Hydraulic Experimental Study for a Direct Electro-Magnetic Wave-Power Conversion (DEMWPC) on TLP System

Hsien-Hua Lee¹ C.-C. Cheng²

¹ Professor, Department of Marine Environment and Engineering, National Sun Yat-sen University, Taiwan
² Department of Marine Environment and Engineering, National Sun Yat-sen University, Taiwan

ABSTRACT

In this study, a new type of wave-energy converting system is developed and installed in an offshore platform structure to take the advantage of stronger motion of the platform subjected to waves. It is a device by utilizing the electro-magnetic interactions to generate electricity directly. This system was developed due to the consideration that the efficiencies of power generated from most wave-power converting system are not significant because the power generator is driven through a mechanical system including transmission process that may consume energy. For a direct electro-magnetic power generating system, since most mechanical transmission processes are lacked, the power loss through mechanical transmission can be saved and therefore, the power-converting efficiency can be elevated. The other advantage for a direct electro-magnetic power-converting system is that without a turbine in the system, the weight can be reduced and two directional motions for surging and heaving for an offshore platform system can be both utilized in power-conversion. In order to understand the feasibility of the device applied to an offshore platform system, a set of scaled down models of the direct electro-magnetic wave-power converter were built and installed in a hydraulic testing tank. A series of experimental tests with various wave parameters were carried out to study the efficiency of power generated from the proposed wave-power converting system. It is found that corresponding to various parameters of the incident waves, the performance of individual power converter is varied. When the wave parameters and dimensions of the experimental platform model are constant, in terms of the efficiency of power generation corresponding to model generator, the location of the generator device and its associated responses turn out to be the most significant elements.

Keywords: Offshore platform system; Wave power conversion; Water tank experiment; Direct electro-magnetic wave-power conversion system (DEMWPCS)
效提升發電效能，在平時浮台基本使用時，能達到自給自足的目標；三則因系統在外海，在平時維護及保養上必須具有相當的方便性。

本系統利用電磁發電原理，以直接電磁作用之方式來發電，主要之考量為，一般發電機裝置中除了電磁作用之電力產生部分之外，主要包括了驅動電磁刷轉軸之葉片系統，該葉片系統配合驅動之能量來源而有構造及材料上之區別，如風力、水力、其他流體驅動等。然就波能轉換之利用而言，不似一般流體具有固定方向或常時穩定之作用，波浪之行為為不同方向之相對運動為主，如上下、左右或前後等。因此，如果將傳統以葉片帶動之發電機型式應用於波浪發電將具有相當之拘限性，如效率降低，發電及驅動源穩定性差，如應用於海上浮式平台甚至將有載重問題。當然發電機葉片的旋轉，齒輪帶動或其他間接式傳動系統也將消耗相當之能量；另外則是驅動時必須達到最小之驅動源，如流速或風速需求。而這些問題，對於直接式電磁發電系統則都變成次要，甚至可不予考慮。基於以上所述之優點，本研究中以造波水槽實驗之方式，設計了一系列之直接電磁式波浪發電系統縮尺模型，裝置於一繫纜式海域浮式平台上，施予不同週期、波高之波浪作用，以檢視系統在不同波浪條件作用下，其發電功率及平台之運動行為。經整理試驗數據並分析後發現，本直接電磁式發電系統確實能將波浪能轉換成電能。電能轉換除了與浮台形式、尺寸及入射波浪之各種參數密切相關之外，發電機裝設之位置及其裝設於平台所使用之材料及構造形式為最重要之影響因素。

關鍵詞：海域平台系統、波能轉換、造波水槽實驗、電磁式波能發電系統

1. Introduction

Recently, due to the dramatic requirement of petroleum from new developed countries, the price of crude oil has reached skyrocketing height. The exhaustion of crude petroleum in the near future becomes a more realized fact now. Therefore, the development of new energy, particularly reproducible energy such as solar energy, wind energy and ocean energy et al. gets higher and higher attention and in many countries, the green energies have been adapted to a regular power grid system. For the time being, the exploitation of wind energy and solar energy have been more and more matured in terms of the efficiency and safety but however, for the exploitation of ocean energy, there is still a long way to go.

