that have wind speed potential and how to use it as energy to drive wind turbines. To obtain the potential of wind energy and utilize it, wind speed measurements are carried out using a digital anemometer and recorded for some time. The position of the measuring instrument installed must be protected from wind obstacles so that it is installed as high as 20 meters above the ground in an open position against the direction of the incoming wind. From the measurement results over a period of one day, the wind speed varies and changes at any time and the maximum value is 6 m/s during the day starting at 10:00 to 04:00. The wind speed profile obtained is analyzed and the type of turbine is determined according to the low wind speed below 10 m/s. From the analysis results, the appropriate turbine is the Savonius VAWT type and can produce electrical energy of approximately 2.43 Watts with a diameter of 0.11 m. The use of turbines for wind at low speeds will still have the potential to generate small-scale electrical energy for communities in coastal areas.
Keywords : *Speed, Turbine, Beach, Energy, Wind*

1. Introduction

Utilization of the potential that exists in tourist attractions aims to increase the savings in expenses that must be borne by the community to manage tourism. The world of tourism that is currently developing will certainly increase the need for energy for the purposes of running tourism activities. This energy need must be answered with the community's foresight to look for potential energy producers that are free from dependence on energy provided by state companies such as PLN, which is currently still experiencing an energy deficit, especially in North Sumatra. Therefore, the energy-producing potentials that exist in the community around tourism sites must continue to be explored and utilized. The most abundant energy potential in nature after the sun is air; therefore the potential for air energy needs to be explored in order to obtain new and renewable energy results that are beneficial to the community, especially in tourism areas.

The beach is a place that is rich and abundant in wind potential that can be used to drive wind turbines. The wind in the coastal area will always be there and can be used for free. This potential also supports the new renewable energy mix that must be achieved by the government by 2025. The existing wind potential is in the form of wind speeds greater than 2 m/s which can be used to drive suitable wind turbines.

The Kota Pari Village area is a very large coastal area and still has a sparsely populated area, so that free electrical energy becomes a genuine power that can support the economy and lift the community's economy. Currently the existing beaches are managed by private parties to become tourist attractions visited by people from various regions in North Sumatra.

2. Literature Review

Wind is caused by the uneven heating of sunlight over the earth's surface. Hotter air will expand to become lighter and move upwards, while cooler air will be heavier and move to occupy the area. The difference in atmospheric pressure in an area caused by a temperature difference will produce a force. The difference in pressure expressed in terms of the pressure gradient is the rate of change of pressure due to the difference in distance. Gradient force is a force that acts in the direction of higher pressure to lower pressure. The direction of the pressure gradient force in the atmosphere is perpendicular to the surface of the isobars(Patel, 2005).

The definition of wind that is commonly known to the public is moving air. The global atmosphere can be thought of as a thermal engine in which air masses are transported due to different heat potentials. This thermal engine is powered by the sun. Water is the most important energy carrier in the atmosphere because it is present in the atmosphere in all three states: vapor, droplets and ice. Thus, its latent heat when changing different states from one phase to another is the dominant influence on the weather. The Earth is a sphere, so the closer you are to the equator to the poles, the less the total irradiation by the sun decreases. As a result, there is an excess of energy in the atmosphere in the equatorial zone and a deficit in the polar areas. To equalize this imbalance, heat is transported by air currents from the equator to the southern and northern hemispheres. This is done by the exchange of air masses of the global wind system(International, 2004).

In addition, the Coriolis force of the Earth's rotation diverts the direction of global wind flow. The global wind system is shown in Fig. 1. In each hemisphere there are three distinct zones: tropical latitudes, mid-latitudes and polar latitudes. Tropical latitudes (Inter-Tropical Convergence Zone, ITCZ) on each side of the equator lie between the tropical doldrums belt and the subtropical high-pressure belt. This region is also called Horse Latitude and is found along 30° latitudes. Within this region forms the Hadley circulation (also Hadley cells): hot tropical air rises at the equator and flows in the higher atmosphere layers towards the poles while it is deflected more and more eastward due to the rotation of the earth. At about 30° latitude the air descends and flows back to the equator in the lower atmosphere layers causing the Trade Winds. Two Trade Wind systems meet at ITCZ, closing Hadley's circulation loop(Wiley, 2008)(Patnaik, 2009).

