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The Study of Overtopping Wave Energy Converter Control and Monitoring System

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Abstract : This paper describes the control and monitoring system for OWEC (Overtopping Wave Energy Converter) which shows the characteristic of power stabilization in overtopping wave energy converter system. Overtopping waves generates different water pressure and the turbine is rotated by this pressure. As a result, overtopping wave energy converter is able to convert wave energy into electricity. Small size of overtopping wave energy converter is developed to simulate the control monitoring system which is able to control power generation and also monitor the system condition. The result shows the reduction of fluctuation from the overtopping wave energy system by the developed control monitoring system. In addition, the DB(Data Base) of test results are contributed to the research and development for OWEC

Key words : Overtopping Wave Energy, Renewable Energy, Monitoring System, DC/DC Converter, LabVIEW

1. Introduction

Recently, issues related to global warming has been raised, blaming deforestation and the burning of fossil fuels for the warming effect. In addition, since the oil and gas prices have been increased, the countries' cost on imported fossil fuels has also been increased. As a result, Korea government has published a slogan of 'low carbon green growth' and committed to invest more in renewable energies and green technologies, hopping it would solve the problem we are facing.

There are many renewable energies such as solar, wind and wave energy. In case of wave generation, our country has a wave energy resources according due to its enclosure to the sea. So, we are turning many interests in wave generation development.[1-3]

Among several methods of wave-power generation, the overtopping wave energy conversion has relatively higher efficiency and low power pulsation. The over topping wave energy converter generates electricity by converting mechanical energy of the hydraulic turbine rotated by flowing differential head generated by overflow wave through the helical structure as in Figure1. This system maximizes wave-power conversion efficiency through wave energy concentration. Moreover, it is more convenient to maintain due to its simple structure of the unit module. However it is difficult to control and monitor the system because the over

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topping wave energy converters are installed far from the land. The fact that the converter generates highly pulsating energy is another major drawback. In this article, we would like to suggest the future direction of development by introducing the simulator for the over topping wave energy converter, building the power control and the monitoring system and so.[4-6]

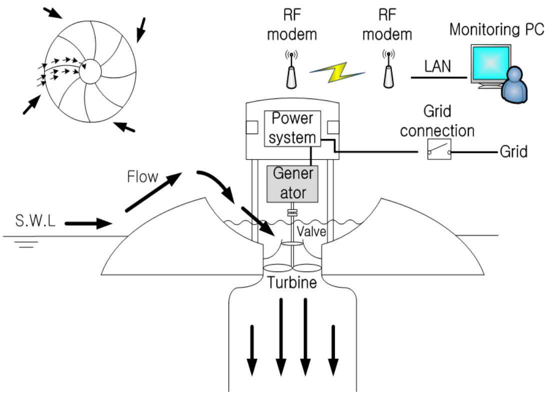


Figure 1: Schematic diagram of OWEC

2. OWEC Power Controller

2.1 Necessity of Power Controller

Wave energy resources generated by meteorological phenomena of sea is irregular due to its characteristics. Power of overtopping wave energy converter is determined by overtopping wave flow in this converter. So, power of overtopping wave energy converter is changed rapidly by meteorological phenomena or the condition of the sea

Instable power causes an instable output voltage of generator. But commercial power connection system requires a bounded voltage range. Therefore, to connect the overtopping wave generation into a grid, we must keep the stability of overtopping wave generator output voltage.

In the study, we proposed a system that installed the power controller by Buck-Boost converter to overtopping wave generator, reducing the instability of output voltage. So, overtopping wave generator is obtained the stability of output power.

2.2 Operation of Power Controller

Proposed overtopping wave energy converter power controller is consisted of capacitor, transistor, inductor, diode and DC/AC inverter for grid.

