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The Study on Wells Turbine for Operation of Sensor Node in Marine Environment

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Abstract

It is an undeniable fact that renewable energy is nearly infinite and pollution-free, and that the demand for it is increasing. What is important here is the conversion of this energy into a usable energy form. Among new renewable energy, ocean wave energy is highly efficient, with various routes to harvest this energy. A lot of research is still in process on wave energy. Also, as the wave surges in the ocean far away from the land, applications in fish farms or drill ships that are distant from land is also made possible. The purpose of this paper is to utilize Wells Turbine with enhanced efficiency. We examined the variation of produced electric power with Wells turbine's different tip to hub ratio like 3:1 and 2:1. There was a noticeable distinction between 3:1 turbine and 2:1 turbine. We have examined the elements that influenced this outcome and how it affected the operation of the sensor node. The result of this research may be adopted in real marine environments, utilized in fish farms, and referred in research for reinforcing the structure of independent power plants.

Keywords*: Wells Turbine, Wave Power, Fish Farm, Sensor-Node*

1. Introduction

There are many problems in using energy sources such as the finiteness of fossil fuels, potential dangers of nuclear energy, and environmental pollutants. To solve these problems, many researchers have been studying renewable energy. Among diverse new renewable energies, wave energy has the advantage of wide availability as it could be obtained in any ocean. Converting wave power into wind power is also possible through OWC [1]. Surely, wave energy has the advantage of easy conversion into a different energy form.

In diverse oceanic environments, research on adjacent seas that are hardly supplied with electric power from land, and obtaining stable electricity that is necessary for the operation of LED lights or sensor nodes [2] in an open sea fish farming environment are essential and in progress [3]. Especially in places like fish farms, there are many situations when procuring electricity from land is difficult. Considering these hurdles, we concentrated our study on Wells turbine and OWC to find out their maximum efficiency.

2. Related Work

2.1. Wells Turbine Blades NACA0020

Wells turbine's airfoil in symmetrical structure rotates continuously in one way regardless of whether airflow reverses its way [4]. Various application is possible using

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this fact, especially available with methods using general OWC, and is usable in environments where wind direction changes frequently.

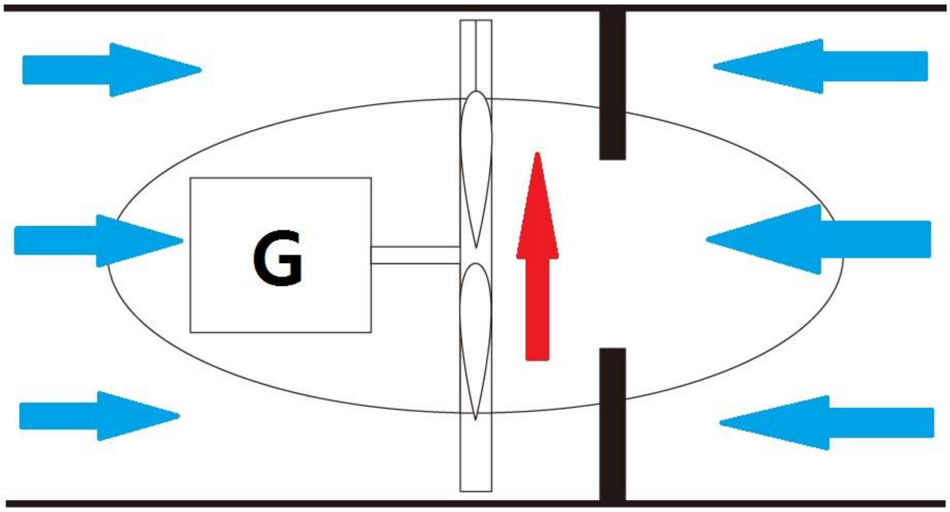

Figure 1. The Concept of Wells Turbine

Among the rest, NACA0020, which is being used most frequently for experiments and research and is known for its good efficiency, has a 5:1 horizontal to vertical ratio [5][6]. We have measured solidity and the generated electric power by changing the length, weight of wing and the existence of blade support. Through solidity, we could figure out torque and rotational velocity of turbine [7] and through electric power, the optimum wind speed of turbine.

