Sea Wave Energy Simulation of Oscillating Water Column (OWC) Technology, Binongko Island, Wakatobi, Southeast Sulawesi

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Abstract. Indonesia is a country that has the largest sea area of several countries spread across the world. This is an advantage for Indonesia in utilizing the energy potential of the seas and oceans. One of which is the potential of Oscillating Water Column (OWC) Technology, to utilize the energy potential of the seas and oceans not only requires sea potential but also must have location parameters with suitable seabed topography. gentle and constant sea wave height, usually influenced by wind speed. One area of Indonesia that has these parameters is Binongko Island, Wakatobi, Southeast Sulawesi, whose wave characteristics are a basic reference for exploring the enormous energy potential of the seas and oceans in that location. The author uses a simulation model with the Graphical User Interface (GUI) method in the Matlab program to determine the potential energy produced. The data used in this research uses data analysis from the Southeast Sulawesi Regional Meteorology, Climatology, and Geophysics Agency using data samples for 2021 and 2022. The data used includes sea wave height data and sea wave period data at the research location in 2021 and the 2022 time period. Through this data, it is known that Binongko Island, Wakatobi, Southeast Sulawesi 2021 will have minimum sea wave height. of 0.5125 meters and a maximum value of 1.04167 meters, for the minimum sea wave period of 2.34993 seconds and a maximum value of 3.57008 seconds, while in 2022 the minimum sea wave height will be 0.341667 meters and the maximum value will be 0.895833 meters, for a minimum sea wave period of 1.91045 and a maximum value of 3.30481 seconds. With this data, Binongko Island, Wakatobi, Southeast Sulawesi in 2021 will be able to produce a minimum of 20.8844 watts and a maximum of 75.7116 watts, while in 2022 it will be able to produce a minimum of 12.7715 watts and a maximum of 43.5652 watts.

Keywords: Sea Wave Energy, OWC, GUI, Renewable Energy.

INTRODUCTION

Reducing fossil energy production, especially petroleum, and the global commitment to reducing greenhouse gas emissions, encourage all countries, including Indonesia, to continue to strengthen the role of new and renewable energy in maintaining energy security and independence. Indonesia's new and renewable energy mix target in 2025 is a minimum of 23% and in 2050 a minimum of 31%. Indonesia has a large potential for new and renewable energy to achieve the primary quantity target of the new renewable energy mix [1].

The sea and ocean energy technology that is currently popular is Oscillating Water Column (OWC) technology. This technology has been researched and tested by several research groups and countries, for example, England, Japan, Portugal, Norway, and several other countries [2] [3]. This technology consists of two basic components including an oscillating column chamber and a turbine, with the principle of producing electrical energy through the energy potential of the seas and oceans with a working system to convert sea wave energy into compressed air (pneumatic) energy by utilizing the rising and falling movements of seawater to drive turbines to produce electrical energy [4] [5].

Sea and Ocean Energy with Oscillating Water Column (OWC) technology. Apart from requiring potential sea waves, oscillating water column (OWC) technology must also have location parameters with sloping seabed topographic conditions and constant sea wave height. which is usually influenced by wind speed. This technology also does not require large construction areas in the implementation process [6]. Indonesia is a country that has the largest sea area of several countries spread across the world. This is an advantage for Indonesia in utilizing the energy potential of the seas and oceans. One of which is the energy potential of the seas and oceans using oscillating water column (OWC) technology. especially on Binongko Island, Wakatobi, Southeast Sulawesi, which has maximum sea waves. The power in the season reaches 4-6 meters [7]. This wave characteristic is suitable to meet energy needs, especially to overcome existing problems, including service and fulfillment of electrical energy which is still limited at this time. This research was conducted to determine the potential for sea and ocean energy using Oscillating Water Column (OWC) technology on Binongko Island, Wakatobi, Southeast Sulawesi using GUI (Graphical

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User Interface) simulation. It is hoped that the results of research will determine the potential of wave energy which can be used as a parameter for developing Oscillating Water Column (OWC) technology at future research locations.

