Wave Energy Prototype (WEP) Designs for Renewable Energy System

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***Abstract*—Energy crisis had been aware worldwide. Public transportation such as MRT became popular and internet community in 24 hours online could possible leads to insufficient electricity to the remote community. Electrical taarif of each country had gone through revised and consumer facing new cost of living. Nowadays, renewable energy had become popular research replacing fuel fossil and hydropower from lakes and river. Ocean's wave is one of the natural resources as renewable energy for the country surrounded by sea. Peninsular Malaysia had it natural potential for wave's energy esurrounded by South China Seas, Straits of Malacca and Straits of Tebrau. Through Hydraulic and Instrumentation Laboratory testing at National Hydraulic Research Institute of Malaysia (NAHRIM) undered program of hydraulic's energy harvesting, initiative of innovation had been in progress studies in wave energy convertion from the surface of ocean water. Five design had been tested in order to see the performance of wave energy prototype (WEP) in generating electric. In this study, material and physial structural had been gone through scenarios of testing in order to determine the WEP possible performance factors. The overall physical design had been founded as a prime factors for the construction of WEP in order to dissipated more kinetics energy from the water wave and converting into electric. Real on site testing had overcome the significant findings that similar result of WEP performance. Studies found that WEP could possible dissipated energy from water wave producing Direct Current (DC) and possible to be convert into alternatives current (AC).**

***Index Terms*—Energy harvesting, electrical taarif, renewable energy, wave energy, dissipated energy, alternative current.**

I. Introduction

Energy will continue increasing over the years ahead, to meet the needs of consumption patterns and economic growth, given interuption of natural resources each country. Today, renewable energy had been given attention around the world in order to encounter climate change impact by achieving zero carbon disscharged for next generation.

According to United Nation, on April 2010, about 1.5 billion have no access to electricity. More have access only to unreliable electricity networks. At about 1.8billion in the region use solid fuels for cooking and no using electrical household for cooking. WHO estimates that more than 1.45 million people die prematurely each year from indoor air pollution caused by burning solid fuels without using electric cooking burner [1]-[4]. Malaysia have coastaline 4,675kilometers. Ocean tide is a natural resources and it create natural gravitational effect in a day. Thus, given point that Malaysia coastaline have it natural resources for electrical harvesting [5]. Every years, some placed at Malaysia east coast, had frequent happen coastal erosion due to strong ocean wave forcing along the coastaline [6], [7].

Ocean wave is an energy contain tremendous energy potential. Many designs of wave energy prototype (WEP) had been made to extract energy from the surface motion of ocean waves [8]. There are variety of technologies of WEP in differences technical concept and design to capture the energy from ocean waves [9]-[11]. Some WEP demonstrated at commercial scales, designed to be installed either at nearshore or offshore or away from offshore. Around the world, basically, there are four category of WEP, which are point absorbers, attenuators, overtopping devices, and terminator [12], [13].

Initiatived by National Hydraulics Research Institute of Malaysia (NAHRIM), under Programme of Hydraulic's Energy Harvesting, since 2015, NAHRIM had begun some research and development on hydraulics energy harvesting in dedicated ISO9001:2008 laboratory, testing new invention WEP using electromagnet conceptual to harvest electricity. In this study, four WEP will be presented the invention in order to have a renewable energy in Malaysia.

II. Objectives and Scope of Study

The objectives of this research is to study suitable design of wave energy prototype for alternative electricity generator of coastline and island community.

As to fulfill the objectives, research scope had covered four (4) WEP design's conceptual which are (i) vertical movement forces design, (ii) swinger movement forces design, (iii) horizontal magnetic forces design; and (iv) magnetic polarity forces design; All WEP will be tested inside the water basin before the real test at selective coastline.

