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Design of the Electronic Anti-Fouling System for a Wave Energy Converter

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Abstract : *There are many difficulties to supply constant power to marine facilities which operate in the sea. Especially, there is a limit to stand alone power supply systems due to the influence of weather conditions. That's why a hybrid power supply system is required to overcome these problems. This paper will describe an Electronic Anti-Fouling System (EAFS) to maximise the power efficiency for a solar - wave hybrid power generation system. A main factor reducing the efficiency of a Wave Energy Converter (WEC) is due to the attachment of aquatic life forms. Therefore the aim of this research is to develop a simulation programme to enable the design of more efficient EAFS for hybrid power generation systems and to provide valuable data for production of more efficient EAFS.*

Key words : *Electronic anti-fouling system, Buoy, Renewable energy, Wave generation, Simulation*

1. Introduction

It is difficult to supply power to marine facilities such as buoys and radio beacons which have a very important safety role for sea transportation. Storage batteries have been used so far but these need to be changed regularly which is difficult to bad weather conditions. Therefore, nowadays, stand alone power supply systems are being developed and applied to these systems. According to research, a hybrid power generation system based on a solar power generator in combination with a wave or wind or tidal generator is superior to tradition single power sources. The solar -wave combination is considered to be the most promising of these three hybrid systems, so recently it has been put to practical use with marine facilities, especially buoys. However, there still remain many difficulties to be overcome in order for these to be a viable commercial system. Therefore this paper will address one of these problems with the object of identifying a solution for their applications on a commercial basis. The efficiency of WEC rapidly drops within three months after its installation due to the growth of aquatic life forms. In addition, their added weight lowers the flotation line, sometimes to the point of sinking the system. One method used to remove them is to paint the structure with an anti-fouling paint. However, this paints leaks toxic chemicals into the water which are hazardous to life in the waterways. Furthermore, the efficacy of the paint decreases rapidly with time so that the floating structures have to be hauled out for periodic scraping and painting at considerable cost and down-time. Therefore this paper will suggest an Electronic Anti-Fouling System(EAFS) which prevents aquatic life forms from building up, so that the WEC keeps its generating efficiency with minimal disruption to the marine ecology. To achieve this aim, it is necessary to study the operational characteristics of the WEC as applied to buoys out at sea and design it through simulation. (Hong, 2005)

2. Characteristics for the WEC

Among the hybrid power generation systems for marine facilities, the solar-wave power generation system outperforms because it can continuously produce a constant energy output. However, there are many reasons which contribute to a decrease in generating efficiency during operation. In a solar power generation system, there are three main problems. First, from birds' excrement. Second, salinity both of which can easily be resolved by the suitable arrangement of the solar panels combined with the installation of preventative equipment. Third, the natural decrease in efficiency which occurs during the life time of a solar panel. Therefore this paper focuses on the WEC which is broadly applied to many marine facilities. The most serious problem for a WEC is decreased efficiency through the attachment of aquatic life form. (Oh, 2007;Balaji, 2008)

The pressure form the internal water column P_{awc} is closely related to output of turbine. Therefore, we need to confirm the change of P_{awc}.

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P_{awc} is calculated by formula (1): where η_n is nozzle efficiency, γ is reaction of turbine, S_n is the cross sectional area of turbine, ρ_a is the density of air and K is proportional factor.

$$P_{awc} = \frac{1}{2} \cdot \rho_a \cdot \frac{1}{\eta_n} \cdot \frac{1}{(1-\gamma)} \cdot \frac{1}{(S_n)^2} \cdot K \qquad (1)$$

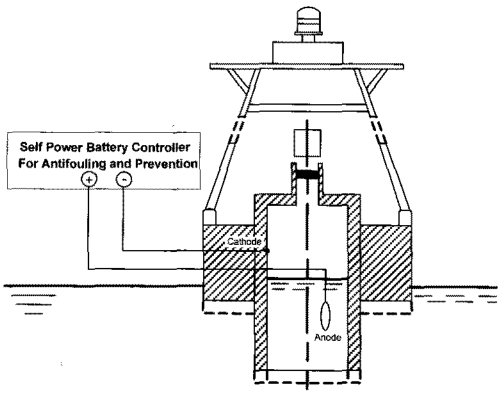

Fig. 1 Schematic diagram of wave energy converter (WEC)

Where K is $((T \cdot S_1 \cdot Q_{wm})/(S \cdot T_1))^2$.