METHODOLOGY

This technology is a type of technology with the working principle of converting sea wave energy into compressed air (pneumatic) energy which is produced through the rising and falling movement of seawater in an oscillating column which results in the movement of a wind turbine. The mechanical energy produced by the wind turbine is converted into electrical energy through an electric generator [8].

The steps to find out the energy produced from Oscillating Water Column (OWC) technology are as follows. The initial step is to find out the relationship between sea wave height and sea wave period, using the equation formula [9] (1):

$$T = 3.55\sqrt{H} \tag{1}$$

where T is the sea wave period [s] and H is the sea wave height [m].

Sea wave energy can be calculated using the equation formula [8] (2):

$$E_w = \frac{1}{2}\rho g a^2 \tag{2}$$

where ρ is the sea water density = *1030* [*kg/m3*], g is the gravitational force =*9.81* [*m/s²*] and a is the amplitude = $\frac{h}{2}$[m], h is the wave height [m].

next to determine the wave power can be calculated using the equation formula (3):

$$P_w = 0.195 w \rho g h^2 T \tag{3}$$

where w is the wave width is assumed to be equal to device column width [m], ρ is the sea water density = *1030* [*kg/m3*], h is the sea wave height [m], g is the gravitational force =*9.81* [*m/s²*] and T is the wave period [s].

The value of the wave power produced; it is necessary to find out the value of the airspeed flowing in the OWC column using the equation formula [10] (4):

$$v_1 = \frac{\omega H1}{2} cos(\omega t) \tag{4}$$

where ω is the angular velocity $\omega = \frac{2\pi}{T}$

to determine the acceleration value of the orifice column air flow, which is influenced by the area of the OWC device (A_1), the area of the orifice (A_2), and v_1 using the equation formula [9] (5):

$$v_2 = \frac{A1}{A2} v_1 \tag{5}$$

where A_1= 5 m², and A_2= 1 m²

Air Discharge at the Orifice also needs to be known using equation formula [11] (6):

$$Q = v_2 A_2 \tag{6}$$

next calculate the pressure on the turbine using the equation [12] [13](7):

$$P2 - P0 = \rho \frac{A1}{A_2}\frac{\partial\varphi 1}{\partial t} - \rho \frac{Q}{A_2}(v_2 - v_1) \tag{7}$$

where $\frac{\partial\varphi 1}{\partial t} = \frac{{H_1}^2}{4}\omega^2(2cos(\omega t)^2 - 1)$

The power of the Oscillating Water Column (OWC) can be determined using the equation formula (8):

$$P = (P2 - P0)Q \quad (8)$$

by obtaining wave energy and OWC energy, so that you can then calculate the OWC efficiency using the equation formula [14] (9):

$$\eta OWC = \frac{P}{P_w} x100\% \quad (9)$$

next calculate the PLTGL efficiency that can be generated using the equation (10):

$$\eta PLTGL = \eta OWC \; x \; \eta Generator \; x \; \eta Turbine \quad (10)$$

After getting the wave power, OWC power, and efficiency, to find out the electrical energy that can be generated by the OWC device, it can be determined using the equation formula (11):

$$Pg = P_w \; x \; \eta PLTGL \quad (11)$$

The Sea Wave energy model simulation using Oscillating Water Column (OWC) technology used in this research uses the GUI (Graphical User Interface) method. The GUI working system flowchart is shown in figure 1:

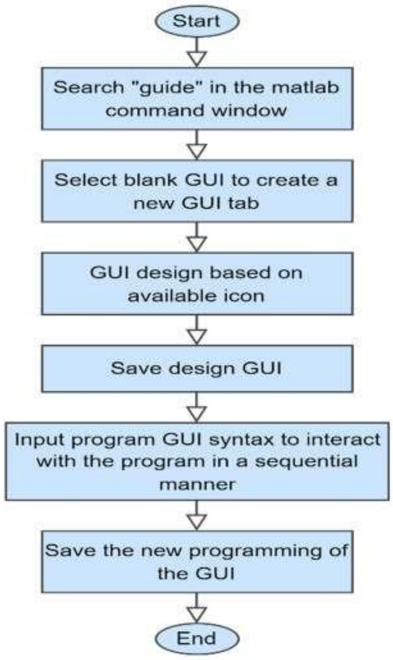

FIGURE 1. Graphical User Interface (GUI) design

In the analysis of the Graphical User Interface (GUI) method. First, design the model on the GUI worksheet. After creating the model design to run the model design that has been created, you will find an editor window containing program syntax (data coding). At this stage, programming is carried out using written commands on the GUI design that has been created via the GUI worksheet. After completing the program syntax according to the model that has been created, the run GUI program uses the data parameters that have been obtained to find out the values produced in the Oscillating Water Column type sea wave energy generation model (OWC) with the GUI method.