The development of wave-energy conversion system has been lasted for decades and all kinds of model were developed in terms of various power-converting mechanisms [1, 2, 6, 7, 9]. The air-power converting system by utilizing the air confined in a wave oscillation chamber either moored or installed on the seafloor is one of the most popular systems [3, 8]. Some other wave-power converting systems use the motion of the water wave to drive mechanical members directly to generate electricity such as the snake system and the vibrating stick system. The one by using water sloshing motions to drive a turbine system was also developed lately [4, 5]. All of these wave-power converting systems have their advantages and drawbacks as well.

In this study, a new type of wave-energy converting system is developed and installed in an offshore platform structure to take the advantage of strong motion of the platform subjected to waves. The floating platform system has been extensively applied to ocean exploitation, particularly, a tension-leg platform (TLP) system in deep water. In this study, a new type of wave-energy converting system is developed and installed on an offshore platform structure. It is a device by utilizing the electro-magnetic inductions to generate electricity directly. This system was developed due to the consideration that the efficiencies of power generated from most wave-power converting system are not significant because the power generator is driven through a mechanical system that may consume energy during the transmission. Cases such as power-generators driven by mechanical turbines are the most popular ones, where turbines are either driven by water flows or wind flows. Due to the rotational friction and transmission connections of various gears in the mechanical system, unless the driving power is
large enough, usually, the efficiency of power converted from the source media (winds, water flows, waves and etc.) will be low. In most cases, a minimum velocity of source flow is required for the application otherwise, the source power may not large enough to drive the turbines or fans. However, for a direct electro-magnetic power generating system, since most mechanical transmission processes are lacked, the power loss through mechanical transmission can be saved and therefore, the power-converting efficiency can be elevated. The other advantage for a direct electro-magnetic power-converting system is that without a turbine in the system, the weight can be reduced and two-way motions of surge and heave for an offshore platform system can be both utilized in power-conversion.

In order to know the feasibility of the device applied to an offshore platform system, a set of scaled down models of the direct electro-magnetic wave-power converter (DEMWPC) were built and installed in a hydraulic lab. A series of experimental tests with various wave parameters were carried out to study the efficiency of power generated from the proposed wave-power converting system. It is found that corresponding to various parameters of the incident waves, the performance of individual power converter is varied. When the wave parameters and dimensions of the experimental platform model are constant, in terms of the efficiency of power generation corresponding to model generator, the array of the generator device and its responses to the platform system are the significant elements.

2. System Introduction

A new type of wave-energy converting system developed in this study is presented in Fig.1, where the system includes three major parts, namely, the floating platform and its associated pontoon and column structural members, the generators and its associated supporting posts, and the mooring cable system. To make sure the platform will always direct to the direction of incident waves, which may ensure a maximum responses subjected to incident waves and of course, the possible maximum generation of the electricity, a rudder-board is installed underneath the platform. Besides, since the platform may turn into the direction of incident waves that is arbitrary, the traditional multi-moored system is abandoned and substituted by a single-moored system, which will allow a 360 degree turn for the platform when a universal connections are installed between the mooring system and platform.

Fig.1 Schematic view of DEMWPC system installed on an offshore platform (serial array)

It is also noticed that the generators installed on the platform are lined into a serial array, one front and the other at the back. However, a parallel array is also built and tested in order to know the effectiveness for various array systems.

3. Water Tank Testing Setup

The test was performed in the water tank experimental lab, where testing set-ups consist of water tanks, data acquisition system and hydraulic-power controlling systems. A schematic view of the testing set-up is presented in Fig.2. The testing water tank is 30 m long, 1 m wide and 1.2 m high. At one end of the tank a piston-type hydraulic wave maker is installed while the other end of the tank the energy dissipation device is installed to reduce the reflecting waves. The testing water tank is capable of making a wave of 2.8 seconds long of period and 0.12 m high of amplitude, which is located in the hydraulic laboratory of Dept. of Marine Environment and Engineering, NSYSU. The data acquisition facilities include the wave meters of capacitance type to measure the wave height of water, signal amplifiers of multi-channel, load-cell measuring for the tension force of the mooring cables, accelerameters, power suppliers and computers. For the motion of the platform system, a high-resolution video
camera of CCD high-speed recording system was set-up in front of the water tank to catch the motion of the floating platform under test.

