DESIGN AND CONSTRUCTION OF A SAVONIUS TYPE L WIND TURBINE PROTOTYPE WITH OPEN VARIATIONS AS AN ELECTRIC ENERGY ALTERNATIVE FOR LIGHTING IN LIFT NET NORTH SEMARANG

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Received: June 25, 2024 | **Accepted:** February 6, 2025 | **Published:** February 19, 2025
DOI: 10.12962/j27745449.v5i2.1805 | **Issue:** Volume 5 Number 2 2024 | **E-ISSN:** 2774-5449

ABSTRACT

This study investigates wind speed, wind turbine design to be implemented on fixed lift net in the waters of North Semarang in fishing with the help of lights. The research was carried out by designing and making a prototype of a Savonius type L wind turbine with a blade diameter of 400 mm and a height of 400 mm which was carried out directly on the beach for 10 hours and tested with a blue light to produce fish catches on the fixed lift net. The results of the use of blue lights were obtained from seven types of catfish, anchovies, Rebon fish, Selar fish, Cucut fish, mullet and layur fish with a total catch of 125.16 kg. The results obtained from processing wind turbine data are that the generator power at a wind speed of 1.3 m/s is 0.896 W, the highest power at a speed of 4.9 m/s is 5.214 W and the total generator power for 10 hours is 389.9 W. The energy produced is sufficient to light a 30-W lamp for 12 hours of use which will later be stored in a 12V 38 Ah capacity battery because the battery capacity used is 35.2 Ah with a battery efficiency of 85%.

Keyword: Fixed Lift Net, Wind Turbine, Vertical, Savonius, Light Intensity

Introduction

Wind energy is a form of natural energy whose availability is abundant, timeless, and can be used for various human needs. Wind turbines serve as facilities for converting wind energy into electrical energy[1]. The resulting amount of electrical energy from wind power plants is influenced by the meteorological conditions of a region, especially wind speed which cannot be influenced by human intervention. The average wind speed in Indonesia ranges from 4.16-7.00 m/s, especially in areas south of the equator with large amounts of wind energy in Indonesian territorial waters is 100 W/m^2[2].

Most of the people on the coast of North Semarang make their living as fishermen. Fixed lift net is a fishing tool used by fishermen with the help of light. The use of electrical energy as lighting is very effective for catching fish. The lamp functions to attract fish and other small marine biota. The assumption that the higher the intensity of light used, the greater the catch, causes fishermen to use lamps on a large scale and consume large amounts of electrical energy.

Figure 1. Map of prototype wind turbine Savonius type L in North Semarang

Most fishermen still use Petromax and generators as electricity sources in fixed lift net [3]. The lighting from this generator is very dependent on fuel oil so its operational costs will increase greatly, it is vulnerable to the issue of rising fuel prices, and it also greatly affects the fish catch of the fixed lift net fishermen and has a bad impact on the environment, the sound produced by the generator power plant itself will affect the number of fish, which is gathered below the fixed lift net. By looking at the wind speed conditions in coastal areas, research on making a prototype open variation Savonius wind turbine needs to be considered so that it can be used as a substitute for electrical energy sources from fuel oil for fishermen.

The Savonius Turbine

The Savonius turbine is one of the simplest types of turbines. First developed by Finnish inventor Sigurd Johannes Savonius in 1924. The working principle of this turbine is that a blade that moves against the wind will throw back wind air and cause the wind speed on the other side of the blade to increase [4]. These wind turbines generally move more slowly than horizontal axis wind turbines, but the torque produced is large, they are flexible and are not influenced by wind direction so they can rotate freely following the wind direction and have simple construction. Currently, Savonius wind turbines are experiencing developments in rotor shape. There are three types of Savonius windmills, namely U, S, and L [5].

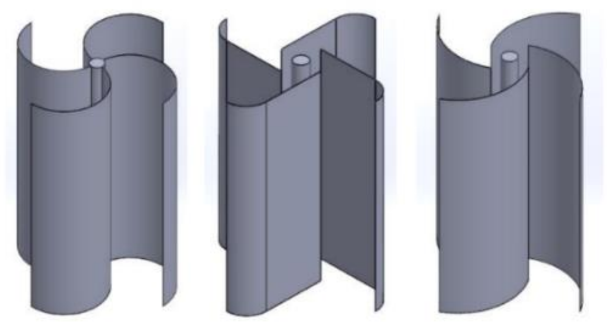

Figure 2. U, L, and S-type wind turbines

Wind capture capacity is wind power before it is converted or it passes through a wind turbine. To find the wind input power it can be formulated as follows [6]:

$$P_{in} = \frac{1}{2}\,\rho.\ \mathrm{A}\,.\,v^3 \quad (1)$$

Where: Pin is wind power (watts), ρ is air density (kg/m^3), A is turbine cross-sectional area (m^2), and v is wind speed (m/s). To obtain the turbine cross-sectional area value, it can be calculated using the following formula [7]:

$$\mathrm{A} = L.H \quad (2)$$

$$= (2\mathrm{D} - \mathrm{b} - 2\mathrm{x}).\mathrm{h}$$

Where: L is the characteristic length of the turbine (m), H is the height of the turbine (m), D is the diameter of the turbine (m), b is the shaft overlap (m), x is the thickness of the turbine blade (m).

Windmill power is the power produced by a wind turbine because the rotation of the turbine blades produces kinetic energy which is converted into electrical energy. To find the power of a windmill it can be formulated as follows [6]:

$$P_{out} = \tau.\omega \quad (3)$$

Where: Pout is the power produced by the windmill (watts) τ is the torque on the rotor (Nm), ω is the blade speed (rad/s). To get the torque value on the rotor, it can be calculated using the following formula [8]:

$$\tau = \frac{0.5\ C_P.\rho.A.r.V^2}{TSR} \quad (4)$$

Where: r is the turbine radius (m). To obtain the blade speed value, it can be calculated using the following formula [6]:

$$\omega = \frac{2\pi n}{60} \quad (5)$$

Where: n Turbine rotor rotation (rpm)

The generator output power is determined by the amount of electric current produced by the generator. To find the generator output power, it can be formulated as follows:

$$P_{generator} = V\,.\,I \quad (6)$$

Where: P generator is the electric generator power (watts), V is the electric generator voltage (volts), and I is the electric current (volts). the generator power efficiency value can be calculated using the following formula [7].

$$\eta_g = \frac{P_{generator}}{P_{in}} \times 100\% \quad (7)$$

Where: η_g is the generator efficiency

Methodology

Manufacturing of wind turbines

The design results of the vertical axis wind turbine are modeled using the student version of AutoCAD 2021 software in 2D form. Manufacturing the turbine, is designed with 4 L-type blades with a blade angle size of 150 which are made from 5mm plywood with a height of 400 mm and a diameter of 400mm which is coated with resin to make it stronger against the heat of the sun and rain. Next, the turbine is connected to the turbine axle shaft which is made of thin steel pipe with a diameter of 1.7 cm and each blade has an overlap distance of 3 cm with the axle shaft. The generator is placed under the wind turbine which is connected to the axle shaft. The generator functions to convert the mechanical energy of the shaft rotation into electrical energy. The turbine holder is made of angle iron, the hole is 30 cm high and 50 cm wide.

Figure 3. wind turbines

Testing measuring instruments

In testing the open variation L-type Savonius turbine, several measuring instruments are used, including:

1. An anemometer is a tool used to measure wind speed, placed in front of the wind turbine.
2. A tachometer is a tool used to measure the rotation speed of a wind turbine shaft.
3. A digital clamp meter is a tool used to measure voltage and electric current in generators.

Data retrieval

To determine the performance of the wind turbines that have been made, this research was carried out on the coast in the Tambakrejo area from 08.00 Western Indonesia Time (Waktu Indonesia Barat/WIB) to 18.00 WIB, with the following testing procedures:

1. Prepare the open variation Savonius type L vertical wind turbine test equipment.
2. Prepare measuring instruments (anemometer, tachometer, and digital clamp meter) and collect data simultaneously.
3. Record the data obtained every five minutes.
4. Carry out data processing to get wind power and electrical power.

Result and Discussion

Research data

Primary data includes wind velocity throughout North Semarang, the test results started at 08.00 WIB and finished at 18.00 WIB. This data includes wind speed (m/s), shaft rotation (rpm), generator voltage (volt), and generator current (A).