After knowing the design model and GUI program syntax that will be used, it is necessary to know the data on sea wave characteristics and sea wave periods at the research location which will be used as input data at the GUI analysis stage. The data used in this research is an analysis of data from the Southeast Sulawesi Regional Meteorology, Climatology and Geophysics Agency with data samples for 2021 and 2022. The data can be seen in table 1:

TABLE 1. Sea Wave Characteristic

	Wave Height [m]				Wave Period [s]			
	2021		2022		2021		2022	
	Min	Max	Min	Max	Min	Max	Min	Max
1	0.75	1.0	0.1	1.0	3.07	3.55	1.12	3.55
2	1.25	1.5	0.5	1.0	3.96	4.34	2.51	3.55
3	0.1	0.75	0.1	0.5	1.12	3.55	1.12	2.51
4	0.1	0.75	0.1	0.5	1.12	3.55	1.12	2.51
5	0.5	1.25	0.5	1.0	2.51	3.96	2.51	3.55
6	0.5	1.25	0.5	1.0	2.51	3.96	2.51	3.55
7	0.5	1.25	0.75	1.25	2.51	3.96	3.07	3.96
8	1.0	1.5	0.75	1.5	3.55	4.34	3.07	4.34
9	0.5	1.25	0.1	1.0	2.51	3.96	1.12	3.55
10	0.1	0.5	0.1	0.5	1.12	2.51	1.12	2.51
11	0.1	0.5	0.1	0.5	1.12	2.51	1.12	2.51
Avg.	0,51	1,04	0,34	0,89	2,34	3,57	1,91	3,30

To find out the shape of the input data panel in GUI design, the following can be seen in figure. 2:

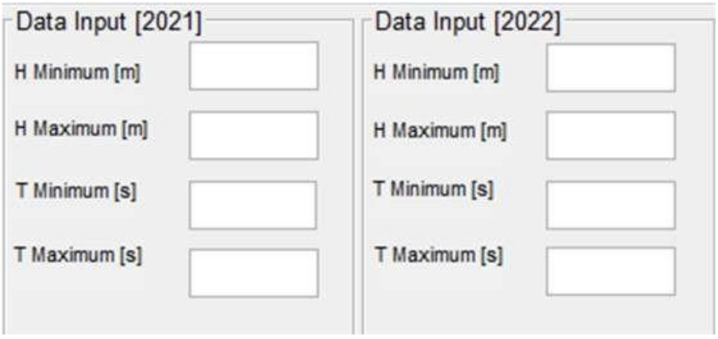

FIGURE 2. Display of the Input Data Panel in the Graphical User Interface (GUI).

This data panel can be used to determine each variable used for analysis purposes so that wave energy, wave power, OWC power, and OWC efficiency values can be generated.

RESULT AND DISCUSSION

Sea wave energy simulation using oscillating water column technology using the Graphical User Interface (GUI) method first completes the input data in the form of wave characteristic data required in the GUI design, along with the input data in the GUI design can be seen in figure. 3

FIGURE 3. Data Input in the Graphical User Interface (GUI)

It is known that the sea wave characteristic data in 2021 will have a minimum sea wave height of 0.51 meters and a maximum of 1.04 meters. The minimum sea wave period is 2.34 seconds and the maximum is 3.57 seconds.

In 2022, the minimum sea wave height will be 0.34, the maximum will be 0.89 meters. The minimum sea wave period will be 1.91 seconds and the maximum will be 3.30 seconds.