3. OWC (Oscillating Water Column)

OWC (Oscillating Water Column) is a technology generating wind power using the rise and descent of water as a wave surges. A lot of research has been done about OWC in order to design a more efficient model [8].

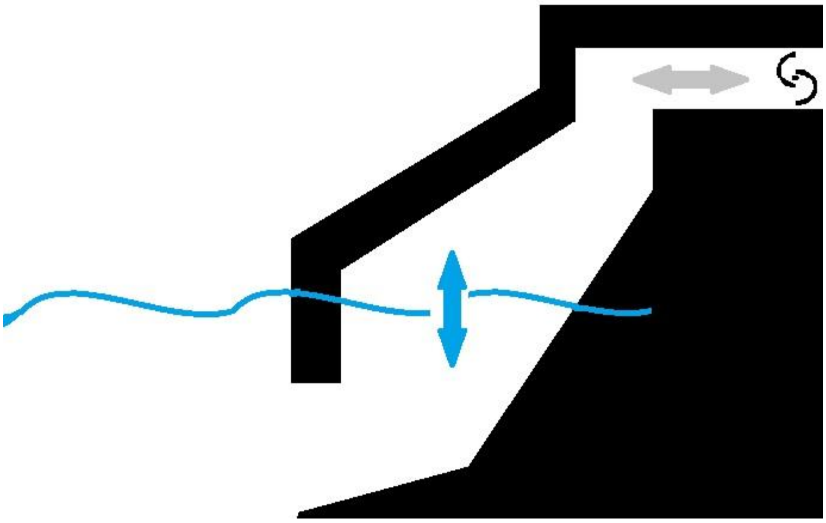

Figure 2. Concept of OWC

The wind power generated by OWC keeps reversing its direction continuously [9]. For OWC, Darrieus turbine, Savonius turbine, and Wells turbine is used as they rotate regardless of wind direction. More significantly, it is closely related to Wells turbine because Savonius turbine has high air resistance when rotating and Darrieus turbine takes a while to rotate with speed. For these points, Wells turbine is most frequently used for OWC model.

3. Experiments and Analysis

The experiment was separated into two types, Wells turbine and OWC. In an experiment of Wells turbine, the amount of generated electricity according to tip to hub ratio and the difference made by the presence of support was analyzed.

In an experiment of OWC, the wind speed according to the wave height was measured.

3.1. Wells Turbine Test

In the experiment, blades with two different conditions were used. The common conditions were the number of blades, which were eight, and the total 12cm tip Wells turbine. We compared the turbine of 3:1 tip to hub ratio with the turbine of 2:1 tip to hub ratio. The configuration specifications of the two experimental turbines are given below in table 1. Additionally, experiments were done with and without the presence of blade support.

Table 1. The Configuration Specification of Two Experimental Turbines

Tip to hub ratio	hub	tip	blade width (C)	weight	solidity
3:1	4cm	12cm	1.657cm	16.04g	0.53
2:1	6cm	12cm	2.485cm	32.19g	0.7

Figure 3. Testing Generated Voltage with the Load Resistance

Like Figure 3, we measured the voltage of every load resistance in order to test electric power of Wells turbine. The experiment was done with a circulator. The wind speed straight from the circulator was 6m/s and the wind speed to blade was measured as 4.7m/s. We were able to verify the difference in voltage and electric power as resistance changed. As seen in Figures 4 and 5, the 3:1 tip to hub ratio turbine showed a rapid increase in voltage from .7V to 3.6V in the load resistance range of 200Ω to 250Ω.