T is period of wave, T_1 is period of decreased wave by the attachment of aquatic life forms, S is cross sectional area in the buoy, S_1 is decreased cross sectional area in buoy and Q_{wm} is quantity of seawater which changes in the water column. (A.F, 2002;Michael, 1974;Cho, 2002)

3. Proposed EAFS

3.1 Principle and design

Numerous of Electronic Anti-Fouling Systems (EAFS) have been studied to remove various aquaticlife forms from the wave power generation system, such as chemical and electrical methods. In this study, an electrolytic procedure was applied to creating a sacrificial anode and galvanic cathodic protection. Fig. 2 shows the schematic diagram of the EAFS principle for a WEC. Formula (2) depicts the formation of the anode

$$Cu \rightarrow Cu^{2+} + 2e \qquad (2)$$

Formula (3) depicts the cathode

$$O_2 + 2H_2O + 4e \rightarrow 4OH \qquad (3)$$

The resulting cupper ion(Cu^{2+}) at the anode and reduction of oxygen at the cathode destroy any marine life present thus preventing any build up on the wall. Additionally, formula (4)

$$Al \rightarrow Al^{3+} + 3e \qquad (4)$$

Provides galvanic cathodic protection created by the attachment of an aluminum bar to the wall. This, not only inhibits corrosion but also aluminum ions(Al^{3+}) create a film on the water surface at the wall preventing the growth of marine life.

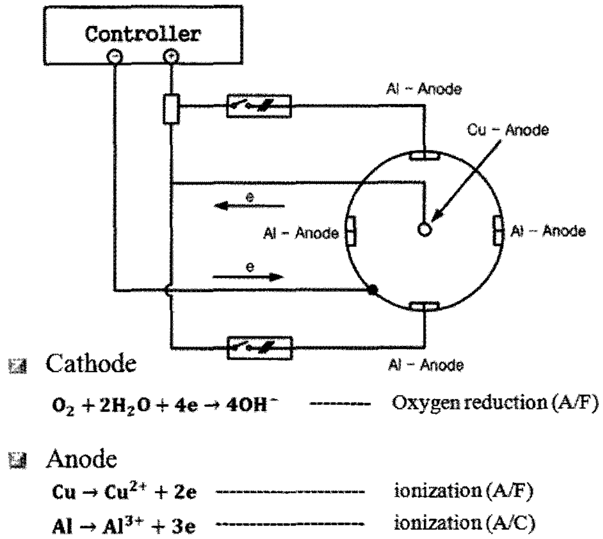

Fig. 2 Schematic diagram of the EAFS principle

The required weight of the Cu anode depends on the flux of seawater Q which is calculated by formula (5):

$$Q = A \cdot V(m^3/h) \qquad (5)$$

Where $A(m^2)$ is the cross sectional area across the water line, $V(m/h)$ is the seawater velocity of internal water column. Table 1 shows the flux of the seawater relative to the speed of seawater. The formula (6) is used to calculate the rate of erosion of the Cu anode Q_{AW}

$$Q_{AW} = 2ppb \times Q \times Y \times 10^{-6} \qquad (6)$$

Where $2ppb$ is standard density, Q is flux of seawater and Y is useful life time. Table 2 shows anode consumption for three years.

Table 1 Flux/fluid speed relationship

	Φ640 mm	Φ850 mm
$0.5 m/s$	$578.8 m^3/h$	$1020.9 m^3/h$
$1 m/s$	$1157.5 m^3/h$	$2041.8 m^3/h$

Table 2 *Cu* and *Al* anode consumption after three years

	Φ640 mm		Φ850 mm	
	Cu anode	*Al* anode	*Cu* anode	*Al* anode
0.5 *m/s*	30.4 kg	7.6 kg	53.7 kg	13.4 kg
1 *m/s*	60.8 kg	15.2 kg	107.3 kg	26.8 kg
2 *m/s*	121.7 kg	30.4 kg	214.6 kg	53.7 kg
3 *m/s*	182.5 kg	45.6 kg	322.0 kg	80.5 kg
4 *m/s*	243.4 kg	60.8 kg	429.3 kg	107.3 kg

3.2. Control algorithm

Fig. 3 represents an EAFS control system. The EAFS's power is supplied via an auxiliary storage battery supplying current to the *Cu* anode which is controlled by an optimization algorithm varying to the required power generation characteristics.

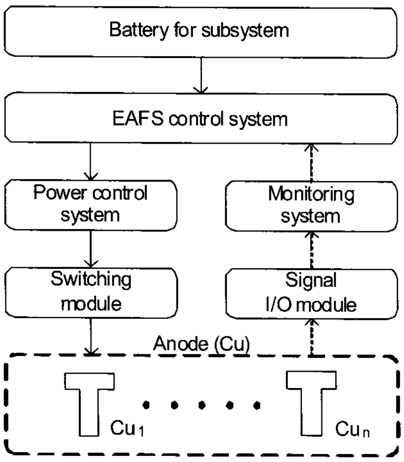

Fig. 3 Control system for EAFS

The EAFS perceives the thickness of any attached aquatic life forms on the internal water column wall by sensing the power output and voltage of the storage battery. Depending upon this thickness the supply current to the Cu anode is appropriately controlled. When the attached life forms exceed a set value the controller increases the current in steps of 0.4A. Conversely reading below this set value decreases the current in steps of 0.2A. This system has a 0.4A minimum current limit due to safety reasons. All these sensing data are monitored in the Host PC through TCP/IP wireless communication.

