The performance of salt farmer’s windmill from Demak for water pumping with low-speed centrifugal pump

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Abstract. Wind energy is a renewable energy source. Windmill generally used to convert shaft power to electrical power for battery charging. Another benefit of wind energy is wind power for pumping, which usually called windpump. Indonesian salt farmer uses traditional windmill for pumping water for salt production process. The piston lever of the reciprocating pump is directly connected to the windmill shaft. This study will discuss the performance of salt farmer windmills from Demak region with a low-speed centrifugal pump. The variation used in this study is the number of blades on the windmill. There are four blades and two blades. Windmill shaft rotation connected to the AC generator shaft with permanent magnet and then produce electricity. The electric power from the AC generator connected to the DC electric motor, then the DC electric motor rotating the low-speed centrifugal pump. Data required for this study are wind speed, windmill’s shaft speed, and volume flow rate. The results are at wind speed between 2 – 4.5 m/s, a windmill with four blades and two blades has 0.13 liter/s and 0.21 liter/s. The daily average volume for four blades and two blades has 2901.6 liters and 4492.8 liters. The maximum of total efficiency of the windpump system with four and two blades is 34.06% and 37.32%.

Keywords: Salt farmer windmill, Indonesian traditional windmill, windpump, low-speed centrifugal pump

1. Introduction

Indonesia as a maritime country has a lot of natural resources that can be used to support Indonesia energy needs. Based on the last data in 2019 which is given by National Energy Council of Indonesia, Indonesia already has 14% of renewable energy has been installed, but it still dominated by 50% of coal usage [1]. Indonesia has a national target of the energy mix in 2025 of 45 GW or 34% on renewable energy [2]. One of the potential energy sources in Indonesia is wind energy. Indonesia has more than 81,000 km of coastline, these numbers could show that wind energy potential in Indonesia [3]. Indonesia has 60 GW of wind energy potential based on the Ministry of Energy and Mineral Resource of Indonesia [4].

The utilization of wind energy to do some works has been done by salt farmers in the northern part of Java. Salt farmers who lived there have salt ponds used to process seawater became salt crystals. These ponds exposed to sunlight, then the seawater on the ponds will
evaporates and leaves salt crystals. Then, these salt crystals will be processed into salt and distributed to household needs. Salt farmers in the north coast of Java uses windmills to transport seawater into the salt ponds, and the other function is to circulating seawater from one pond to another pond.

Salt farmers’ windmills in the northern part of Java especially in Demak, still uses reciprocating pumps to transport water. In actual conditions shows that the windmill could not be built away from the water source, because the windmill's shaft connected directly to the reciprocating pump. There is a reason why Indonesian salt farmer's windmills have a difficulty in obtaining a steady source of wind. The utilization of low-speed centrifugal pump is one of the solutions for this problem. With this combination, salt farmers' windmill could be built away from the pump. The windmill built on a place with steady wind speed and the low-speed centrifugal pump built on a place with good seawater sources.

This study discusses the performance of WEWP system [5]-[6]. The windmill used in this study is SFWD directly brought from Demak, Central Java, Indonesia [7] and low-speed centrifugal pump (LSCP) [8]-[10]. The results are a chart of wind speed and LSCP flow rate, chart of daily average volume of this windpump, and chart of efficiency of this WEWP system are shown also.

2. **Experiment Methods**

This study requires some types of equipment needed, there are SFWD with two and four blades and its tower, AC generator, Wheatstone bridge (WB), large wires with 50 metres long, DC electric motor, LSCP with rigid structure and measuring cup. The SFWD with two and four blades has 200 cm of diameter and 29 cm width. This SFWD directly bought from the salt farmer of Demak, Central Java, Indonesia. The dimensions of the SFWD tower are 20 cm x 20 cm and 150 cm in height. The SFWD’s shaft directly connected to the electric generator. The generator has 500 watt capacity with permanent magnet brushless AC (ACG). This ACG usually used as a driving motor on electric bikes. The output from ACG is alternating current (AC), converting to direct current (DC) by WB, which connected directly from ACG. The electric cables used to transmit electric power from ACG to DC electric motor (DCEM) has 50 metres long, which connected from WB to DCEM. The output from WB as DC electricity, directly connected to DCEM with 450 watt capacity brushed DC. DCEM shaft directly connected to LSCP pipes, which assembled in a rigid structure. The rigid structure has 25 cm x 25 cm x 50 cm of dimension and three feet to prop up the rigid structure. The DCEM is assembled on the rigid structure with two F209 bearings. The DCEM shaft directly connected to LSCP pipes below. LSCP pipes are arranged into vertical and horizontal sections (shown in Figure 1.). The vertical section as inlet where water comes through, and the horizontal section as impeller [11]. Pipe diameter from inlet to outlet in a row are 2.54 cm, 5.08 cm, and 1.905 cm. LSCP works by using centrifugal force to transport water from inlet to outlet [11]. LSCP pipes configured T shape junction. Outlet pipes have double U configuration which inline with pump impeller [9]-[10]. Pump head counted from inlet pipe which sinks in water to outlet pipes. On this study, head is constant at 50 cm.
Around LSCP pipes is provided with a cover to prevents water from splashing out due to the effects of centrifugal force.

