



# PERFORMANCE MODELING OF A WAVE ENERGY CONVERTER: PEMBANGKIT LISTRIK TENAGA GELOMBANG LAUT SISTEM BANDULAN ("PLTGL-SB")

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## ABSTRACT

In the design of a pontoon system as a floating supporting structure for a Sea Wave Energy Conversion System (Pembangkit Listrik Tenaga Gelombang Laut Sistem Bandulan or simply "PLTGL-SB"), the motion of the pontoon in the sea is a very important parameter. It is needed a pontoon with good motion characteristics, so that an integrated pendulum on it can steadily move with sufficient torque. In this study a 1:10 scaled model of tripod pontoon was used as a model of the prototype that has been installed in Tanjung Bumi, Madura, East Java. This paper describe the motion characteristics of the model which has been tested in a towing tank of Indonesian Hydrodynamics Laboratory (LHI) in Surabaya. The test also for collecting the test data in well-controlled condition for calibration and validation of numerical simulations. The pontoon motion measurement method using an optical tracking device that has digitally integrated. In order to obtain the pontoon responses the test was carried out on a regular wave with two variation on period which are 5 and 10 seconds and with wave height of 5.0, 10.0 and 20.0 cm. From the analysis, it was found that the tripod pontoon model has significant roll and pitch motions that suitable as a supporting structure for "PLTGL-SB".

**Keywords:** sea wave energy converter, a tripod pontoon, floating supporting structure, a towing tank, optical tracking device.

## INTRODUCTION

Ocean energy has become one of the sources of energy to be reckoned in the world today as a future clean energy. Theoretical global ocean energy resource is equivalent to 17, 400 Terra Watt hours/year [1]. As the biggest archipelagic country in the world, Indonesia has potential energy resources from its ocean. Theoretically, the potential of ocean energy reaches about 4,680 Giga Watt (GW). By considering the advancement of the existing technology and the constrains on marine transportation and seabed as well as environmental conditions, the number of this potential is reduced to some 61 GW. The Indonesia's ocean energy potential is shown in Table-1. That numbers are still fantastic because it is still greater than the amount of current power that generated by National Electric Company (Perusahaan Listrik Negara or simply PLN). With a consistent development, ocean energy is expected to have a significant role in increasing the national electrification ratio.

**Table-1.** Indonesian ocean energy resources [2].

	Theoretical Resources (GW)	Technical Resources (GW)	Practical Resources (GW)
Ocean Thermal	4,250	140	41
Tidal Current	290	72	18
Ocean Wave	140	8	2

The largest potential of Indonesia's ocean energy is Ocean Thermal Energy Conversion (OTEC) but this technology still waiting for the technology to be commercially established. Currently, Indonesia is still in the process of feasibility study in implementing OTEC technology. As for the utilization of OTEC, Indonesia still has to rely on foreign technology. On the other side, other ocean energy potential such as wave energy is more realistic to be developed with existing established technology.

Although still relatively new, the technology conversion of ocean energy has been developed by many countries and there's even at commercial stage. Indonesia is also already doing a lot of effort in developing the



technologies of ocean energy conversion. Some of them are already in the prototype stage. These technologies might be expected to be utilized as Indonesia ocean energy frontier in the future. Some research institutions from government and universities in Indonesia have already developed some various ocean wave energy conversion technologies. "PLTGL-SB" wave energy conversion technology is one of the technologies that have been developed by the Research and Development Center of PLN in cooperation with Institut Teknologi Sepuluh Nopember (ITS), Surabaya. A prototype of "PLTGL-SB" has been installed as a sea-trial in water of Tanjung Bumi, Madura, East Java (Figure-1). Even so, the understanding of the whole system remains limited, especially for the performance of the device.



**Figure-1.** "PLTGL-SB" prototype has been installed in Tanjung Bumi water.

This paper presents the result of experimental work, i.e. towing tank test, to predict performance of the pontoon system. The test aim is to provide reliable data from well-controlled laboratory conditions for the calibration and validation of the numerical simulations [3]. Moreover, this kind of test may be helpful to understand the data collected in Tanjung Bumi sea trials as well as to explore the scalability of the "PLTGL-SB" [4].

