The effect of pump diameter and penstock pipe on the electric power of a hybrid generator

Massus Subekti [1*], *Parjiman*[1]

[1]Electrical Engineering Faculty of Engineering, Universitas Negeri Jakarta, Jalan Rawamangun Muka, Jakarta 13220, Indonesia
[*]Corresponding author : masus@unj.ac.id

Abstract. Ocean Wave Power Plants (WEC) are divided into 6 types, namely (1) Point Absorber, (2) Oscillating Water Column, (3) Pressure Differential Submerger, (4) Oscillating Wave Surge Converter, (5) Attenuator & Terminator, and (6) Removable Devices. The AquabuOY type is a type of Point Absorber type wave power generator. This type uses a long pump connected to a Pelton turbine and was developed by Finavera (Aquaenergy) Company of Canada. The AquabuOY system has a weakness in that the turbine rotation depends on the wave period that occurs. The slower the wave period occurs, the weaker the resulting turbine rotation, therefore it needs to be improved by adding a reservoir unit to obtain pressure. stability and puffiness of the unit so that the rotation produced in the turbine is much greater. With this addition, the generator will spin more quickly and stably. In addition, the addition of wind energy installed at the top of the unit means that the generator to be built will produce more energy, is more flexible, can be placed in shallow, medium or deep seas, does not require complicated foundations, is relatively cheap, is not affected by extreme weather. and can be used in all sea conditions just by attaching it to a ballast. This study examines the effect of pump diameter and outlet pipe diameter on the electrical power generated at a hybrid power plant. pump diameter variations of 8 inches, 10 inches, 12 inches and 14 inches. Variation of outlet pipe diameter 1 inch, 2 inch, 3 inch and 4 inch. In this paper, we will present a simulation of the calculation of electrical energy from wave power with variations in pontoon volume, pump diameter, and outlet pipe diameter to obtain the most optimal system size. while wind energy power generation is presented in a different pape. Calculation simulation results to get the most optimal pump diameter and outlet pipe diameter in the hybrid power plant system built.
Keywords: Sea Wave Power, Point Absorber, AquabuOY, hybrid

1 Introduction

Ocean Wave Power Plant (WEC) can be divided into 6 types, namely (1) Point absorber, (2)Oscillating Water Column, (3) Pressure Differential Submerger, (4) Oscillating Wave Surge Converter, (5) Attenuator & Terminator, and (6) Removable Device [1] [2]. [3] - [6]. There are 5 types of Point absorber type wave power plants that have been installed (1) the

Power Bouy type which converts the vertical energy up and down waves into rotary energy through a screw mechanism developed by Ocean Power Technologies Company United States, (2) The seabed type that utilizes shapes vertical wave up and down waves to move the rotor on a linear motor, while the stator section is connected to the seabed and developed by the Swedish Seabased AB Company, (3) type CETO with a submerged Buoy system driven by sea waves, a drive pump that presses the sent sea water landward via underwater pipelines.Once on land, high pressure seawater is used to power hydro-electric turbines, generating electricity. High pressure seawater can also be used to supply reverse osmosis to desalination plants, produce fresh water and was developed by Carnegie Wave Energy Limited Company Ireland, (4) Star Wave Type which uses the energy of a floating pontoon that fluctuates due to waves to obtain water that is acceptable and developed by the Denmar Wave Star Energy Company, and (5) the AquabuOY type which uses a long pump connected to a pelton turbine and was developed by the Finavera (Aquaenergy) Company of Canada. [1].

AquabuOY system has a weakness in the turbine rotation which depends on the wave period that occurs, the slower the wave period that occurs, the turbine rotation that is generated is also getting weaker, therefore it needs to be improved by adding reservoir units to obtain pressure stability and pully units so that the rotation is generated in a much larger turbine. With this addition, the generator will spin faster and more stable. Coupled with the addition of wind energy paired at the top of the unit makes the plant to be built will produce greater energy, more flexibility can be placed in shallow seas, medium or deep, does not require complicated foundations, relatively inexpensive, is not affected by extreme weather and can be used in all fields of the sea by simply being tied to the ballast and can be used as a sign lamp or a cellular signal transmitter for the benefit of navigation and communication.[7][6],[8].

2 Methode

Ocean Wave Hybrid Power Plant is a combination of Ocean Wave Power Plant and wind power plant. Ocean wave power plants convert the vertical energy of ocean waves into motion energy which is used to pump seawater into pressurized water to turn a turbine connected to a generator. Wind power plants convert wind energy into rotational energy which is connected to the generator. The energy generated from the two units is combined in the controller unit.