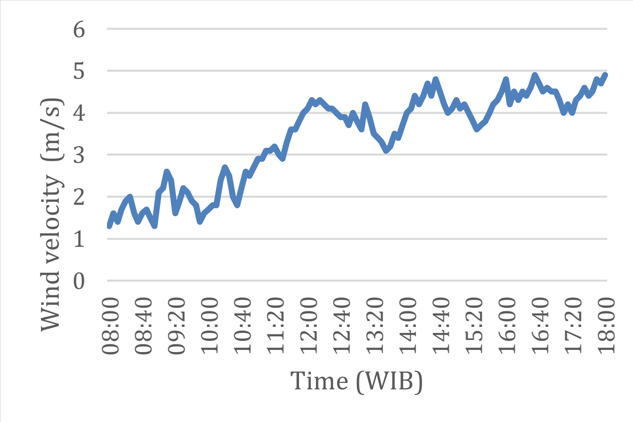

Figure 4. Time Relationship with Wind Speed

The graph in Figure 4 shows the relationship between time and wind speed. In the graph, it can be seen that the maximum wind speed occurred at 16:35 WIB at 4.9 m/s. Wind speed tends to always increase every hour with the wind speed range from 08:00 WIB to 18:00 WIB being 1.3 – 4.9 m/s. The data obtained shows that the average wind speed on the north coast of Semarang is in the low-medium wind speed range.

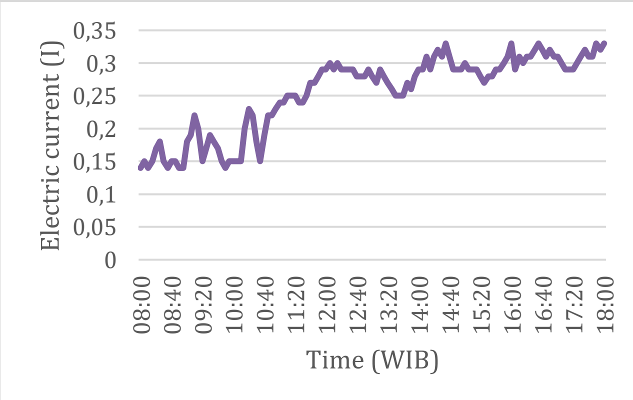

Figure 5. Time Relationship with Turbine Shaft Rotation

The application of savonius wind turbine is very suitable for application because it can rotate in low wind speed conditions.

The difference in wind speed greatly influences the power value of the shaft rotation, the voltage and electric current increase. This is because the greater the wind speed that hits the turbine leaf, the faster the rotor rotation is produced so that the power value in the generator increases. From physics it can be explained that when the wind speed increases, the thrust force of the turbine blades will also increase, thereby increasing the rotation speed of the turbine rpm shaft and the generator power output.

Figure 5 shows the relationship between time and shaft rotation, the lowest speed is 1.3 m/s with the shaft rotation speed obtained being 71.5 rpm, while at the highest wind speed, namely 4.9 m/s the shaft rotation speed obtained as 170.2 rpm.

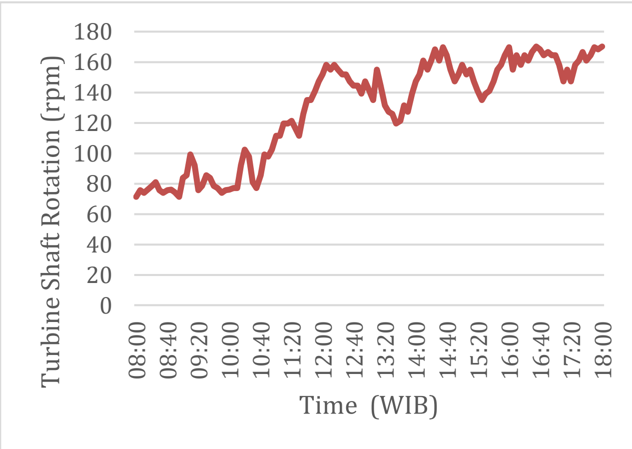

Figure 6. Time Relationship with Electrical Voltage

Figure 6 shows the graph of the relationship between time and electric voltage, at the lowest speed, namely, 1.3 m/s with an electric current of 6.4 volts. At the highest wind speed, namely 4.9 m/s, the electric current obtained is 15.8 volts.