Figure 1. Low-speed centrifugal pump

Data needed for this study are wind speed, windmill’s shaft speed, and volume flow rate. All of the data collected is approaching the actual condition of SFWD. The data is collected at Kuwaru Beach, Bantul, Special Region of Yogyakarta. All of the data took in an unsteady state because of the natural condition of coastline. Figure 2 is shows SFWD and LSCP placement scheme. The wind rotates the SFWD, and the SFWD shaft directly connected to ACG shaft and produce electricity. The output from ACG is transmits electric power from ACG to DCEM. DCEM shaft directly connected to LSCP pipes, and LSCP generates energy to pumping water. SFWD is facing wind directions with various wind speed between 2.0 – 4.5 m/s.

The data taken are wind speed, windmill’s shaft speed, and volume flow rate. The volume flow rate is collected with measuring cup every 5 minutes 50 seconds, the last 10 seconds is used to take the wind speed, windmill’s shaft speed, and volume flow rate data. All these data collected at 09.00 – 15.00 (GMT+7), this is an effective working hour of SFWD.
Data processing uses some of the equations to make charts needed. Wind speed data are needed to calculate wind energy. The study about this SFWD used in this study has been done by Zevalukito et al [7]. Volume flow rate is needed to calculate hydropower produced by LSCP.

The energy conversion begins with wind energy [12]:

\[
E_{\text{wind}} = \frac{1}{2} \rho \text{air} A v^3
\]  

Where \( \rho \) is air density (constant at 1.225 kg/m\(^3\)), \( A \) is swept area of SFWD (constant at 3.14 cm\(^2\)), and \( v \) is the average wind speed in 10 seconds.

Energy captured by SFWD has maximum Coefficient of Power (Cp) of 10.2% with four blades and 8.6% with two blades [7]. The Cp fluctuate from 0 – 10.2% for four blades and 0 – 8.6% for two blades, then \( E_{\text{mech}} \) is Cp times \( E_{\text{wind}} \) [6]. This equation could be written as:

\[
E_{\text{mech}} = C_{\text{SFWD}} \cdot E_{\text{wind}}
\]  

Hydropower is energy could be produced by LSCP to pump water [11], this equation could be written as:

\[
P_{\text{hydraulic}} = \rho \cdot g \cdot h \cdot Q
\]  

Where \( \rho \) is seawater density (constant at 1.03 kg/liter), \( g \) is gravity (constant at 9.81 m/s\(^2\)), \( h \) is head pump (in this study head constant at 50 cm), and \( Q \) is volume flow rate in liter/s.

The efficiency of this WEPW system could be written as:
% = \frac{P_{\text{hydraulic}}}{E_{\text{mech}}} \times 100\% \quad (4)

Phydraulic as an output and Emech as input [10].

3. Result and Discussions

Fig. 3. is shows that this WEWP system could operate in 2.5 – 4.2 m/s. The points in the chart looks fluctuate because of the unsteady wind. This WEWP with four blades and two blades could pumps water start from 2.5 m/s of wind speed and above. In this WEWP system, wind speed will affects the volume flow rate of LSCP. Because the data collections did in the field, then the wind speed depends on natural conditions. This study shows that this WEWP system with two blades has higher trendline than WEWP system with four blades. Electricity produce by GAC is increase along with the rotational speed of GAC [8]. This study shows that the higher wind speed captured by SFWD, the higher electricity produce by GAC [8]–[10]. The higher electricity produce by GAC is to generate electricity for DCEM, the higher electricity to rotate the LSCP. This means that energy given by LSCP to seawater is directly proportional to wind speed.

![Figure 3. Relationship of windspeed and LSCP volume flow rate](image)

Figure 4 shows the volume produces by the WEWP system with four and two blades. Based on Figure 3., WEWP system with two blades has a higher volume flow rate than four blades. Because of that (Figure 3.), the volume produced by WEWP system with two blades has higher volume than WEWP system with four blades. The existing wind speed in a day gives an impact to the volume produced by the WEWP system [9]. The WEWP system with
four blades has a daily average volume of 2901.6 liters in 2.1 – 3.9 m/s of wind speed. Meanwhile, the WEWP system with two blades has a daily average volume of 4492.8 liters in 2.9 – 4.2 m/s of wind speed.

Figure 4. The daily average volume of effective working hours

Figure 5 is a relation of efficiency and time for each hour in a day. It shows that maximum efficiency reach by WEWP system with four blades and two blades are 34.06% and 37.32%. The main factor which gives an effect in this WEWP efficiency is the wind speed and wind energy captured by the windmill. WEWP system with four blades has a lower efficiency than two blades, this happens because when the data are taken, the wind speed is higher at two blades than four blades.
Figure 5. Efficiency

4. Conclusions

The experimental study of SFWD with four blades and two blades combined with LSCP is successfully recorded. The average volume flow rate, daily average volume, and WEPW efficiency on four blades are 0.13 liter/s, 2901.6 liters, and 34.06%. While on two blades are 0.21 liter/s, 4492.8 liters, and 37.32%. Further study is recommended to set this WEPW system in steady wind speed.

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