III. Methodology

There will be four (4) designs of WEP. All WEP design had the same concept of electromagnetic for electricity. Previous study that electricity could be exist from the actities of magnet movement along the copper coils. In this study, all WEP consist of: (a) floatable device system – to dissipate kinetics energy continously from simulated water wave; (b) electromagnetic system - for converting the kinectics energy

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to electricity currrent; and (c) electrical system – to manage electricity output such as an ammeter, LED light, AC-DC converter, light sensored and others, according to WEP design.

Material for floatable device system will be using hollow PVC pipes, attached with joints and PVC adhesive in order to built the conceot of bouy. Any possible leaking leads to the submergence should be avoided. Some standard bouy will be used as safety features and being observed, in all testing scenario. The most attention material in this study is the electromagnetic system. All WEP design in this study will be using basic electromagnetic system that are magnet with certain capacity, a numbers of copper coils wound outside of hollow PVC pipes illustrated in Fig. 1. As to avoid the system being wet, rise will be attached about 500mm from floatable system bases.

Fig. 1. Electromagnetic system applied in all WEP design.

Each of the WEP carries the same testing procedure at the same testing venue, using water basin located inside the Port and Harbour Wave Basin Facilities (PHWBF) of NAHRIM's Hydraulic and Instrumentation Laboratory with ISO9001:2008 certified operational as Fig. 2. Setting of simulated water wave at PHWBF are: (a) wave height, (W_H) at 0.65meter; (b) wave frequency, (W_F) at 0.1Hertz; and with water level (WL) of 0.60 meter.

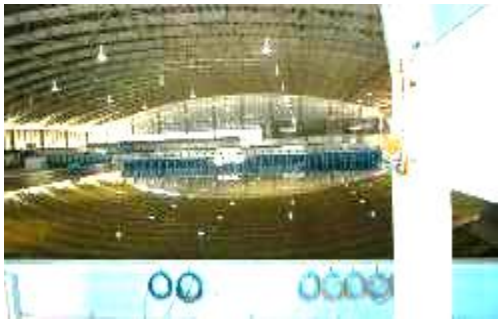


Fig. 2. Port and Harbour Wave Basin Facilities (PHWBF) of NAHRIM's hydraulic and instrumentation laboratory with ISO9001:2008 certified.

The first testing of WEP design had started tested in January 2015 and continously tested with different WEP design till December 2016. Below are the methodologies of each design of WEP:

A. *Vertical Movement Forces Design (VMFD)*

The design material consist of: bicycles dynamo, bicycle gears and chain, mild steel support frame (MSSF), floatable structures, led light, simple wiring for electricity measurement and electrical instrument devices. All design's component were assembled within the MSSF as illustrated in Fig. 2. The VMFD will be submerged in the PHWBF and wave will be generated for some testing scenario: (a) WEP Structural Stability (b) WEP Energy Dissipation and (c) WEP Overall Perfomance.

B. *Horizontal Magnetic Forces Design (HMFD).*

The design material consist of: 1 inches Hollow PVC Support Frame (1HPSF), nylon rope, magnet bars and copper coils as illustrated in Fig. 3. All design's component were assembled within the 1HPSF as illustrated in Fig. 3. The VMFD will be submerged in the PHWBF and wave will be simulated for some testing scenario: (a) WEP Structural Stability (b) WEP Energy Dissipation and (c) WEP Overall Perfomance.

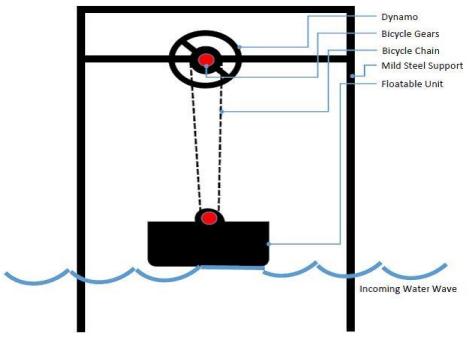


Fig. 3. WEP design of VMFD.