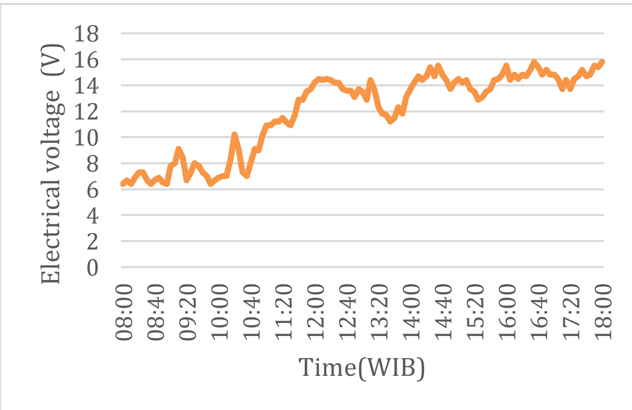

Figure 7. Time Relationship with Electric Current

In Figure 7, it shows a graph of the relationship between time and electric current, the lowest speed is 1.3 m/s with an electric current of 0.14 amperes. At the highest wind speed, namely 4.9 m/s, the electric current obtained is 0.33 amperes.

Calculation Result Data

The data obtained from the parameters obtained from the research were processed using Microsoft Excel to display the relationship between time and the values of wind power, wind turbine power, and generator output power.

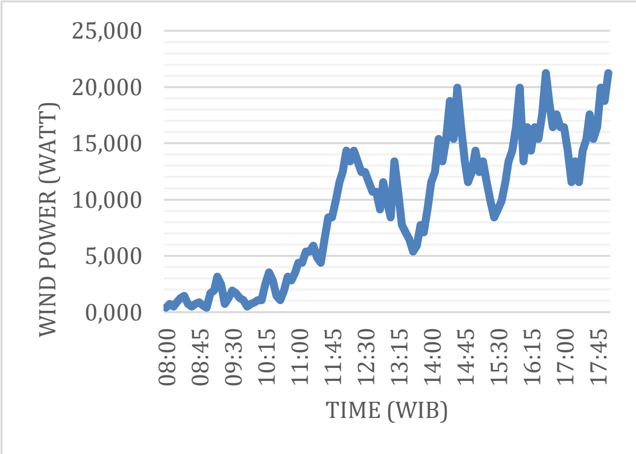

Figure 8. Time Relationship with Wind Power

Figure 8 shows that the wind power produced tends to increase following the amount of wind speed captured. From Figure 8, it can be seen that the maximum speed obtained by the wind turbine is 21,240 W with the highest wind speed being 4.9 m/s which occurs at 16:35 WIB and 18:00 WIB.

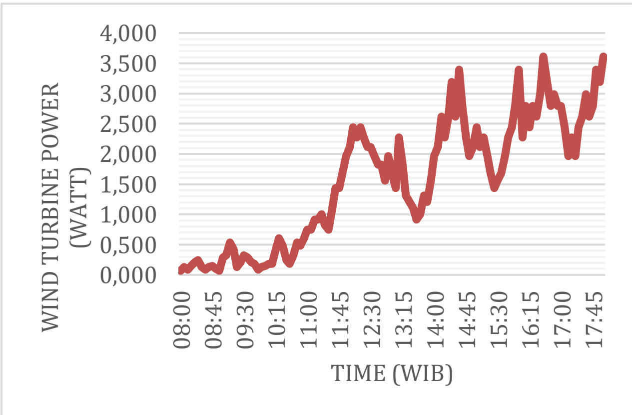

Figure 9. Time Relationship with Wind Turbine Power

Figure 9 shows that the resulting wind turbine power tends to increase according to the amount of wind speed captured. The wind speed will be related to the rotational motion of the rotor, meaning that the greater the wind speed obtained is in line with the increase in rotation of the turbine shaft produced so that the energy that the turbine can convert into rotation increases.

From Figure 9, it can be seen that the maximum speed obtained by the wind turbine was 3,611 watts with the highest wind speed being 4.9 m/s which occurred at 16:35 WIB and 18:00 WIB. The lowest speed with a wind speed of 1.3 m/s at 08:00 WIB and 08.55 WIB obtained a wind turbine power of 0.067 W.

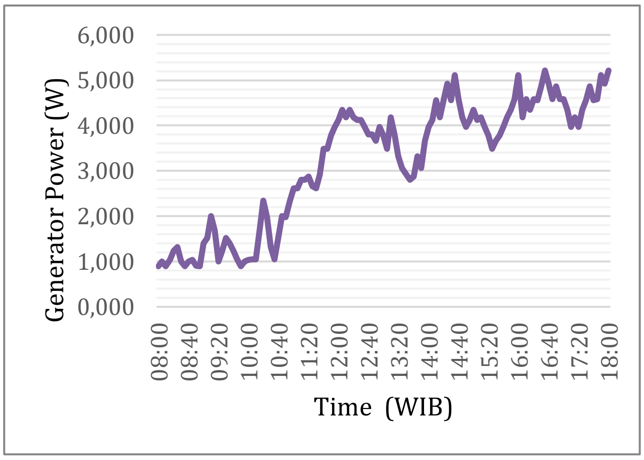

Figure 10. Time Relationship with Generator Power

In Figure 10 the results of the electric voltage obtained by the generator vary depending on the characteristics of the wind speed. From the graph it can be seen that the resulting voltage is proportional to the wind speed, meaning that the greater the force generated, the greater the wind speed. This is due to the effect of increasing turbine rotation with increasing generator rotation. When the generator rotates, the magnetic flux in the stator changes, producing different voltages and currents that are directly proportional to the wind speed.