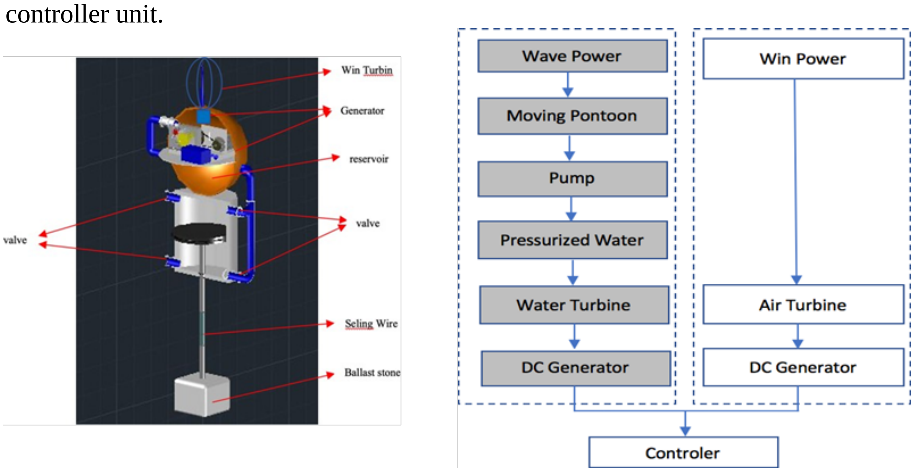

Fig. 1. (a) Generator Design (b)Block diagram of a Hybrid Wave Power Plant

The energy change is shown in the block diagram of a hybrid wave power plant. In the ocean wave power plant block, vertical ocean wave energy is captured by the pontoon unit, the energy produced by the pontoon is used to drive the pump and produce pressurized seawater, pressurized seawater is used to turn the turbine connected to the generator. Whereas in the wind power plant block, sea wind energy is used to rotate the turbine connected to the generator. To get energy stability, the electric power generated by 2 dc generators is controlled using a controller.

In this paper, we will present a simulation of the calculation of electrical energy from wave power with variations in pontoon volume, pump diameter, and outlet pipe diameter to obtain the most optimal system size. while wind energy power generation is presented in a different paper.

The research flow:
1) Research at the beginning by evaluating and refining the design.
2) Pontoon design, this stage designs the pontoon unit based on the most optimal shape.
3) Designing the pump unit, this stage is designing the pump unit according to the size of the system design.
4) Turbine unit design, this stage designs the turbine unit based on the calculated model size.
5) Selection of the generator unit, this stage determines the required generator size
6) Simulation calculations, this stage simulates system optimization calculations with variations in the pump diameter of 8 inch, 10 inch, 12 inch, 14 inch and 16 inch, as well as variations. diameter of pipe out 1 inch, 2 inch, 3 inch and 4 inch
7) Analysis, analyzes the amount of potential electrical power generated by the unit
8) In conclusion, with the conclusion it is hoped that the calculation results of the amount of potential electrical energy produced are obtained