3. Research Methods

To assist this research, a research phase framework is needed. The stages of this research are the steps that will be tried in solving the problems discussed. There are also stages of research used are as follows:

Identification of problems

At this stage the authors carry out identification of problems in the system that is currently running in order to identify the needs that must be met by the author. With the method of observing, studying, and studying more deeply what problems of wind in the beach area of Wong Polo.

Literature Research

At this stage the author conducts a search on the theoretical foundations obtained from various dailies on the internet, in order to assist the author in completing the research conducted. Wind energy conversion system (WECS) has experienced an expressive development in the past few years. New technologies on turbines, machines, drives, and protection devices have been developed and these devices have been improved progressively. The machine used to convert mechanical rotational energy into electrical energy is the core of any WECS. According to the machine chosen, all other devices are affected; fixed- or variable-speed turbine, power electronic converter type, and the respective power, protections used, and so forth(Domingos S.L. Simonetti, 2018).

Meanwhile, improvements in rotor aerodynamics and turbine-operating modes, along with increases in turbine size, have boosted the conversion efficiency of wind energy systems. Under good wind conditions, modern systems typically achieve capacity factors of 28% or more(Soderholm, 1984).

Wind power is one of the fastest growing sources of renewable energy in the world. This is partly due to its cost effectiveness and also as a result of improvement in the technology involved. The global installed capacity has increased by a factor of approximately 75, increasing from 7.5 GW in 1997 to about 564 GW in 2018. The quantum of power that can be harnessed from the wind is dependent on the size of the turbine and the length of its blades. Therefore, turbine blades are being made longer to increase efficiency. The rated capacity and rotor diameter of wind turbines have grown from 0.05 MW and 15 m in 1984 to 8 MW with rotor diameters of up to 164 m in 2016.(Mudathir Funsho Akorede, 2022)

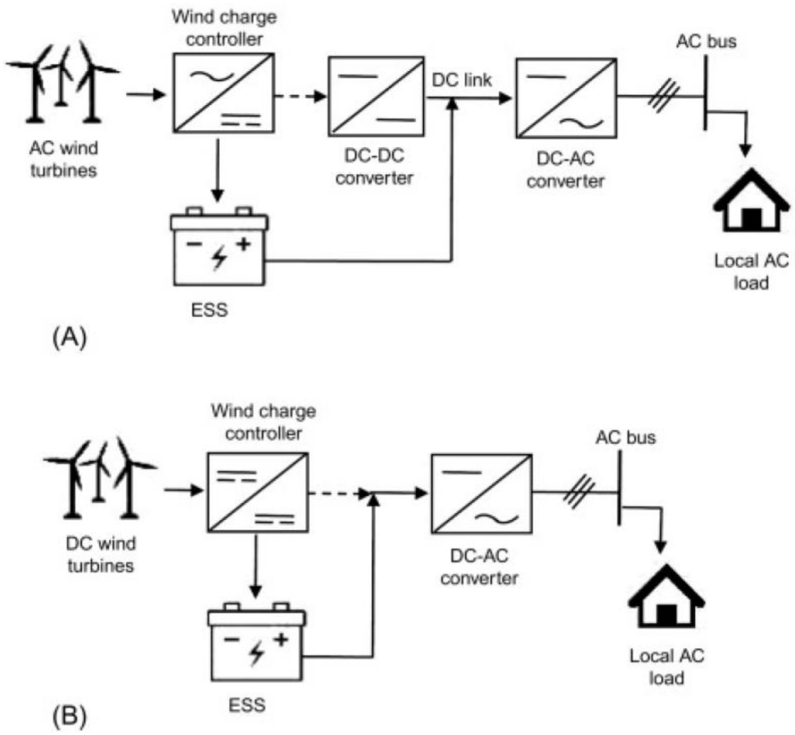

Fig. 1. WECS connected to load. (A) AC wind turbine generator. (B) DC wind turbine generator.