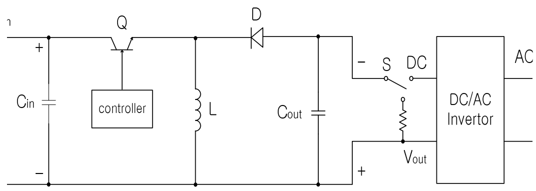


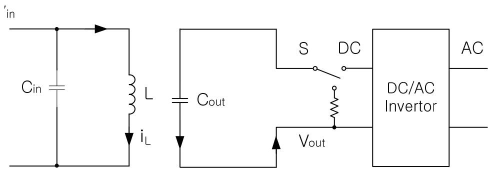
Figure 2: Circuit diagram of power controller

The operating range of the proposed power controller can be divided into 2 different mode, and would be explained as following.

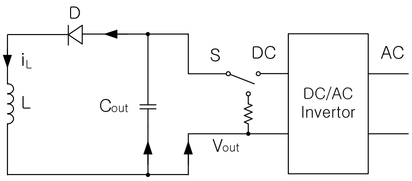
In the mode 1 (On state), transistor Q is on state and diode D is anti-bias. So, input current increases as it flows through the L, Q.

In the mode 2 (Off state), transistor Q is off state and then current i_L flows through the L, C_{out}, $D$and road. The energy which is stored in L pass on load and the inductor current decreases till the switch from the Transistor Q becomes 'ON' on the next period.[7-8]

Figure3(a) and (b) shows about each modes.



(a) mode 1 (On state)



(b) mode 2 (Off state)

Figure 3: Equivalent circuits

If we assume that inductor current increases lineally while the on state time, input voltage can be calculated as follows.

$$V_{in} = L\frac{\Delta I_L}{t_1} \tag{1}$$

And if the inductor current decreases lineally while the off state time, output voltage is described as follows.

$$V_{out} = -L\frac{\Delta I_L}{t_2} \tag{2}$$

And Δ I is achieved in Eq.(3) using Eq.(1) and (2)

$$\Delta I = \frac{V_{in} \cdot t_1}{L} = \frac{-V_{out} \cdot t_2}{L} \tag{3}$$

Where t1,t2 are described as follows

$$t_1 = kT \qquad t_2 = (1-k)T \tag{4}$$

Where k is duty rate by on/off signal.

And then the relation of input voltage V_{in} and output voltage V_{out} is achieved in Eq.(5) using Eq.(3),(4).

$$Vout = -\frac{Vin \cdot k}{1-k} \tag{5}$$

2.3 Experimental Equipment

For the test performance of OWEC power controller, composed experimental equipment. Figure4 shows the schematic diagram of experimental equipment.

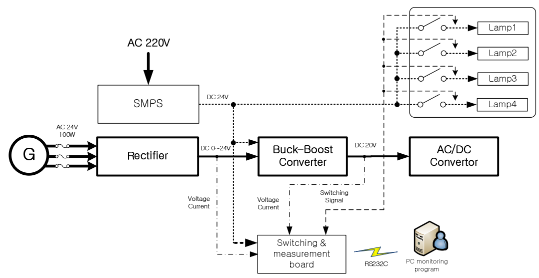


Figure 4: Schematic diagram of experimental equipment

To make a simulator that power pulsation of wave period, we conducted the circuit by using the components such as AC 24V 100W BLDC motor and wave generator. We connected the motor and generator, which controls the speed and electric energy and generates electricity by receiving shaft power respectively. Therefore, we could obtain the wave period dependence of generated energy by changing the speed of motor with a constant period. Figure5 shows the simulator of the overtopping wave energy converter system.

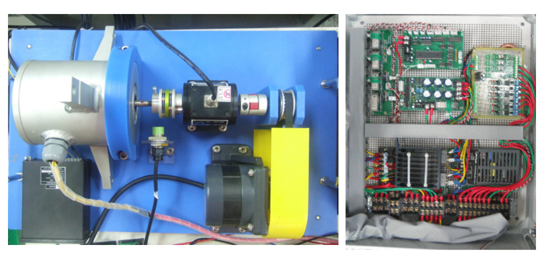


Figure 5: Simulator of Overtopping Wave Energy Converter System

Power from the above processes is converted to DC having range of 0~24V by the rectifier. Voltage depending on the period of the wave is fixed to DC 20V by Buck-Boost converter, and supplies stable voltage. Voltage and current sensors measure such processes and acquired information is transmitted to the switching & measurement board. Finally, the PC monitoring program receives the data trough RS-232C protocol.