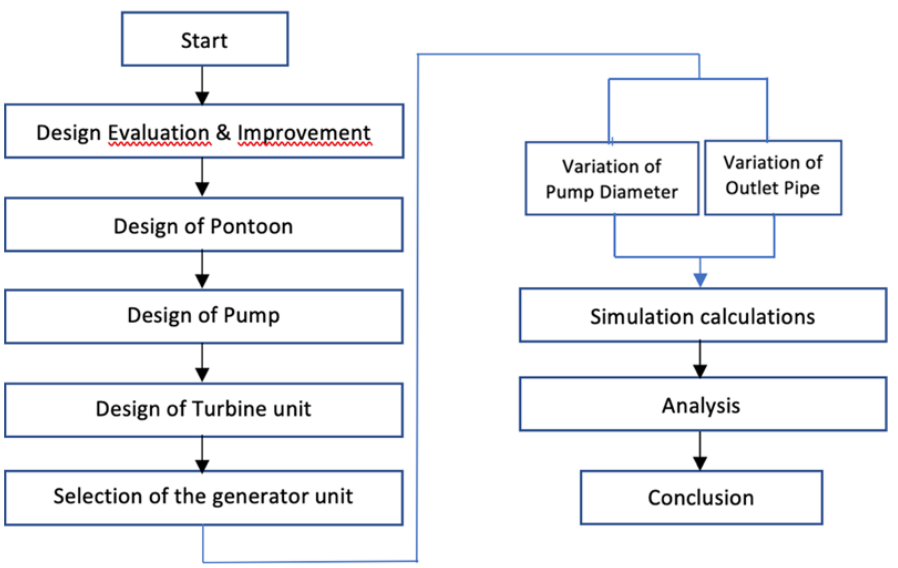

Fig. 2. Research Flow

3 Result and Discussion

3.1 Result

Table 1. The electric power generated at the pump diameter is 8 inches

Pipe Diameter Exit (Inchi)	Volume Pontoon (liter)	Ponton Force (N)	Speed Incoming water (m/s)	Speed Water Comes Out (m/s)	Pressure Piston (N/m^2)	Pressure Exit (N/m^2)	Discharge (m^3/s)	Head (m)	Turbin Power (kW)	Electric Power (kW)
1	65	328	0.33	21.3	10,112	647,164	0.005	64	2.38	2.03
1	113	570	0.33	21.3	17,579	1,125,070	0.005	111	4.14	3.53
1	180	908	0.33	21.3	28,002	1,792,147	0.005	177.5	6.59	5.62
1	268	1353	0.33	21.3	41,692	2,668,308	0.005	264.3	9.82	8.37
1	382	1928	0.33	21.3	59,427	3,803,335	0.005	376.8	13.99	11.93
2	65	328	0.33	5.3	10,112	161,791	0.005	16.0	0.60	0.51
2	113	570	0.33	5.3	17,579	281,268	0.005	27.9	1.03	0.88
2	180	908	0.33	5.3	28,002	448,037	0.005	44.4	1.65	1.41
2	268	1353	0.33	5.3	41,692	667,077	0.005	66.1	2.45	2.09
2	382	1928	0.33	5.3	59,427	950,834	0.005	94.2	3.50	2.98
3	65	328	0.33	2.4	10,112	71,907	0.005	7.1	0.26	0.23
3	113	570	0.33	2.4	17,579	125,008	0.005	12.4	0.46	0.39
3	180	908	0.33	2.4	28,002	199,127	0.005	19.7	0.73	0.62
3	268	1353	0.33	2.4	41,692	296,479	0.005	29.4	1.09	0.93
3	382	1928	0.33	2.4	59,427	422,593	0.005	41.9	1.55	1.33
4	65	328	0.33	1.3	10,112	40,448	0.005	4.0	0.15	0.13
4	113	570	0.33	1.3	17,579	70,317	0.005	7.0	0.26	0.22
4	180	908	0.33	1.3	28,002	112,009	0.005	11.1	0.41	0.35
4	268	1353	0.33	1.3	41,226	164,902	0.005	16.3	0.61	0.52
4	382	1928	0.33	1.3	59,427	237,708	0.005	23.5	0.87	0.75

Table 2. The electric power generated at the pump diameter is 10 inches

Pipe Diameter Exit (Inchi)	Volume Pontoon (liter)	Ponton Force (N)	Speed Incoming water (m/s)	Speed Water Comes Out (m/s)	Pressure Piston (N/m^2)	Pressure Exit (N/m^2)	Discharge (m^3/s)	Head (m)	Turbin Power (kW)	Electric Power (kW)
1	65	328	0,33	33,3	6.472	647.164	0,008	64,1	3,72	3,17
1	113	570	0,33	33,3	11.251	1.125.070	0,008	111,5	6,47	5,51
1	180	908	0,33	33,3	17.921	1.792.147	0,008	177,5	10,30	8,78
1	268	1353	0,33	33,3	26.683	2.668.308	0,008	264,3	15,34	13,08
1	382	1928	0,33	33,3	38.033	3.803.335	0,008	376,8	21,86	18,64
2	65	328	0,33	8,3	6.472	161.791	0,008	16,0	0,93	0,79
2	113	570	0,33	8,3	11.251	281.268	0,008	27,9	1,62	1,38
2	180	908	0,33	8,3	17.921	448.037	0,008	44,4	2,58	2,20
2	268	1353	0,33	8,3	26.683	667.077	0,008	66,1	3,83	3,27
2	382	1928	0,33	8,3	38.033	950.834	0,008	94,2	5,46	4,66
3	65	328	0,33	3,7	6.472	71.907	0,008	7,1	0,41	0,35
3	113	570	0,33	3,7	11.251	125.008	0,008	12,4	0,72	0,61
3	180	908	0,33	3,7	17.921	199.127	0,008	19,7	1,14	0,98

