Numerical Study of Reciprocating Liquid Metal MHD Generator for Wave Energy Conversion System

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ABSTRACT

3D numerical simulation of a Liquid Metal Magnetohydrodynamic (LMMHD) generator with convergent and divergent sections for Wave Energy Conversion (WEC) system was carried out. Flow, electromagnetic fields and performance characteristics were investigated. The simulated results show that uneven distributions of flow velocity in convergent and divergent sections induce complicated eddy currents, which increase energy loss and thus influence performance of LMMHD generator. An experimental LMMHD system was constructed and the measured power output of about 3kW was obtained. Comparison between simulated and experimental results confirm the validity of the numerical simulated model.

KEY WORDS: Wave energy; MHD generator; liquid metal; Ga alloy; induced magnetic field; 3D simulation.

INTRODUCTION

Ocean waves may become an unquestionable alternative to actual clean energy sources in the near future. The development and utilization of wave energy conversion becomes the world’s hotspot and difficult problem. High speed rotating generators are used traditionally for wave energy conversion, which increases the complexity and cost and at the same time decreases the reliability and efficiency of the system. A new way to generate electric power directly from ocean wave motion has been investigated in Scientific Applications & Research Associates (SARA), USA, and Institute of Electrical Engineering, Chinese Academy of Sciences (IEECAS), China (Yan Peng, 2008, Yuyu Xu, 2012, Baolin Liu, 2014), respectively. It makes use of a LMMHD generator which was first proposed by Haaland (Carsten M. Haaland, 1995) and whose speed-torque characteristics match the mechanical impedance of wave excellently and is expected to be one of the best ways to convert wave energy into electricity directly. The concept of LMMHD WEC system is illustrated in Fig. 1. It is mainly composed of buoyant float, heave plate, spar, PTO system and mooring system. The basic operation principle is that a buoyant float moves up and down along a spar to absorb wave energy, a PTO system with LMMHD generator inside the spar directly converts the relative linear motion into electric power.

Fig. 1 Heave-float LMMHD WEC

As a key component of LMMHD WEC, performance of reciprocating LMMHD generator has great effect on the system. Performance of a rectangular cross-section LMMHD channel, applied in distributed energy systems of residential sectors, was estimated with 3D numerical method (Yamada, 2005). The electromagnetic field and fluid flow in steady state have been clarified, and the effect of the electrode width on the performance has also been examined taking account of the current flow in the electrode. Then influence of the induced magnetic field in LMMHD generator was clarified (Satake, 2007). The results show that induced magnetic field decreases the generator performance and can be negated if the double channels are configured such that the liquid metal flows in counter directions. 3D simulations of LMMHD generator using U47-alloy driven by wave energy were studied in steady state and unsteady state in IEECAS (Lingzhi Zhao, 2009, Yuzhen Hu, 2012), respectively. Zhao investigates that the velocity in MHD channel and end gradient of the applied magnetic field are two key factors influencing the end effect greatly, and the integration of insulate vane and low end gradient of external applied magnetic field can suppress the end current and the induced magnetic field. Hu simulated the variation of flow and electromagnetic fields versus time. The results show that the output voltage and current are sinusoid variations which have the same waveform with inlet velocity of liquid metal and also reveal that the main energy loss is caused by internal resistance.