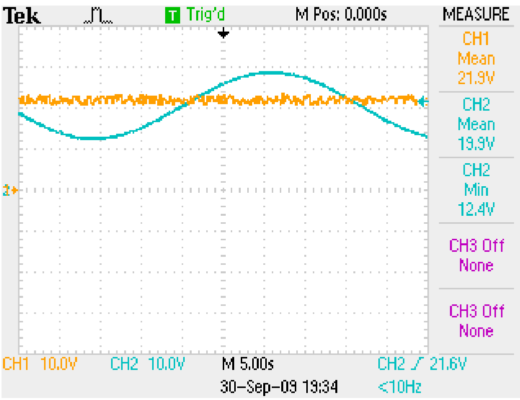


Figure 6: Experimental Waveforms of Power Control System(Normal Operation)
Ch1 : Output voltage Vout
Ch2 : Input voltage Vin

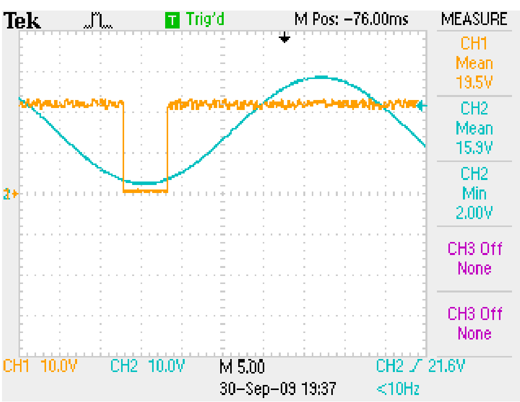


Figure 7: Experimental Waveforms of Power Control System(Safety Operation)
Ch1 : Output voltage Vout
Ch2 : Input voltage Vin

2.3 Experimental Results

By experimenting the OWEC simulator and power controller, we observed the output voltage while the input power and input voltage have changed rapidly. Figure 6 shows the input voltage and output voltage by power controller. Even though the input voltage changes, we confirmed that output voltage is kept in a constant level.

Figure 7 shows if the input power or input voltage is lower than a certain level, the model disconnects the output power as a result. By this operation, we could reduced unreasonable output voltage amplification from the Buck-Boost converter and defined the power stability of commercial power connection system. In the low voltage (3V), we could observe that the system disconnects the power, which has been supplying to the commercial power connection system.

3. Conclusions

This paper proposed the power controller for OWEC. We confirmed the fact by the experiment that even though there is a change on the input power and voltage, the overtopping wave energy converter output power is constant, being supplied to commercial power connection system used by proposed the power controller. And by the experiment, if the generator output voltage is low, the system disconnects the power controller from the commercial power connection. So, power controller contributes to the stability of the commercial power connection system. For the experiment result, we could confirm that reduce pulsation overtopping wave energy converter used power controller applied to buck-boost converter. This application is expected to be possible to power stabilization of OWEC system

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Author Profile

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He was born in Kyung -Nam Korea, in 1978. He received the B.E. degree in Marine Engineering from Korea Maritime University in 1983. Since 1983, He has been with the Zodiac(England Company) including early 4years of System Engineer. He received the M.E. and Ph. D. degrees from Korea Maritime University, Busan ,Korea in 1989 and 1996, respectively. Also, he received the Ph.D. degree from Kyushu University, Fukuoka, Japan in 2009. He had been with the Agency for Defense Development(ADD) as a re searcher from 1989 to 1992. From 1992 to 1996, he was an Assistant Professor in the Department of Industrial Safety Engineering at Yangsan College. In 1996, he joined the Division of Mechatronics Engineering at Korea Maritime University. His research interests include a renewable energy system, electrical drive system, ship control system and PC-based Control applications.