From Figure 10 it can be seen that the highest generator output power obtained was 5,214 watts with the highest wind speed, namely 4.9 m/s, which occurred at 16:35 WIB and 18:00 WIB. The lowest power was 0.896 W in the early morning.

The results of direct testing using the generator for 10 hours on the north coast of Semarang resulted in a total of 389.9 watts and it can turn on a 5-watt lamp directly, in the application, the power that has been produced will be used to recharge the battery, so that later it can It is used by fixed lift net fishermen as lighting at night to catch fish.

Design of LED Strip Lighting on fixed lift net

The calculation of the daily lamp power required is obtained from calculating the load power (Watt) x usage time (hours), 30 W x 12 hours = 360 Wh. With a daily consumption requirement of 12 hours, it requires 360 watts of power/hour to turn on a 30-watt lamp. From the results of research on open variation wind turbines for 10 hours (08.00-18.00 WIB), the electrical power was obtained at 465.5 Watts, so this power is sufficient to meet daily lamp consumption needs.

Determining the need for the batteries used, before getting the value of the needs for the batteries used, it is necessary to find the efficient number of batteries, by calculating the total energy required: battery efficiency. For battery efficiency between 80%~90% need 360w: 0.85 = 423.5 Wh. After that battery capacity: battery voltage then 423.5 Wh: 12 V + 35.2 Ah. Using a 12 V 38 Ah battery capacity, the battery is sufficient to store all the energy produced by the windmill with a battery capacity of 35.2 Ah and a battery efficiency of 85% for the needs of this research.

The Effect of Blue Light Color on the Number of Fish Produced

Table 1. Fish catch results

Name	**Catch (Kg)**						**Total catch**
	1	2	3	4	5	6	
Mayung	4.21	7.87	4.27	4.15	4.13	6.01	30.64
Teri	3.25	4.31	3.81	3.12	1.96	4.15	20.60
Rebon	3.64	2.91	3.76	2.26	3.59	2.16	18.32
Selar	3.81	2.33	3.92	3.05	2.77	1.63	17.51
Cucut	1.32	2.51	3.11	2.69	3.48	0.93	14.04
Belanak	2.94	2.41	3.62	1.54	2.13	1.15	13.79
Layur	1.09	1.03	1.90	2.01	1.77	2.46	10.26
Total catch							**125.16**

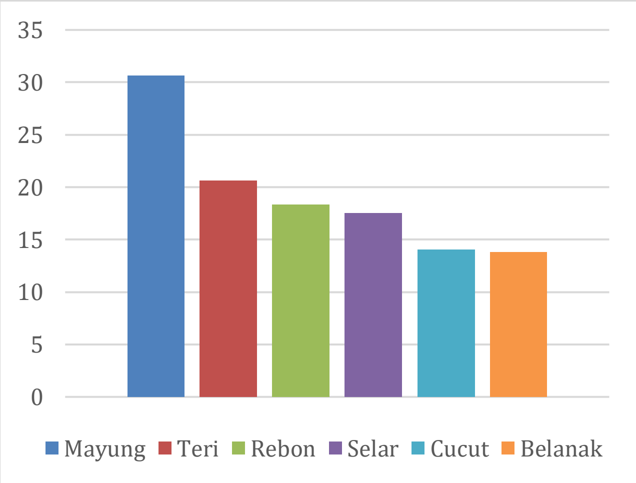

Figure 11. Total catch of the blue lights (kg)

The catch results in Table 1. obtained from six fishing operations using blue LEDs obtained a total catch of 125.16 kg with 7 different fish variations, namely: catfish (Ariidae) of 30.64 kg, anchovies (Engraulidae) amounting to 20.6 kg, Rebon fish (Acetes) amounting to 14.04 kg, Selar fish (Selaroides leptolepis) amounting to 17.51 kg, Cucut fish (Rhizoprionodon acutus) amounting to 14.05 kg, Mullet fish (Moolgarda seheli) amounting to 13, 79 kg and Layur fish (Trichiurus lepturus) amounting to 10.26 kg.