After completing the wave characteristic data in the GUI design, the results of the wave power, OWC power, and efficiency produced can be obtained. The following displays the results of wave power, OWC power, and efficiency in the GUI design, in figure 4:

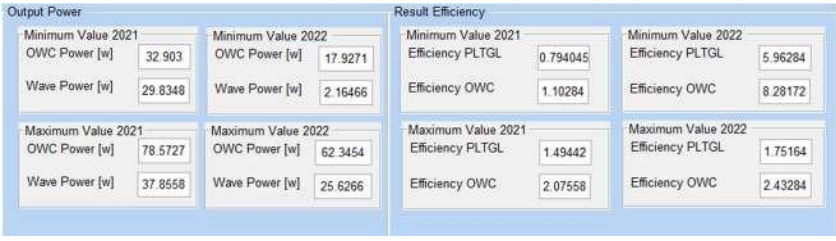

FIGURE 4. Results of wave power, OWC Power, and Efficiency in the Graphical User Interface (GUI)

The results of the 2021 OWC power analysis produced a minimum value of 32.903 watts, and a maximum value of 78.2727 watts, and the results of the sea wave power analysis produced a minimum value of 29.8348 watts, a maximum value of 37.8558 watts. The calculation results in 2022 produce OWC power with a minimum value of 17.9271 watts, a maximum value of 62.3454 watts, a minimum wave power value of 2.16466 watts, and a maximum value of 25.6266 watts.

The results of the OWC efficiency analysis in 2021 produce a minimum value of 1.1%, and a maximum value of 2.0%, and the results of the PLTGL efficiency analysis in 2021 produce a minimum value of 0.7% and a maximum value of 1.4%. the calculation results in 2022 produce OWC efficiency with a minimum value of 8.2%, and a maximum value of 2.4%, and the results of the PLTGL efficiency analysis in 2022 produce a minimum value of 5.9% and a maximum value of 1.7%.

After obtaining the OWC power results and PLTGL efficiency, the results of the electric power generated can be obtained, along with the results of the electric power generated in Figure. 5:

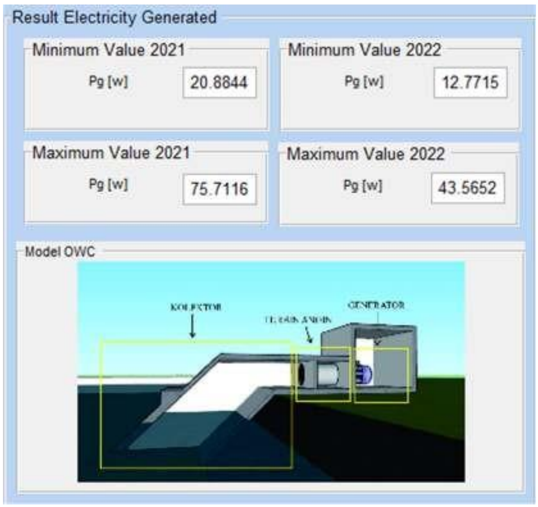

FIGURE 5. Results of Electric Power Generated in the Graphical User Interface (GUI)

The results of the analysis of electric power generated in 2021 with a minimum value of 20.8844 watts, and a maximum value of 75.7116 watts, while the results of the analysis of electric power generated in 2022 with a minimum value of 12.7715 watts, and a maximum value of 43.5652 watts.

CONCLUSION

Conclusions from the results of the Oscillating Water Column (OWC) type sea wave energy simulation using the Graphical User Interface (GUI) method, the research location is Binongko Island, Wakatobi, Southeast Sulawesi, the average value of the sea wave characteristics of Binongko Island, Wakatobi, Southeast Sulawesi, in 2021, the minimum sea wave height is 0.51 meters the maximum is 1.04 meters. The minimum sea wave period is 2.34 seconds and the maximum is 3.57 seconds. In 2022 The minimum sea wave height is 0.34 and the maximum is 0. .89 meters, the minimum sea wave period is 1.91 seconds and the maximum is 3.30 seconds.

The results of the 2021 OWC power analysis produced a minimum value of 32.903 watts, and a maximum value of 78.2727 watts, and the results of the sea wave power analysis produced a minimum value of 29.8348 watts, a maximum value of 37.8558 watts. The calculation results in 2022 produce OWC power with a minimum value of 17.9271 watts, a maximum value of 62.3454 watts, a minimum wave power value of 2.16466 watts, and a maximum value of 25.6266 watts.