The power coefficient (C_P) and the TSR are tested by the PI–MPPT and PSO–MPPT algorithms; they show that the CP is maintained at its maximal value after a perturbation when the wind speed suddenly changes. Remarkably, the PSO algorithm ensures a better pursuit and very good optimization of these parameters. That allows the mechanical power and the rotation speed of generator optimization regardless of the variation of the speed wind(Elmostafa Chetouani, 2021).

In condition the wind speed is low end we need to the highest blade power values produced from two blades wind turbines with a wind booster of that could increase watts with a wind speed of 7 m/s. TSR value of the highest wind speed in wind turbines will more power by add the blade of wind booster(Yohana, U, Luhung, Reza, & Zaman, 2019).

Data analysis

In this session the authors carry out an analysis of the information obtained to design a new data system. This analysis has the aim of identifying what turbine is needed on the system that is running after it is adjusted to the program to be built.

System planning

Calculation of wind potential that can generates electricity through a generator. The turbine is designed to be able to rotate with low wind speed. The wind will produce speed at certain times. The speed is received by the VAWT Savonius turbine so that it can rotate(Chang, Tsai, & Chen, 2021). The rotation is forwarded to the generator shaft to produce 500 watts of power. The shape of the Savonius turbine design according to various sources can convert low wind speeds. The shape of the Savonius turbine design is as follows:(Shah, Alsibiani, & City, 2020)

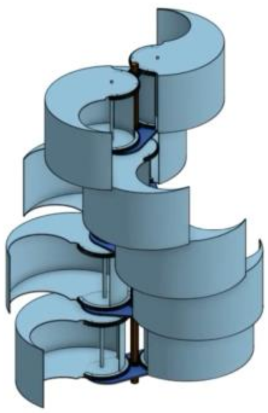

Fig. 2. Savonius wind Turbine

The wind speed ranging for all the above mentioned testing was kept from 0.7 m/s to 6 m/s. This speed was taken in accordance with the design parameters and considering the use of duct, as higher wind speeds could have resulted in the breakage of the small scale model of the turbines made of plastic polymers. Also, the primary motto of this research was to capture and test the performance of a Savonius turbine for low to very low wind speeds which is otherwise not possible through any other wind turbines(Darhmaoui & Sheikh, 2017)(Science, 2021).
The design for converting wind energy into electricity using a Savonius turbine can be seen in the following Fig.:

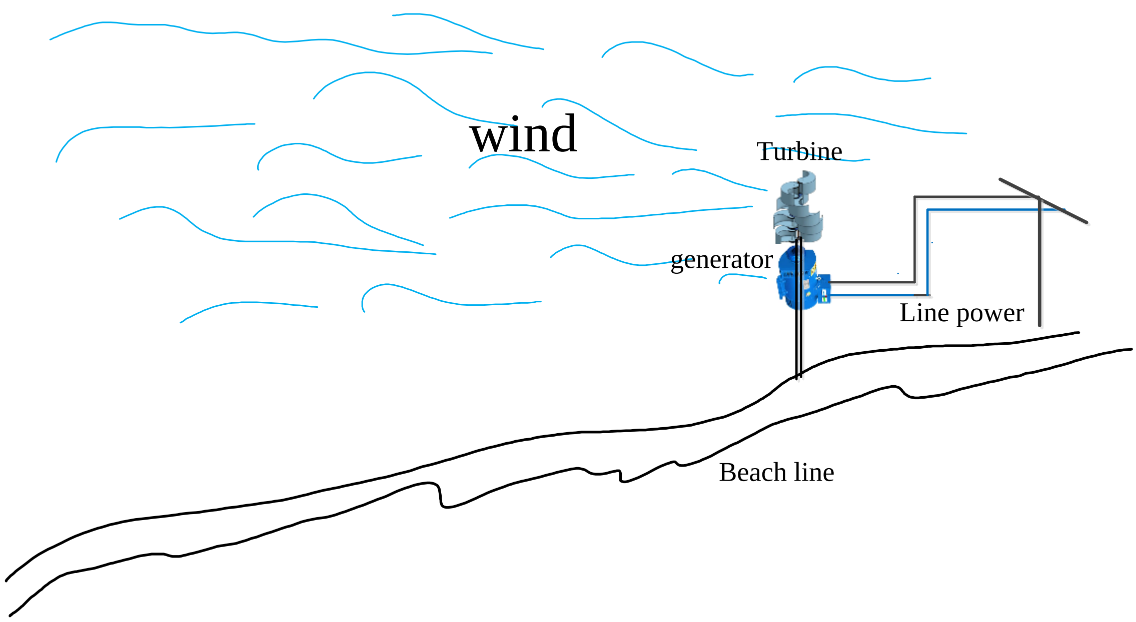

Fig. 3. Wind-to-electricity conversion design using the Savonius turbine

1. System design with activity diagram is a technique to describe procedural logic, business processes and work flow in many cases. Activity diagrams describe how the activities that occur in the system to be designed. The activity diagram is the same as a flowchart that describes the processes that occur between actors and the system, the design of the activity diagram for the village fund allocation system is as follows:(Dhote, 2015)