 https://doi.org/10.1051/e3sconf/202447302005

Pipe Diameter Exit (Inchi)	Volume Pontoon (liter)	Ponton Force (N)	Speed Incoming water (m/s)	Speed Water Comes Out (m/s)	Pressure Piston (N/m^2)	Pressure Exit (N/m^2)	Discharge (m^3/s)	Head (m)	Turbin Power (kW)	Electric Power (kW)
3	268	1353	0,33	3,7	26.683	296.479	0,008	29,4	1,70	1,45
3	382	1928	0,33	3,7	38.033	422.593	0,008	41,9	2,43	2,07
4	65	328	0,33	2,1	6.472	40.448	0,008	4,0	0,23	0,20
4	113	570	0,33	2,1	11.251	70.317	0,008	7,0	0,40	0,34
4	180	908	0,33	2,1	17.921	112.009	0,008	11,1	0,64	0,55
4	268	1353	0,33	2,1	26.683	166.769	0,008	16,5	0,96	0,82
4	382	1928	0,33	2,1	38.033	237.708	0,008	23,5	1,37	1,16

Table 3. The electric power generated at the pump diameter is 12 inches

Pipe Diameter Exit (Inchi)	Volume Pontoon (liter)	Ponton Force (N)	Speed Incoming water (m/s)	Speed Water Comes Out (m/s)	Pressure Piston (N/m^2)	Pressure Exit (N/m^2)	Discharge (m^3/s)	Head (m)	Turbin Power (kW)	Electric Power (kW)
1	65	328	0,33	48	4.494	647.164	0,012	64,1	5,36	4,57
1	113	570	0,33	48	7.813	1.125.070	0,012	111,5	9,31	7,94
1	180	908	0,33	48	12.445	1.792.147	0,012	177,5	14,83	12,65
1	268	1353	0,33	48	18.530	2.668.308	0,012	264,3	22,08	18,83
1	382	1928	0,33	48	26.412	3.803.335	0,012	376,8	31,48	26,84
2	65	328	0,33	12	4.494	161.791	0,012	16,0	1,34	1,14
2	113	570	0,33	12	7.813	281.268	0,012	27,9	2,33	1,98
2	180	908	0,33	12	12.445	448.037	0,012	44,4	3,71	3,16
2	268	1353	0,33	12	18.530	667.077	0,012	66,1	5,52	4,71
2	382	1928	0,33	12	26.412	950.834	0,012	94,2	7,87	6,71
3	65	328	0,33	5,3	4.494	71.907	0,012	7,1	0,60	0,51
3	113	570	0,33	5,3	7.813	125.008	0,012	12,4	1,03	0,88
3	180	908	0,33	5,3	12.445	199.127	0,012	19,7	1,65	1,41
3	268	1353	0,33	5,3	18.530	296.479	0,012	29,4	2,45	2,09
3	382	1928	0,33	5,3	26.412	422.593	0,012	41,9	3,50	2,98
4	65	328	0,33	3	4.494	40.448	0,012	4,0	0,33	0,29
4	113	570	0,33	3	7.813	70.317	0,012	7,0	0,58	0,50
4	180	908	0,33	3	12.445	112.009	0,012	11,1	0,93	0,79
4	268	1353	0,33	3	18.530	166.769	0,012	16,5	1,38	1,18
4	382	1928	0,33	3	26.412	237.708	0,012	23,5	1,97	1,68

Table 4. The electric power generated at the pump diameter is 14 inches

Pipe Diameter Exit (Inchi)	Volume Pontoon (liter)	Ponton Force (N)	Speed Incoming water (m/s)	Speed Water Comes Out (m/s)	Pressure Piston (N/m^2)	Pressure Exit (N/m^2)	Discharge (m^3/s)	Head (m)	Turbin Power (kW)	Electric Power (kW)
1	65	328	0,33	65,3	3.302	647.164	0,017	64,1	7,29	6,22
1	113	570	0,33	65,3	5.740	1.125.070	0,017	111,5	12,67	10,81
1	180	908	0,33	65,3	9.144	1.792.147	0,017	177,5	20,19	17,21

