論文の内容の要旨

論文題目

Electric Power Generation from Deep Sea Hydrothermal Vent Using Thermoelectric Generators

（熱電発電素子を用いた深海噴出熱水からの発電について）

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With the development of underwater technology and profound understanding of hydrothermal vent influences, more extensive researches have been conducted in vent areas. In these researches, ROV and AUV are indispensable in observing and exploring these places and deep sea sensors also play a very important role in long term data collection. In order to solve the power supply problems for underwater vehicles, seabed stations and other seabed sensors, in this research work, hydrothermal vent is used as power source, and a deep sea power generation system is developed that is capable of generating, storing and supplying power to these deep sea appliances.

Thermoelectric module (TEM) is a solid state device, which can convert thermal energy to electricity power based on the principle of the Seebeck effect. It was employed here as a medium to produce power by utilizing the temperature difference between the hot fluids and cold seawater. Because it will be used in deep sea, a system was developed to test its performance under different thermal and pressure conditions. It has been found the output power of TEM varies in proportion to temperature differences and it performs well under high pressure up to 20 MPa which is the depth of most hydrothermal vents exist.

Because the heat is dissipated into surrounding cold seawater very quickly, a compact power generator model was developed in order to confirm whether the water is still hot enough to drive TEM to produce power after ejection. The feasibility experiment was carried out at Yamanaka vent located in Kagoshima Bay in Apr. 2012. The output power was recorded as 1.7 Watts from four series connected TEMs. This is the first model to generate power from hydrothermal vent, and the results confirmed that it is possible to produce power from hydrothermal vent if the hot fluids are captured properly as soon as ejected from vent orifice.

A deep sea power generation system was designed, constructed and fabricated. The power generation system is composed of the power generator and power management system. A comprehensive study of power generator on stress intensity, corrosion resistance, heat transfer effect and flexibility in mechanical design was done. A novel hexagonal shape

prototype was proposed which can mount cuboid TEMs and related circuits properly and ensure good heat transfer effect simultaneously. The differences in temperature distribution of concentric double pipes prototype and hexagonal shape prototype under different conditions were compared. When the power generator is set on top of the hydrothermal vent, the limited space inside the generator will prevent the particles from dissipating into surrounding environment free and quickly. In this process, the hydrothermal vent might be get clogged and the particles also possibly adhere to the inner surface of generator. The influences on heat transfer effect and power generation ability were analyzed and discussed based on the numerical simulation.

For one single TEM, the output power is decided by the temperature differences on both sides of it. MPPT (maximum power point tracking) method was employed here, which can extract the maximum output power from TEM under any thermal conditions and without being influenced by the different loads. However, in large power generation system, the output power is not only concerned with the temperature differences on single TEM, but also the topology of TEMs connection methods. According to the thermal distribution, centralized architecture and distributed architecture were compared and the limitations of both methods were analyzed. Ideally, the distributed architecture can solve any mismatching problem, but actually this is not feasible. Combined with the simulation results, the power mismatch problem caused by the non-uniform temperature distribution on TEMs was studied, and the solutions for distributed architecture were proposed. The modification of the system has been done to enable the output voltage of TEMs is in the operating range of load.

The field experiment was carried out at artificial hydrothermal vent located in Okinawa Trough in Nov. 2013. This is the first deep sea power generation system which has really produced electrical power by utilizing the thermal energy released from hydrothermal vent in the world, and above 60 Watts were obtained. The experiment also verified the rationality and correctness of theoretical developments, simulation results and electric power management system. This research provides a reference for the development of large power generation system in deep sea.

Keywords: *power generation, hydrothermal vent, TEM, power generator, MPP, power management*