In Figure 11, the total fishing results show that using blue LED lights attracts more fish so the results obtained are greater. Blue lights are best for attracting fish because of the characteristics of blue colour which has the ability to penetrate deeper in water and has a low wavelength ranging from 450-570 nm [9]. This means that blue light can penetrate the water longer, thus creating light that can be seen by fish at greater depths and ultimately making fish interested in congregating in the blue light area [10]. Attention to fish from a greater distance at the depth of the water so the use of blue light is considered the most effective in fish collection due to the optical properties of seawater.

Conclusion

This study provides recommendations and applications of renewable energy from wind turbines in North Semarang, especially fishing communities who use fixed lift nets to help lighting in fishing. The wind speed at the location at 08.00-18.00 WIB has different wind variations with wind strength fluctuating every hour and greatly affecting the output power of the turbine. In the research results, the wind turbine produced 389.9 watts of electrical power for 10 hours and was stored in a battery with a capacity of 12 V and a voltage of 38 Ah. The lighting of fixed lift net needs 360 Wh to turn on a 30-W lamp for 12 hours.

The results of this study also show that the use of blue light greatly affects the catch of fish on the fixed lift net. This is because blue light has a low wavelength so it can last for a long time and can penetrate deeper water depths, eventually easily attracting fish.

References

[1] Satwika NA, Hantoro R, Septyaningrum E, Mahmashani AW. Analysis of wind energy potential and wind energy development to evaluate the performance of wind turbine installation in Bali, Indonesia, *J Mech Eng Sci.* **13(1)** (2019) 4461–76. DOI: 10.15282/jmes.13.1.2019.1.0386.

[2] P Dida H, Suparman S, Widhiyanuriyawan D. Pemetaan potensi energi angin di perairan indonesia berdasarkan data satelit QuikScat dan WindSat, *J Rekayasa Mesin*. **7(2)** (2016) 95–101. DOI: 10.21776/ub.jrm.2016.007.02.7.

[3] Lestari DP, Hadi AP, Rahman FA. Penerapan teknologi panel surya pada bagan tancap untuk peningkatan tangkapan ikan di Teluk Jor, Kabupaten Lombok Timur, *Abdi Insa*. **7(2)** (2020) 104–112. DOI: 10.29303/abdiinsani.v7i2.123.

[4] Building JW, Street M, Xxj G. University of Strathclyde investigation of performance characteristics of a Novel VAWT, *Mech Eng*. **9** (2001) 45–70. DOI: 10.1049/me:20010904.

[5] Wijianti ES, Saparin S, Setiawan Y. Turbin angin savonius empat sudu dengan variasi model profil sebagai media belajar mahasiswa. *Mach J Tek Mesin*. **5(2)** (2019) 57–61. DOI: 10.31253/mesin.v5i2.123.

[6] Alqodri MF, Rustana CE, Nasbey H. Rancang bangun generator fluks aksial putaran rendah magnet permanen jenis neodymium (NdFeB) untuk turbin angin sumbu vertikal tipe double-stage savionus, *Semin Nas Fis SNF 2015*. **IV** (2015) 135–42. DOI: 10.21009/03.SNF2015.01.EK.23.

[7] Priyaningsih N. Analisis efisiensi generator pada wind turbine, *J Edukasi Elektro*. **1(2)** (2017) 157–68. DOI: 10.21831/jee.v1i2.123.

[8] Purbaya T, Jannifar A, Bahri S. Rancang bangun blade kincir angin vertikal axis wind turbin model savonius dengan variasi tertutup dan terbuka. *J Mesin Sains Terap.* 5(2) (2021) 65–70. Available from: http://e-jurnal.pnl.ac.id/mesinsainsterapan/article/view/2388.

[9] Loupatty G. Analisis warna cahaya lampu terhadap hasil tangkapan ikan, *BAREKENG J Ilmu Mat dan Terap*. **6(1)** (2012) 47–9. DOI: 10.30598/barekengvol6iss1pp47-49.

[10] Sofijanto MA, Rasyidi I, Saputra DM. Led lamps improvment using photovoltaic technology for fish aggregating device at liftnet fisheries. (2019). DOI: 10.1109/ICOIACT46704.2019.8938412.