C. *Swinger Movement Forces Design (SMFD)*

The design material consist of: 1 inches Hollow PVC Support Frame (1HPSF), nylon rope, additional floatable balss, pendulum, magnet bars and copper coils illustrated in Fig. 4. All design's component were assembled within the 1HPSF as illustrated in Fig. 4. The SMFD will be submerged in the PHWBF and wave will be simulated for some testing scenario: (a) WEP Structural Stability (b) WEP Energy Dissipation and (c) WEP Overall Perfomance.

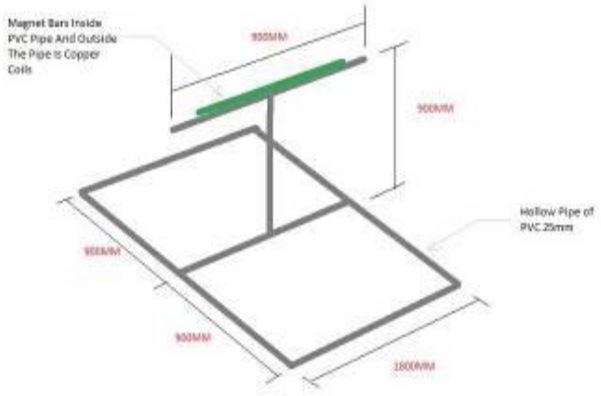


Fig. 4. WEP design of HMFD.

D. *Magnetic Polarity Design (MPFD)*

The design material consist of: 2 inches Hollow PVC Support Frame (2HPSF), 2 kilogram of artificial reef of WABCORE, capacitors, nylon rope, magnet bars and 2HPSF

as illustrated in Fig. 5. The MPFD will be submerged in the PHWBF and wave will be simulated for some testing scenario of: (a) WEP Structural Stability (b) WEP Energy Dissipation and (c) WEP Overall Perfomance. Site test will be carried out at Pantai Sepat, Kuantan, Pahang for improvement.

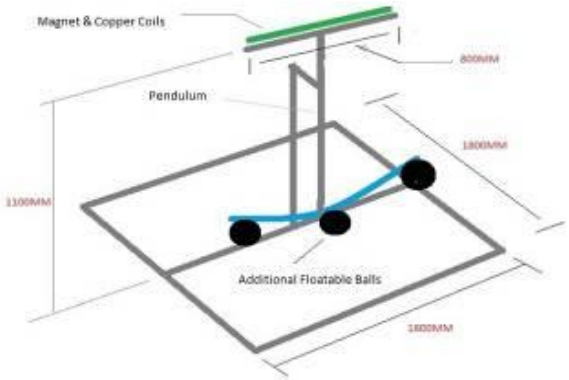


Fig. 5. WEP design of SMFD.

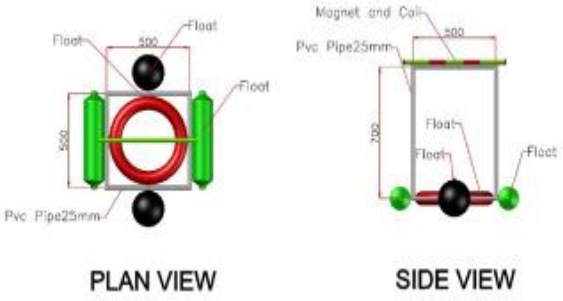


Fig. 6a. WEP design of MPFD (Plan/Side View).

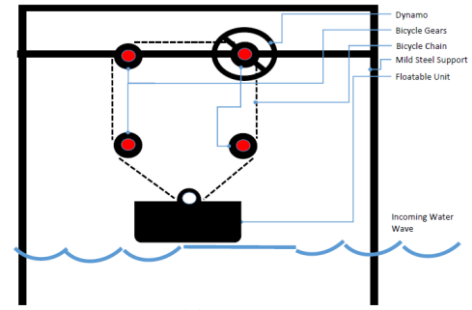
Fig. 6b. MPFD laboratory testing inside PHWBF.

Fig. 6c. MPFD coasal testing at pantai sepat, kuantan, pahang, Malaysia east coast.