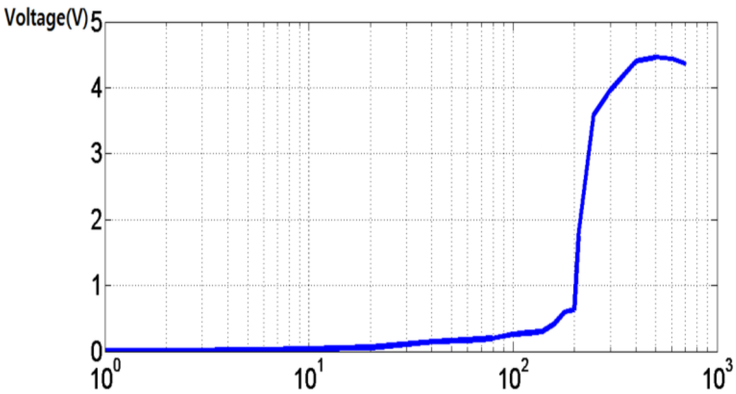

Figure. 4 Generated Voltage with the Load Resistance in Case of 3:1 Wells Turbine

The maximum electric power was 52.272mW, when the load resistance was 300Ω.

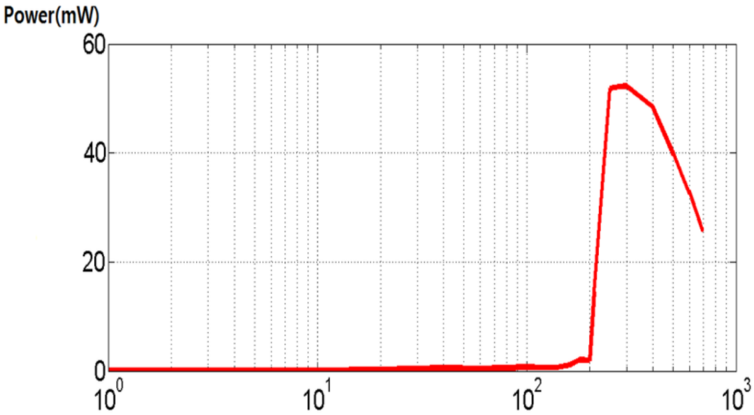

Figure 5. Generated Power with the Load Resistance in Case of 3:1 Wells Turbine

The 2:1 tip to hub ratio turbine seen in Figures 6 and 7 showed a stable increase of voltage overall compared to 3:1 turbine. Also, there was no more increase of voltage as it showed a peak at 400Ω

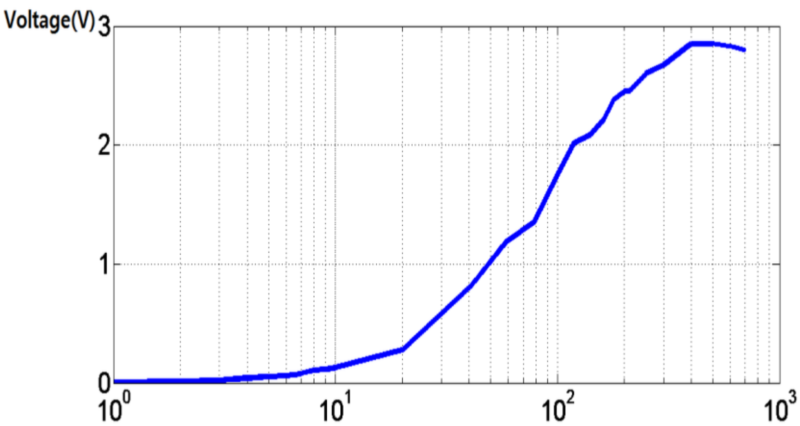

Figure 6. Generated Voltage with the Load Resistance in Case of 2:1 Wells Turbine

The electric power was 34.289mW maximum when the load resistance was 120Ω.

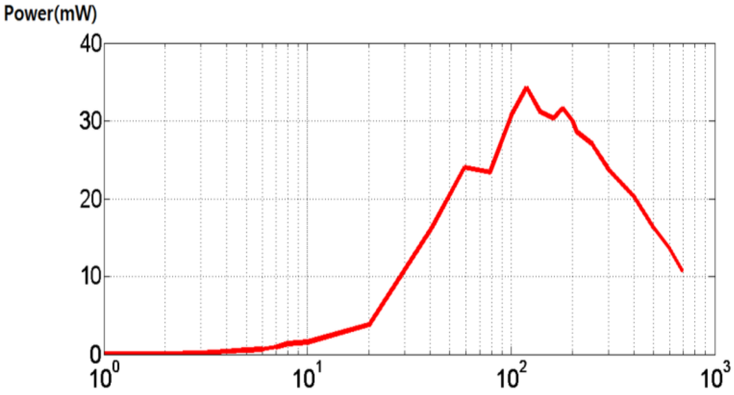

Figure 7. Generated Power with the Load Resistance in Case of 2:1 Wells Turbine

The results of the experiment are arranged in the table below.