This EAFS was designed with consideration of a WEC's fluid mechanics for marine facilities. Its control algorithm and controller were also designed for optimized effect of minimal power consumption and also a mechanism to consume power, when the storage batteries for illuminating the buoy are fully charged, the extra generated power is sent to the EAFS and its auxiliary storage battery.

4. Test and analysis results

Matlab simulation was used to test the performance of the proposed EAFS. For this test, the standard buoy employed in Korea was used. The WEC output for an oscillating type of buoy becomes higher in proportion to the turbine inlet pressure. Turbine inlet pressure in turn increases proportionally to the amplitude of the internal water column and this movement reaches a maximum when the period of the water's surface wave and the buoy's oscillations are the same. Therefore to design the buoy with a WEC, all these factors should be considered from the fundamental design step.

The most high rate among wave period at test area is from four to six seconds, therefore during design the buoy's oscillations should be matched to from four to six seconds.

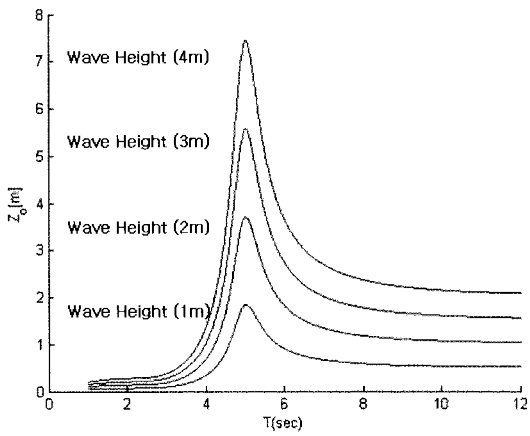

Fig. 4 Graph depicting buoy motion amplitude(Z_0) of bouy relative to period(T)

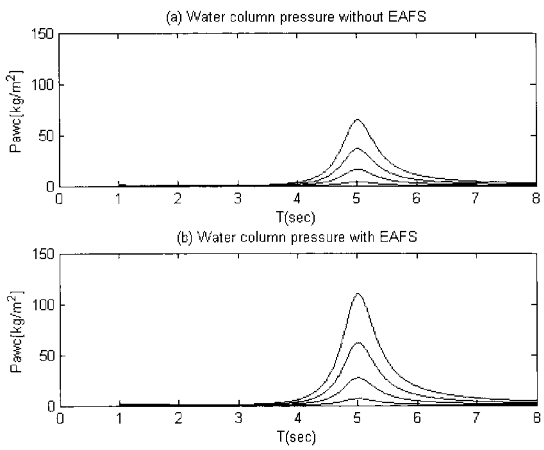

Fig. 5 Graph depicting water column pressure with and without EAFS

Fig. 4 and Fig. 5 show the simulation result graphs from Matlab using the previous modelling formulas and parameters. Fig. 4 shows the buoy's motion amplitude Z_0 in relation to water's surface wave period T(sec). This shows when T(sec) is equal to five seconds, Z_0 becomes a maximum.

Fig. 5 depicts the internal water column pressure in relation to the period. Fig. 5 (a) shows the pressure without an EAFS whilst (b) shows pressure with an EAFS. Thus without an EAFS the internal water column pressure decreases due to the build up of aquatic life forms. Simulation results demonstrate that the performance of a WEC without aquatic life forms (or fitted with an EAFS) outperformed producing greater efficiency. Furthermore according to testing of an EAFS performance over a 3 week period, the internal water column pressure reduction markedly decreased by inhibiting the attachment of aquatic life forms. These results show EAFS will play an important role in improving the efficiency of a WEC.

5. Conclusion

Buoys have been operated by solar power generation systems alone but there are large deviations in the generators output due to the changing conditions. In addition, nowadays buoys operate with a variety of additional systems. This has led to a rapid increase in power consumption. Therefore existing solar power generating systems are not adequate to supply the necessary power. As a result, a WEC plays a very important role in the stability of a buoy's power system. However, one serious problem of a WEC is the decreased efficiency due to aquatic life forms. Therefore this paper introduced an EAFS as a promising solution and simulated it with Matlab. Simulation results show that a decrease in the water column's diameter causes a serious decrease in the efficiency of a WEC, so an appropriate EAFS for a WEC was designed to solve this problem.

Following additional future trials in situ the relationship between an EAFS performance and the generating characteristic of a WEC will systematically be studied more.

Acknowledgements

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