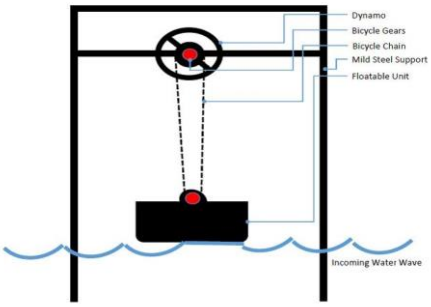
IV. Results and Discussion

The type of waves in this study is regular waves of Johnswap Equation with constant forces of wave frequency. Irregular waves had been tested once and resulting total mechanical operational failure for all WEP design. Below are findings of each WEP designs:

A. Vertical Movement Forces Design (VMFD)

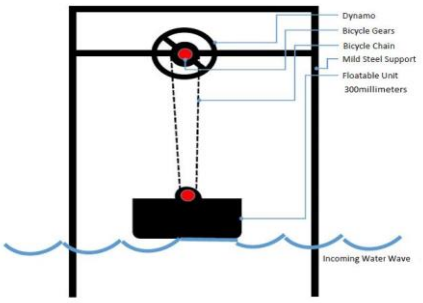


(a)

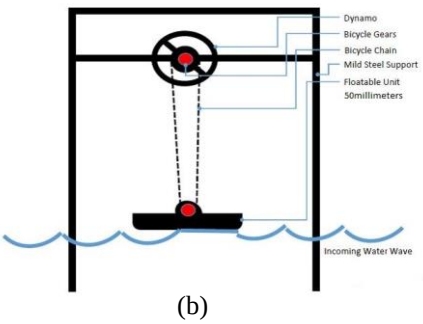


(b)

Fig. 7. The failure and succes design during the VMFD testing between all gears positioning: (a) with 4 gears positioning (b) 2 different gears positioning.



(a)



(b)

Fig. 8. The option design of the VMFD's base: (a) 300millimeter thickness) (b) 50millimeter of surfing board type.

The testing scenario shows that the VMFD had great structural stability. However VMFD does not dissipated energy at all. From observation, the floatable unit of VMFD does not move frequently. The movement was not in vertical

axial properly that lead to less rotation of the VMFD's dynamo. The dynamo does not rotate 360 degree continously in split second. Thus, does not produce electricity at all. Observation found that, the failure cause of VMFD are mostly at mechanical system failure, which involved the component of floatable unit, bicycle gears and bicycle chain. Among the three component, floatable unit is the crucial part in dissipating the energy from the wave. Some modification of floatable unit design had been go through but does not performed better results. Less oppurtunity captured on the changes spesification of bicycle gears and bicycle chain. In this study, the size, type and numbers of gears and chain does not influence the VMFD. Some floatable unit designs that had been tested shows in Fig. 7.

B. Horizontal Magnetic Forces Design (HMFD)

The HMFD shows weak structure and had a little stability during the testing. From the selected laboratory testing scenario, the energy from wave had been dissipated by HMFD for sometime and prooven the concept of energy harvesting from water wave. Observation found that the HMFD movement is not frequent in order to generate electricity. Some improvement had been suggested to add on additional elements in order to increase the HMFD movement.

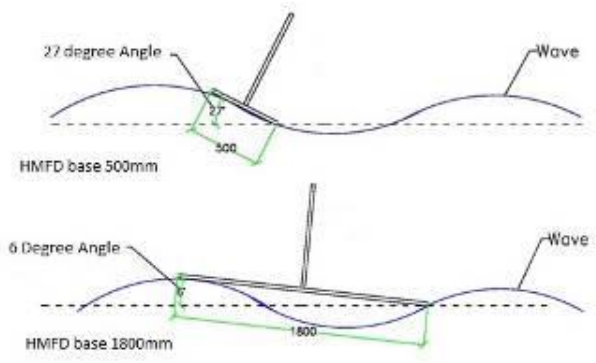


Fig. 9. The HMFD base of 1800mm and 500mm given different degree angle of movement.