## EXPERIMENTAL DESCRIPTION

Experiments were carried out in the towing tank of the Indonesian Hydrodynamics Laboratory (Laboratorium Hidrodinamika Indonesia or simply LHI) at Surabaya. The tank has 11 m wide, 234.5 m long, 5.5 m deep, and it is equipped with a wavemaker for generating regular and irregular waves. The maximum wave heights are 0.5 m with periods of 0.5 – 3.5 sec and direction of 0° and 180°. The integrated components for this experiment included motion tracking cameras, LED markers and data acquisition.

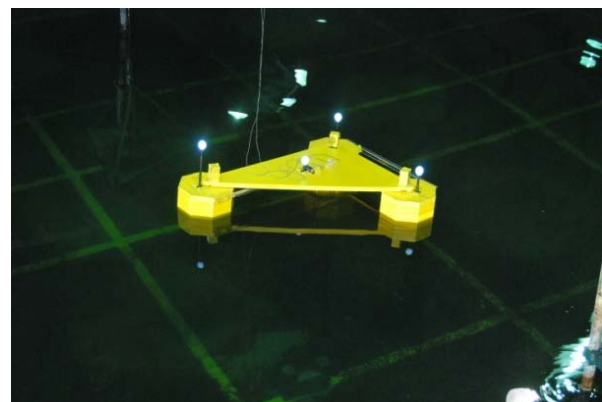
The wave energy converter developed in this work were oscillating bodies designed to capture energy in roll, pitch and yaw motions and convert it directly into high-torque rotary motion using generators. As illustrated

in Figure-1, the device is comprised of three pontoon or moving bodies connected by rigid triangular deck. The moving bodies, then named pontoon tripod, has an octagonal shape to permit large amplitude motion to extract energy from the waves [5,6]. At full scale the pontoon diameter is approximately 3 m respectively and its draft from the surface to its lowest point is 1.5 m.

In order to reliably test and accurately characterize the scaled hydrodynamic model of "PLTGL-SB" model, a wave tank testing system was developed. Wave tank tests have been carried out on a 1/10th scale model of the "PLTGL-SB" device to evaluate its performance. The model is shown in Figure-2. Froude scaling has been used to obtain the model values. Table-2 shows the Froude scaling of model and hydrodynamic parameters.

In order to estimate device performance, a motion tracking system was used to track the moving bodies using three attached LEDs (see Figure-2). These LEDs are tracked with carefully positioned cameras. During wave action, the system of markers and cameras allows the motion of the marked components to be mapped and translated into  $x$ - $y$ - $z$  coordinates for motion analysis.

The roll, pitch and yaw of the device were measured for various regular wave characteristics selected based on the result of decay test in the wave tank. Decay tests have been carried out to measure PLTGL-SB's natural frequency. In the decay tests the device is pulled in still water toward maximum displacement and then released while recording the time history of its position. Table-3 shows the variation of regular wave characteristics selected for the experiments in the wave tank. Roll, pitch and yaw are angular motion around the  $x$ -axis,  $y$ -axis and  $z$ -axis, respectively.



**Figure-2.** Photograph of the 1:10 scale "PLTGL-SB" device in a wave tank. LEDs for motion tracking can be seen attached to the vertical posts on the pontoon of "PLTGL-SB".

**Table-2.** Froud scaling of model and hydrodynamic parameters [7].

Quantity	Prototype	Model	Scale Factor
Mass	$m_p$	$m_m$	$\lambda^3$
Wave height	$L_p$	$L_m$	$\lambda$
Wave period	$T_p$	$T_m$	$\lambda^{1/2}$
Frequency	$L_p$	$L_m$	$1/\lambda^{1/2}$
Angle	$Deg_p$	$Deg_m$	1