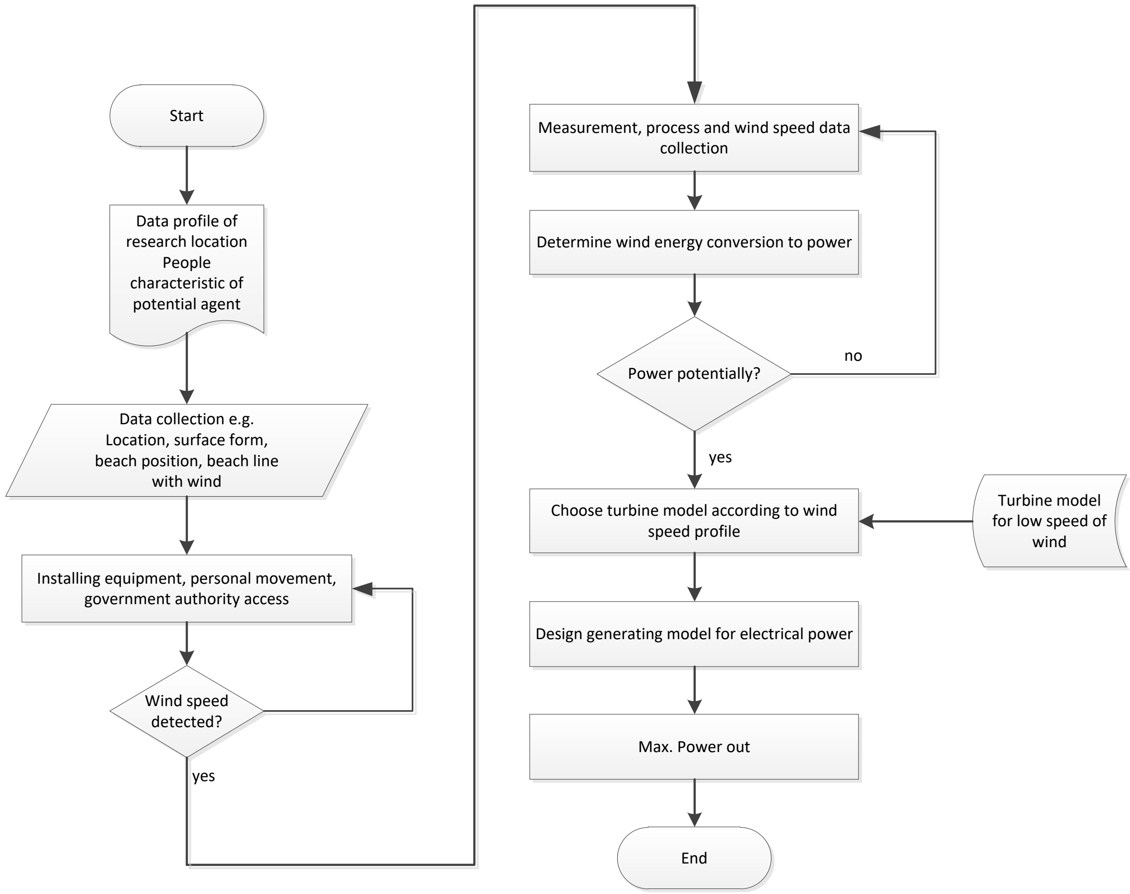

Fig. 4. Activity Diagram

2. The location of the wind speed measurement will determine the measurement results. Generally each topography of earth has different wind profile. In this study, wind speed data was collected at the Mangrove Wong Polo Beach, Kota Pari Village. Measurements were made on the shoreline at a distance of about 5 m from sea water at full tide. This location was chosen in order to obtain the desired coastal wind profile.

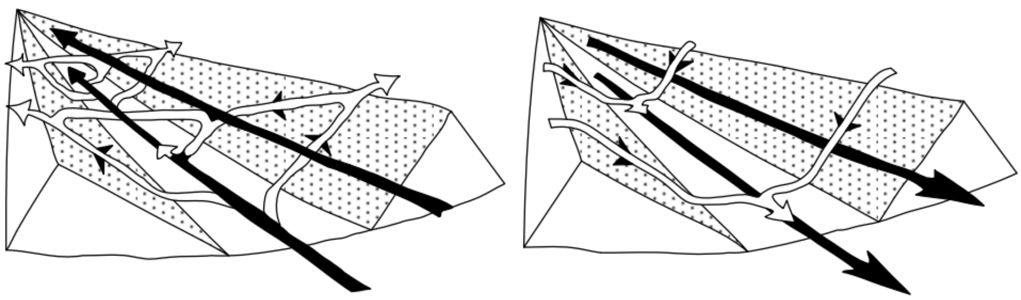

Fig. 5. Beach wind topographic diagram(Troen I., 1989)

3. Results and Discussions

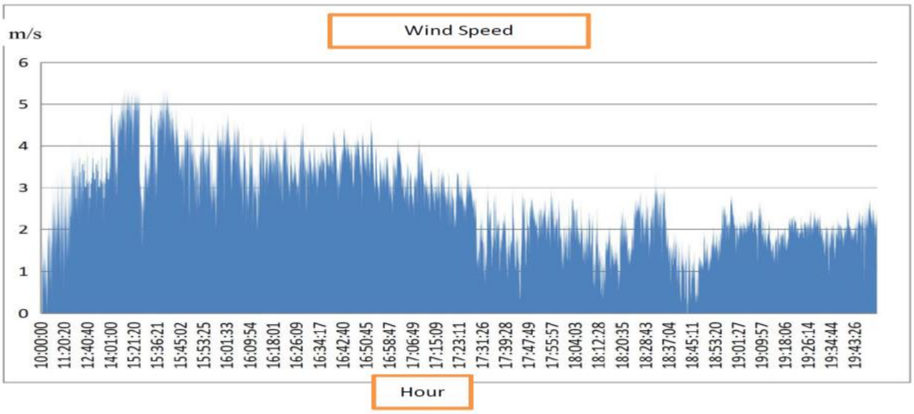

Fig. 6. Wind speed graphic for daylight on the Wong Polo Beach

Based on the wind speed graph in Fig. 4, it can be classified that the average wind speed at Wong Polo Beach, Kota Pari Village, includes low speeds, which is between 2.5 m/s – 5 m/s. Thus, the type of blade that is suitable for low speeds is an inverse-taper, i.e. a blade that has a blade tip that is wider than the base of the blade. This is so that the blade can rotate at a low speed. According to research based on the simulation results,(Handoko, 2019)(Sharma, Sellami, Tahir, & Mallick, 2021) the coefficient of performance for the same TSR is 1.8-2.6, when compared with taper and taperless blades, it can be seen that the inverse taper blade is superior at low wind speeds. The inverse taper blade has a better C_p value. The type of wind turbine used is the Savonius wind turbine. The specifications for the Savonius type wind turbine are listed in Table 1 below:(Altmimi, Alaskari, Abdullah, Alhamadani, & Sherza, 2021).