Table 2. Peak Power of 3:1 and 2:1 Wells Turbine

	Peak power(mW)	Open MPPT load resistance(Ω)
3:1	52.272	300
2:1	34.289	120

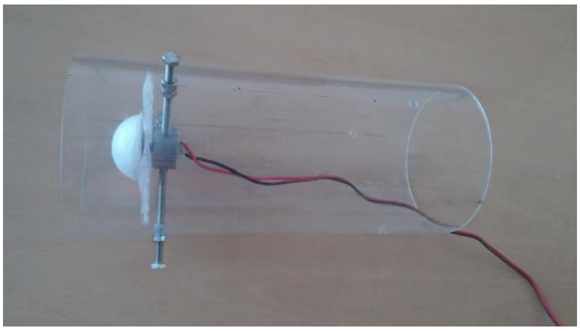

Figure 8. Wells Turbine Support Test

Without the load, both the 3:1 and 2:1 turbines each generated maximum 5V and 3.4V respectively. We progressed the test checking the effectiveness of blade support.

Table 3. Time to Reach at Peak Power of 3:1 Wells Turbine

3:1 wells turbine 5V reaching time (s)				
Non-support	23	24	23	22
Support	19	18	19	18

Table 4. Time to Reach at Peak Power of 2:1 Wells Turbine

2:1 wells turbine 3.4V reaching time (s)				
Non-support	28	29	29	28
Support	22	20	20	21

As shown in table 3, in Non-support condition, the maximum electric power condition of the 3:1 turbine was reached in 23 seconds on average, while it took18.5 seconds on average to reach maximum power condition in support condition. In table 4, the 2:1 turbine reaches maximum power condition in Non-support condition on the average of 28.5 seconds, while it took an average of 20.75 seconds in support condition.

4.2. OWC Wind Speed Test

The OWC wind speed experiment used OWC structures in conditions of A1’s 600 cm2 area and A2’s 28.26 cm2 area. The entire height is 50cm and width is 30 cm.

The experiment used a self-produced wave generator with the width of 180cm, length of 60cm, and height of 50cm that is shown is figure 9.

Figure 9. Wave Generator

Like figure 10, we have measured the wind speed for every wave height in order to test wind speed according to the OWC’s wave height, and the wave height was generated from 2cm to 10cm.

Figure 10. OWC Test

The result is shown in table 5.

Table 5. Wind Speed Changes According to Wave Height

Wave height	Front OWC	Back OWC	Wind speed
	Height of inside surface rise	Height of inside surface rise	
2~3Cm	2 Cm	1 Cm	0.5~2.4m/s
4~6Cm	3 Cm	2 Cm	2.8~5.1m/s
8~10Cm	8 Cm	6 Cm	5.4~9.8m/s

Table 5 shows the wind speed difference according to the wave height that is generated from the wave generator. When the wave height was generated up to 2~3 cm, the surface rose by 2 cm in the front OWC and the wind speed was at its slowest at 0.5 m/s, and 2.4 m/s at its fastest. When the wave height was generated up to 8~10 cm, the surface rose by 8 cm in the front OWC and the wind speed was at its lowest 5.4 m/s, and 9.8 m/s at its highest.

4. Application Plan

Wells turbine's rotating speed and power changes, depending on the turbine's tip to hub ratio and the numbers of blades that were tested earlier. Based on this, the experiment may be executed with the difference in Wells turbine's number of blades.