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REFERENCES

[1] Walujanto, Suharyati, S. H. Pambudi, J. L. Wibowo and N. I. Pratiwi, Outlook Energy Indonesia 2018, Jakarta: Dewan Energi Nasional, 2018.

[2] D. G. Dorrell, M.-F. Hsieh and C.-C. Lin, "A Multichamber Oscillating Water Column Using Cascaded Savonius Turbines," *IEEE Transactions on Industry Applications*, vol. **46**, no. 6, pp. 2372 - 2380, 2010.

[3] M. Shalby, P. Walker and D. G. Dorrel, "The investigation of a segment multi-chamber oscillating water column in physical scale model," in *2016 IEEE International Conference on Renewable Energy Research and Applications (ICRERA)*, Birmingham, UK, 2016.

[4] F. Kate, D. Ming and S. Robert, "Control Strategies for Oscillating Water Column Wave Energy Converters," *Underwater Technology*, vol. **32**, no. 1, pp. 3-13, 2013.

[5] K. Kevin, E. F. Simanjuntak, A. R. Utomo, F. Husnayain, F. H. Jufri and D. R. Aryani, "Study on Micro-Scale Ocean Wave Power Generator Using Oscillating Water Column System with Piezoelectric," in *2020 8th International Electrical Engineering Congress (iEECON)*, Chiang Mai, Thailand, 2020.

[6] A. B. Baharin, M. Ismail, M. O. Muhammad and R. M.N.A, "Mathematical model of sea wave energy in electricity generation," *2011 5th International Power Engineering and Optimization Conference*, pp. 154-158, 2011.

[7] Badan Meteorologi, Klimatologi dan Geofisika Stasiun Meteorologi Maritim Kendari, "medcom.id," Thursday August 2022. [Online]. Available: https://www.medcom.id/nasional/daerah/Wb7aoD0K-tinggi-gelombang-di-perairan-wakatobi-capai-6-meter. [Accessed Wednesday December 2022].

[8] K. Bavesh, "Pneumatic Power Measurement of an Oscillating Water," Dissertation presented for the degree of Master of Science in Engineering (Mechatronic) in the Faculty of Engineering at Stellenbosch University, Stellenbosch Central, 2014.

[9] R. Dinzi, H. Hutagalung and F. Fahmi, "Feasibility study of ocean wave energy for wave power plant at Sibolga-Tapanuli Tengah," in *2017 International Conference on Control, Electronics, Renewable Energy and Communications (ICCREC)*, Yogyakarta, Indonesia, 2017.

[10] N. Hiron, I. A. D. Giriantari, L. Jasa and I. N. S. Kumara, "The Performance of a Three-blades Fish-ridge Turbine in an Oscillating Water Column System for Low Waves," in *2019 International Conference on Sustainable Engineering and Creative Computing (ICSECC)*, Bandung, Indonesia, 2019.

[11] M. Amundarain, M. Alberdi, A. J. Garrido and I. Garrido, "Modeling and Simulation of Wave Energy Generation Plants: Output Power Control," *IEEE Transactions on Industrial Electronics*, vol. **58**, no. 1, pp. 105-117, 2011.

[12] M.-. F. Hsieh, I.-H. Lin, D. G. Dorrell, M.-J. Hsieh and C.-C. Lin, "Development of a Wave Energy Converter Using a Two Chamber Oscillating Water Column," *IEEE Transactions on Sustainable Energy* , vol. **3**, no. 3, pp. 482-497, 2012.

[13] M. Malhouni and E. M. Boudi, "Modeling of hybrid system combining an offshore wind turbine and an Oscillating Water Column system," in *2014 International Renewable and Sustainable Energy Conference (IRSEC)*, Ouarzazate, Morocco, 2014.

[14] Setiyawan, E. Affandi and L. A. Anzar, "Study on Wave Energy Conversion by Using Oscillating Water Column in Alindau Waters," in *International Conference on Urban Disaster Resilience (ICUDR 2019)*, Palu, Indonesia, 2020.