Pipe Diameter Exit (Inchi)	Volume Pontoon (liter)	Ponton Force (N)	Speed Incoming water (m/s)	Speed Water Comes Out (m/s)	Pressure Piston (N/m^2)	Pressure Exit (N/m^2)	Discharge (m^3/s)	Head (m)	Turbin Power (kW)	Electric Power (kW)
1	268	1353	0,33	65,3	13.614	2.668.308	0,017	264,3	30,06	25,63
1	382	1928	0,33	65,3	19.405	3.803.335	0,017	376,8	42,85	36,53
2	65	328	0,33	16,3	3.302	161.791	0,017	16,0	1,82	1,55
2	113	570	0,33	16,3	5.740	281.268	0,017	27,9	3,17	2,70
2	180	908	0,33	16,3	9.144	448.037	0,017	44,4	5,05	4,30
2	268	1353	0,33	16,3	13.614	667.077	0,017	66,1	7,51	6,41
2	382	1928	0,33	16,3	19.405	950.834	0,017	94,2	10,71	9,13
3	65	328	0,33	7,3	3.302	71.907	0,017	7,1	0,81	0,69
3	113	570	0,33	7,3	5.740	125.008	0,017	12,4	1,41	1,20
3	180	908	0,33	7,3	9.144	199.127	0,017	19,7	2,24	1,91
3	268	1353	0,33	7,3	13.614	296.479	0,017	29,4	3,34	2,85
3	382	1928	0,33	7,3	19.405	422.593	0,017	41,9	4,76	4,06
4	65	328	0,33	4,1	3.302	40.448	0,017	4,0	0,46	0,39
4	113	570	0,33	4,1	5.740	70.317	0,017	7,0	0,79	0,68
4	180	908	0,33	4,1	9.144	112.009	0,017	11,1	1,26	1,08
4	268	1353	0,33	4,1	13.614	166.769	0,017	16,5	1,88	1,60
4	382	1928	0,33	4,1	19.405	237.708	0,017	23,5	2,68	2,28

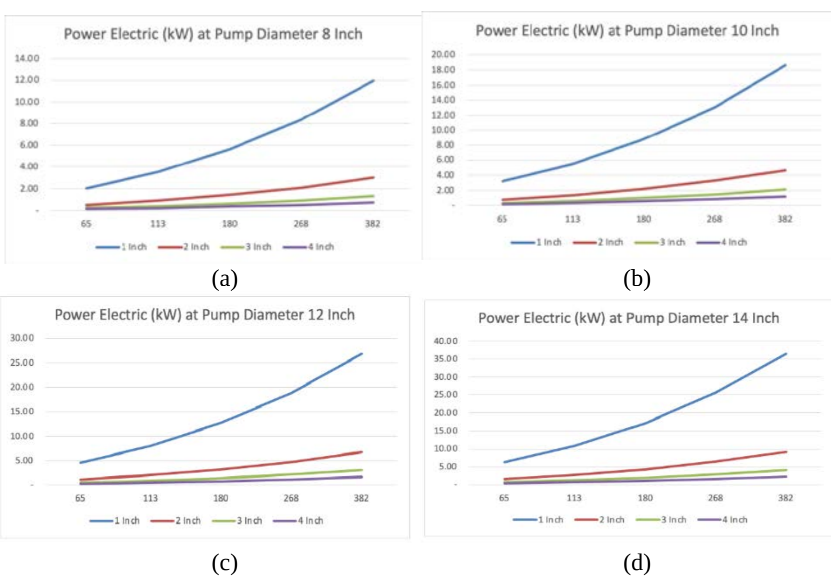

Fig. 3. The electric power produced, (a) the pump diameter is 8 inch, (b) the pump diameter is 10 inch, (c) the pump diameter is 12 inch, (d) the pump diameter is 14 inch

The constants used in the calculation are Pi (π) = 3.14, gravity 9.8m/s2 and sea water density = 1.030 kg/m3, the weight of seawater = 10.094 N/m3. While the assumptions used in the calculations are the wave is assumed linear, maximum wave height (h) = 2 m, wave period (T) = 6 s, turbine efficiency of 70 %, generator efficiency of 87 %, transmisi efficiency of 98 % . Piston diameter (D1) = 8 inch, 10 inch, 12 inch and 14 inch. Diameter output (Dout) = 1 inch, 2 inch, 3 inch and 4 inch. The length of the piston step = 100 cm.

Tabel 1, with pump diameter 8 inch, pipe diameter exit = 1 inch, volume pontoon 65 liters produce pontoon force 328 N, speed incoming water 0.33 m/s, speed water comes out 21.3 m/s, pressure piston 10,112 N/m2, pressure exit 647,164 N/m2, discharge 0.005 m3/s, head 64 m and turbine efficiency of 70 %, the turbine output is 2,398 watts. With generator efficiency of 87% and transmission efficiency of 98%, produces a turbine power of 2.38 kW, electric power 2.03 kW and generator 2.5 kW required.