Table 1 - VAWT specifications

Parameters	Specifications
Axis of rotation	Vertical
Turbine height	0.562 m
Rotor radius	0.22 m
Foil type	NACA 4418
No. of blades	3
Swept area	0.25 m2
Cut-in wind speed	2 m/s
Cut out wind speed	16 m/s
Wind speed range	1–20 m/s
Rotational speed range	RPM 200–500 RPM

After knowing the wind speed at Wong Polo Beach, Kota Pari Village, it can be seen the wind power at Wong Polo Beach, Kota Pari Village. The calculation of the wind power that can be produced per unit cross-sectional area of the windmill blade refers to equation (1) according to.(E. Hau, 2015) Where E is the kinetic energy in W, ρ units, is the air density in kg/m^3, A is the rotor sweep area in m^2 and v is the wind speed in m/s.

$$E = \frac{1}{2}.\rho.A.v^3 \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(1)$$

and,

$$P_o = \frac{\rho . C_P . A . v^3}{2} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (2)$$

C_P depends on how the turbine behaves in a particular condition i.e. for different rotational speeds of turbine, C_P is different. That implies that C_P is a function of the Tip Speed Ratio (TSR) λ, which is defined as

$$\lambda = \frac{tip\ speed\ of\ the\ blade}{wind\ speed} = \frac{\omega . R}{V} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

The output power P_O is found experimentally.(Mishra, Jain, Nair, Khanna, & Mitra, 2020) In this study, the density of the air used is the same as the density of air at sea level.

Electric power estimation

After calculating wind energy, the next step is to calculate electrical energy. Calculate the electrical energy that may be generated by a windmill with a predicted blade radius of 0.8 m. Then it can be calculated using equation (2). Where P is the wind power with units of W, C_p is the efficiency of the blades, and electric is the efficiency of the generator, transmission and controller efficiency which refers to the following table.

Table 2 - Measuring Performance of Hemi-Savonius Windmill Model(Nurdin & Purwanto, 2019)

Nr	Wind Speeds (m/s)	Rotor speed (rpm)	Force (N)	Power	
				$[P_{act}/P_{theo}]$	Watt
1	1,6	10	1,2	0,023	0,0264
2	2,5	27,1	1,3	0,094	0,1101
3	3,2	35,2	1,48	0,194	0,2114
4	4	42,7	1,55	0,353	0,4128
5	4,7	50	1,65	0,463	0,6696
Average	3,2	33	1,44	0,547	1,024

Notes: R_b = 11,0 cm ;L_b = 90, 0 cm ; r_P= 1,0 cm *) Result of Analysis

From the table above we find trend line that meet with the formula of rotor speed as the function of wind speed as

$$y = 36{,}407 . ln(x) - 6{,}9259,$$

y = rotor speed and x = wind speed.

Through the results of the performance tests in the field and the analysis carried out obtained information on the characteristics of savonius turbine applied shows an average rotor power of speed 50 rpm will produce 0,669 watts while 4,7 m/s wind speed. At an average daylight wind speed of V = 2.69 m / sec with an average shaft speed of 29,1 rpm and an average voltage of 15.2 volts. The result of the design of the Savonius prototype was able to convert mechanical energy into generator power by an average of 2.43 Watts. The low efficiency and electricity produced are influenced by low generator efficiency.

In this research we obtain the maximum wind speed is 5 m/s, will meet the power produce about 0,6696 watts with the physical size of model scale construction with diameter/radius 0,11 m.

5. Conclusion

Based on the results of the research above, the following conclusions can be drawn:

The technology of wind power conversion wind speed of Wong Polo beach using Savonius base models can be developed and modified with various physical forms of blade construction. For this turbine model can meet the power generation although low wind speed of 0-5 m/s. The conversion of electrical energy that can be generated by the coastal winds of Wong Polo Beach, Kota Pari Village, depends on the size of the generator used, which must be rotated by a windmill with the right diameter.

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