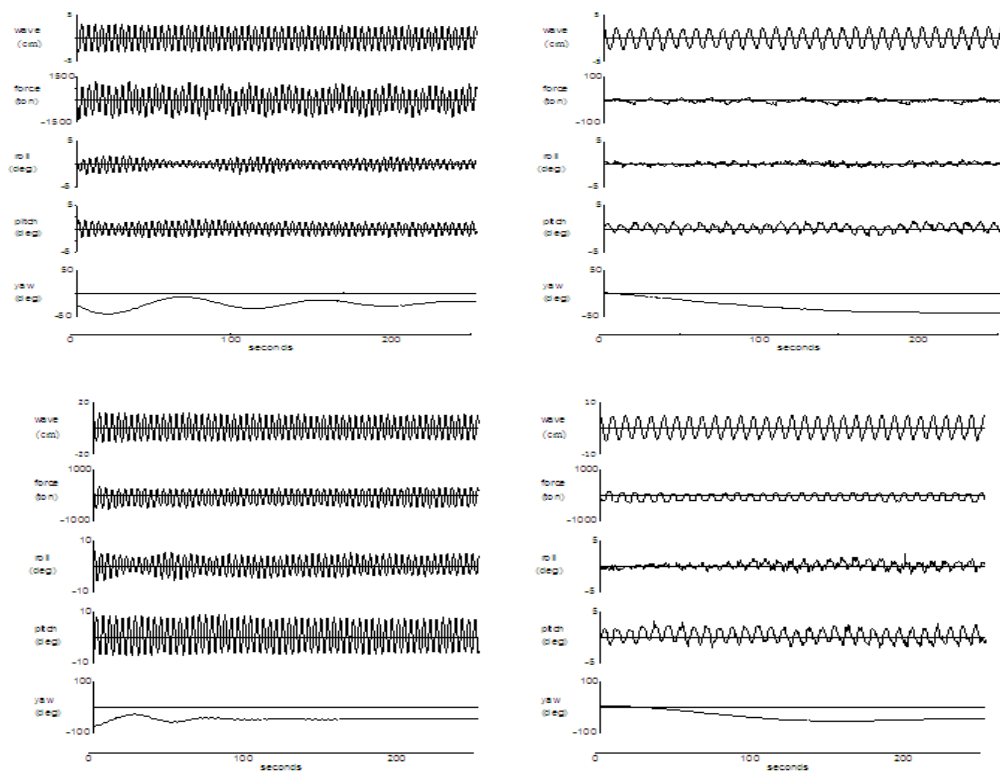
**Table-3.** Experimental conditions - regular waves.

	Variation of wave height and period			
	#1	#2	#3	#4
Wave height (cm)	5.0	5.0	20.0	10.0
Period (s)	5.0	10.0	5.0	10.0

## RESULTS AND DISCUSSIONS

The results of the test shown with mean, standard deviation and amplitude of the device's motions, as shown in Table-4 and Table-5. Device's motions in roll and pitch more influenced by wave height than wave period. While yaw motion more influenced by wave period than wave height. Figure-3 shows a comparison of

the device's motions in roll, pitch and yaw as measured in the tank for each variation of wave height and period for the regular wave. It can be seen that yaw motion are smaller than those under the regular waves. It is quite expected because the roll and pitch motions expected to much larger and effective in moving "PLTGL-SB".

**Figure-3.** Motions characteristic of "PLTGL-SB" model in a regular wave.

**Table-4.** The motions of the device in regular waves with period of 5 s.

Motions (deg)	Wave height 5.0 cm		
	Mean	St. deviation	Amplitude
Roll	0.004	0.87	1.14
Pitch	0.097	1.05	1.42
Yaw	-22.8	8.04	8.88
Motions (deg)	Wave height 20.0 cm		
	Mean	St. deviation	Amplitude
Roll	0.12	2.97	3.99
Pitch	0.52	4.95	6.82
Yaw	-43.7	5.76	4.27

**Table-5.** The motions of the device in regular waves with period of 10 s.

Motions (deg)	Wave height 5.0 cm		
	Mean	St. deviation	Amplitude
Roll	0.07	0.34	0.24
Pitch	0.30	0.74	0.77
Yaw	-30.8	11.83	14.47
Motions (deg)	Wave height 10.0 cm		
	Mean	St.deviation	Amplitude
Roll	0.08	0.64	0.52
Pitch	0.41	1.23	1.16
Yaw	-34.4	17.62	20.13

## CONCLUSIONS

The experimental findings of controlled motion of the "PLTGL-SB" device, in regular waves, has led to an improved understanding of PLTGL-SB's interaction with incoming waves. Based on the results of the test, it is found that a large drift in roll and pitch may happen at a wave height of 20 centimeters with a period of 5 seconds. It is also found that yaw motion is small and it is desirable. That means the three mooring lines configuration may be preferable to minimize the yaw motion. Catenary mooring lines also preferable to keep the performance of the device in roll and pitch motion.

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