Parameters other than the testing model itself are variations of testing conditions such as the period and height of the incident waves applied to the testing model DEMWPC. In order to examine the applicability of the electricity power generated from the DEMWPC system and relationships to the testing environmental conditions, results including motions of the floating platform, acceleration of the DEMWPC and electric voltages generated from the system were all studied.

Fig. 2 A schematic view of the testing set-up

4. Testing Results and Discussion

4.1 Motion of the Floating Platform

The platform applied to DEMWPC system is strained by a single pre-stressed tether designed to allow a universal rotational motion for the platform subjected to incident waves from arbitrary direction. Typical motions observed in two dimensional water tank experimental lab such as surge, heave and pitch are presented in Fig.3 for serial array of DEMWPC devices. An orbit of platform circulating in waves is also presented in Fig.3 that is obtained from the simultaneous combination of surge and heave.

It is noticed that a rather concentrated motion of the platform was found as was shown in the orbit diagram. Fig.4 shows the same motions of the platform subjected to same waves while the array of DEMWPC devices is parallel. Interestingly, the response of the platform has a larger expansion in surge than in heave motions. This phenomenon was observed for the other water tank experiment when the same single mooring scheme was applied to a TLP system but however, this phenomenon was expected to happen to a serial array of DEMWPC devices due to the unstable motion of the platform in surge.

A longer period of 1.45 second of wave was applied to the platform installed with a parallel array of DEMWPC devices. Fig.5 shows the motions of the platform response in surge, heave and pitch. A similar orbit obtained from surge and heave was drawn for comparison. Unlike the previous case, it is found that the response of the platform is concentrated similar to the motion of a serial array case when the incident wave has longer period.

Fig. 3 The platform motions of Surge, heave and pitch and the orbit diagram (H=65 cm, h=10 cm, T=1.2 sec, serial array)

Fig. 4 The same motions of the platform subjected to same waves while the array of DEMWPC devices is parallel.

Fig. 5 The response of the platform is concentrated similar to the motion of a serial array case when the incident wave has longer period.
The responses of the platform installed with serially arrayed DEMWPC devices is also presented in Fig.6. Compared with Fig.5, where the generators were arrayed in parallel, probably due to the same wave conditions that were applied to the platform in the water tank, significant difference was not fund in these two figures. It also indicates that the basic behavior of the platform might not be influenced by the array of installation of the generators as long as their positions are confined in certain space of the platform.

4.2 Voltage from Various Array of Generator

The generated voltage of electricity from the DEMWPC devices was plotted in Fig.7, where for the same wave conditions, the voltage generated from both arrays of generator was presented. For the case of period of 1.20 seconds as shown in Fig.7, it shows a very close pattern in both the voltage amplitude and fluctuations, even though the voltage from serial array (dot-line) seems to be a little smaller than the one from generators of parallel arrayed.

When the period of applied incident waves gets larger such as 1.45 seconds to the same testing model in this study, the voltage was also obtained through data acquisition system and shown in Fig.8. It was found that unlike the case where 1.2 seconds wave was applied, the voltage generated from the serial arrayed generators is much larger than that from parallel arrayed generators. This difference can not be observed from the responses of the platform such as those presented in previous section. It has to be related to the motion of the generator itself.
Fig. 8 Voltage of various arrays of generators induced from waves, H=65 cm, h=10 cm, T=1.45 sec

5. Conclusions

In this study, a new type of wave-energy converting system is developed and installed in an offshore platform structure to take the advantage of stronger motion of the platform subjected to waves. It is a device by utilizing the electro-magnetic inductions to generate electricity directly. Scaled down models of DEMWPC system with various arrays of generators were built and installed in a water tank in laboratory to perform a hydraulic test. According to the testing results some important conclusions are drawn as follows.

1. The new type of wave-energy converting system (DEMWPC) developed in this study can successfully generate electricity and proved to be feasible to install on an offshore floating platform system.

2. Under the same testing conditions such as same wave height and period of the wave, the motion of platform basically shows a similar response pattern no matter the array of the generators are varied differently. The orbit of the motion for the platform generally follows a regular oval shape which is usually found for multi-strained platform system.

3. Both the wave height and period have influence on both the responses of the floating platform and the performance of the DEMWPC system. However, the responses of the platform seem to be not significantly related to the performance of the DEMWPC system.

4. To further understand the performance efficiency of a DEMWPC system, the responses of the generator itself must be considered and the response of interactions between the generator and the platform is also important.

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