Figure 3 (a) shows the amount of electric power generated with a pump diameter of 8 inches, variations in the outside diameter of 1 inch, 2 inch, 3 inch and 4 inch. Electric power with 1 inch outlet pipe produces the most electric power compared to 2 inch, 3 inch and 4 inch.

3.2 Discussion

The greater the volume of the pontoon, the greater the electric power produced, the smaller the exit pipe, the greater the electrical power produced. The larger the pump diameter, the greater the electric power produced.Although 1 inch in diameter produces more electrical energy, it has a weakness, namely that the outlet pressure is very large so there is a risk of leakage, or the unit is not strong.

4 Conclusion

The conclusion in this paper is:

- The greater the volume of the pontoon, the greater the electric power produced
- The smaller the exit pipe, the greater the electrical power produced.
- The larger the pump diameter, the greater the electric power produced.

References

1. N. I. Xiros and M. R. Dhanak, “Ocean Wave E 45.1.4,” pp. 1117–1145.
2. A. F. O. Falcão, “Wave energy utilization: A review of the technologies,” Energy Rev, vol. 14, no. 3, pp. 899–918, (2010).
3. S. Foteinis, J. Hancock, N. Mazarakis, T. Tsoutsos, and C. E. Synolakis, “A comparative analysis of wave power in the nearshore by WAM estimates and in-situ (AWAC) measurements. The case study of Varkiza, Athens, Greece,” Energy, vol. 138, pp. 500–508, doi: 10.1016/j.energy.2017.07.061. (2017)
4. S. Bozzi, R. Archetti, and G. Passoni, “Wave electricity production in Italian offshore: A preliminary investigation,” Renew. Energy, vol. 62, pp. 407–416, doi: 10.1016/j.renene.2013.07.030. (2014)
5. B. Robertson, J. Bekker, and B. Buckham, “Renewable integration for remote communities : Comparative allowable cost analyses for hydro , solar and wave energy,” Appl. Energy, vol. 264, no. February, p. 114677, doi: 10.1016/j.apenergy.2020.114677. (2020)
6. M. I. Bonovas and I. S. Anagnostopoulos, “Modelling of operation and optimum design of a wave power take-off system with energy storage,” Renew. Energy, vol. 147, pp. 502–514, doi: 10.1016/j.renene.2019.08.101. (2020)

7. X. L. Zhao, D. Z. Ning, Q. P. Zou, D. S. Qiao, and S. Q. Cai, "Hybrid floating breakwater-WEC system : A review," Ocean Eng., vol. 186, no. April, p. 106126, doi: 10.1016/j.oceaneng.2019.106126. (2019)
8. C. Liang, J. Ai, and L. Zuo, "Design, fabrication, simulation and testing of an ocean wave energy converter with mechanical motion rectifier," Ocean Eng., vol. 136, no. January, pp. 190–200, doi: 10.1016/j.oceaneng.2017.03.024. (2017)
9. R. I. Penelitian, Rencana Induk Penelitian 2020-2024 Universitas Negeri Jakarta. Lembaga Penelitian dan Pengabdian Pada Masyarakat UNJ, (2020).
10. K. Riset and D. A. N. P. Tinggi, "Riset Nasional Tahun 2017-2045 (Edisi 28 Pebruari 2017)," vol. 2045, (2017).
11. M. Subekti and V. K. Ladesi, "Ocean Wave Power Plant With Air Pressure."
12. P. Parjiman, M. Subekti, D. Daryanto, and M. Rif'an, "Simulasi Gelombang Laut Untuk Pembangkit Listrik Tenaga Gelombang Laut (PLTGL)," J. Teknol. Elektro, vol. 9, no. 2, (2015).
13. M. Subekti, "Performance analysis of ocean water power plant as a renewable power plant for leading regions, outermost areas, underdeveloped region," in Journal of Physics: Conference Series, vol. 1402, no. 3, doi: 10.1088/1742-6596/1402/3/033097. (2019)
14. M. Subekti and M. Rif, "Designing Power Wave AUTOMASS (Automatic Maritime Security System) As Effort to Prevent Illegal Fishing," vol. 2019, pp. 491–497, doi: 10.18502/kss.v3i12.4117. (2019)
15. S. Zheng, Y. Zhang, and G. Iglesias, "Concept and performance of a novel wave energy converter: Variable Aperture Point-Absorber (VAPA)," Renew. Energy, doi: 10.1016/j.renene.2020.01.134. (2020)