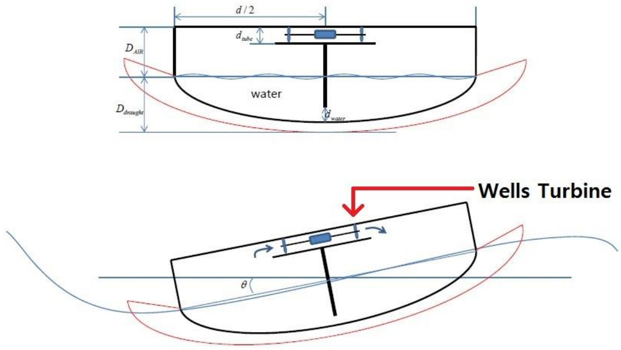

Figure 11. Closed OWC

Figure 11 shows a closed type, offshore floating OWC. It is a unique idea composed of using a fixed amount of water inside a closed, double chambered rectangular device. The device is not separated fully and the chambers remain in fluid contact with each other through an aperture down the barrier. The idea was to use bidirectional turbines in a tunnel positioned at the upper portion of the chamber barrier, inside the device. Upon the arrival of waves, the device gets tilted and water inside the device moves from one chamber to the other while air moves in the reverse direction through the tunnel. The moving air rotates the turbine inside the tunnel and produces electricity through an electric generator. Wells turbine can be an efficient option to be used here as a bidirectional turbine in this application.

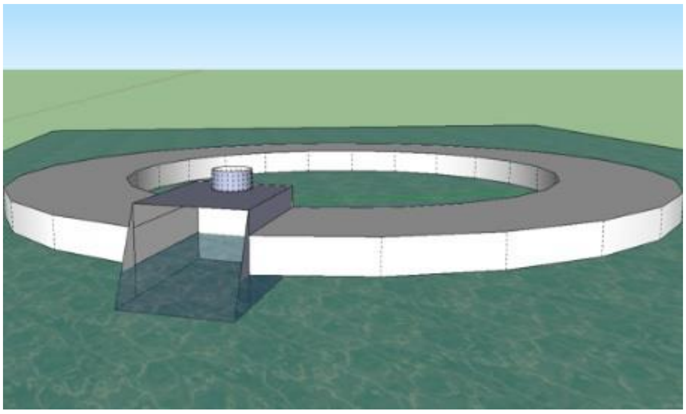

Figure 12. The Study on Wells Turbine with OWC for Operation of Sensor Node [11]

Wells turbine also has a scope of application in classical OWC. Figure 12 shows an example of a floating OWC having an opening under the water level. This is a special case to apply in powering sensor nodes used in a floating fish farm. Like the closed OWC, this system also uses the same working principle and can use bidirectional turbines like Wells turbine in the upper smaller chamber to run an electric generator for generating electrical power.

5. Conclusions

Between Wells turbines with the ratio of 3:1 and 2:1 each, the one with small solidity showed low voltage as the speed did not increase at low load resistance, however, the electric power was noticeably high as it rotated at a fast speed after 200 Ω. Conversely, the one with high solidity did not rotate fast but showed relatively high voltage at low load resistance compared to the 3:1 turbine. We could also confirm a steady increase of voltage. This confirms that the torque of 2:1 turbine is stronger than 3:1 turbine.

The most important part in the operation of sensor nodes is a stable electric power supply. Considering this condition, the 3:1 Wells turbine that showed a stable increase in electric power was chosen to be more appropriate between the 3:1 and 2:1 Wells turbine.

The factors that influence the generating power of the Wells turbine are wind speed, the turbine's tip to hub ratio, weight of the blade, the motor generator's efficiency, and housing.

The blade support decreases the blade's travel time by diverting the wind that is directly hitting hub to blade.

The OWC experiment ensured that our experiment using Wells turbine for electricity generation is a possible development strategy. The wind speed was generated higher than the calculated figure, which took loss rate into account and showed a possibility of stable electric power production once the wave continues.

Afterwards, for the operation of sensor nodes in a marine environment with difficulty in electric power supply, we plan to test by applying equipment using OWC and Wells turbine to a fish farm in an actual environment.

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