C. Swinger Movement Forces Design (SMFD)

The SMFD is the HMFD improvement. Due to frequentless of HMFD movement. The additional floatable sphere does dissipated much energy higher a bit from HMFD. The SMFD had light up the installed LED light once a while, in frequent than HMFD. The SMFD structure was stable except the overall floatable design. The testing secnario found that the movement of SMFD does not generate a lot electricity. However, the concept of improving swing motion had given advantages to further study. The SMFD movement had succesfully prooven that by increasing movement of the magnet could possible increasing in generating electricity. However, the increment of the electricity had could not be further due to the capacity of magnet size and copper coils. There are further study to be concerned to upgrade the SMFD design in terms of magnet capacity, copper coils structure and numbers of movement in time.

D. Magnetic Polarity Force Design (MPFD)

The MPFD design is basically continued from the SMFD design. The MPFD design focused on the changes on the components of magnet installation in order to increase magnet movement that could possible lead to electricity production. The MPFD resulting stable design in energy dissipation. Electricity recorded maximum of 5 watt stored into capacitor. Some anchoring technic have to be reviewed in order to assure the MPFD's body movement.

From this study, the MPFD had potential to be further study. This MPFD had meet the study objectives and potential to dissipating energy from ocean wave. Further scope of study potential are such as preparation for actual on site testing, anchoring between the MPFD prototype to the deployment point and the possiblity electricity convertion from Direct Current (DC) into Alternatives Current (AC).

TABLE I: THE PERFORMANCE OF MPFD

Wave Height Simulated (Meter)	Period Of Charging (minutes)			
	1	10	20	30
	Power Bank Charged (Volt)			
0.15	1.19	3.18	4.69	5.22
0.17	1.10	3.25	4.03	4.40
0.2	0.70	1.55	2.13	2.53
0.23	0.80	1.50	1.91	2.27
0.25	0.72	1.22	1.57	1.83
0.27	0.50	1.02	1.49	1.74

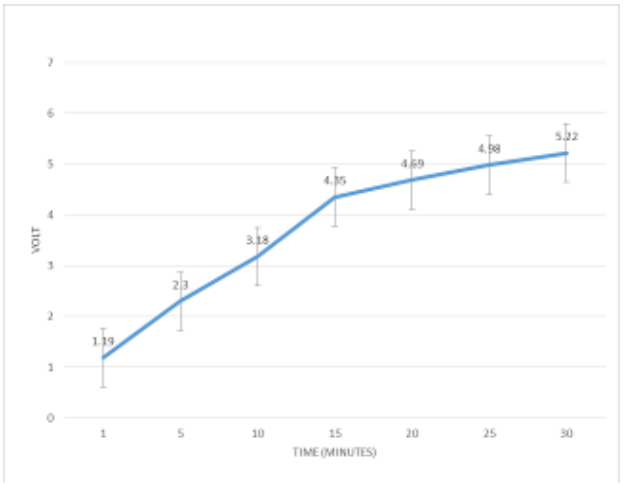


Fig. 10. The performance of MPFD power charging into the capacitor.

V. CONCLUSION

In this study, it shows that the WEP design could be further study for efficiency improvement. All five prototypes design had discover that water waves could be dissipitated electricity. The main factors of the WEP design which are material selection and size. From the study that, size should not be oversized and undersized. Others main factors are floatable structure design, suitable magnet strenght, the magnet movement frequency and anchoring technics.

Using a large magnetic field could increase electricity, however, it will produce heat damaging the component lifespan. Further study could be done in order to reducing heat development. In this study, only one prototype had been

Forces Design (MPFD). The MPFD had meet the objectives of the study. The MPFD found as suitable design of wave's energy prototype (WEP) for alternative electricity generator, brnrfit fot the community of coastline and area in Malaysia. Further study could be done for looking forward the others parameter of testing such as robustness, maintenance for parts replacement after few years, economic selection for non corrosive material, overall economical design, affordable cost and could be use by the Malaysian's society lives along the coastaline and island as to prioritising Malaysian.

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