Piezoelectric energy harvesting system for volcanic seismic acquisition equipment

Normandino Carreras, Daniel Mihai Toma, Spartacus Gomariz, Montserrat Carbonell, Jordi Vidal, Joaquín del-Río-Fernández

SARTI Research Group. Electronics Dept. Universitat Politécnica de Catalunya (UPC).
Rambla Exposició 24, 08800, Vilanova i la Geltrú. Barcelona. Spain. +(34) 938 967 200.
www.cdsarti.org

Abstract –In this paper it is presented a volcanic seismic acquisition equipment that has been developed together with an energy harvesting system, based on piezoelectric elements, in order to work in autonomous conditions. The energy harvesting system has been developed to convert the wind or marine currents energy into electrical energy through a new method based on piezoelectrics. For the deployment of the volcanic seismic acquisition equipment in marine environments, this power generator produces energy obtained from harnessing of the kinetic energy of marine currents. The first results have shown that the system is capable to provide a small amount of energy that can be used to extend the deployment time of the volcanic seismic acquisition equipment.

Keywords - *acquisition, volcanic, low power, energy-harvesting, piezoelectric.*

I. INTRODUCTION

In volcanic monitoring, in order to obtain a good localization and characterization of the volcanic activity, it is necessary to install seismic acquisition stations in the volcano environment [1]. There are commercial devices that allow such monitoring, however these present problems of environmental impact, vandalism and high energy consumption and cost.

The autonomous volcanic seismic acquisition equipment are usually constructed using a battery for power, and in some cases accompanied by energy harvesting (EH) systems, as it is typical use solar panels. The biggest problem in the use of these systems is the high volume of them and the need to be installed in places with no natural camouflage, which can lead to increased vandalism towards these systems [2].

Moreover, on land, the resolution, and coverage is adequate at the regional level, and is relatively easy to be increased in specific cases using portable seismic stations (e.g. for microseismic studies). However, it is important to note that the dynamics of the lithosphere associated with the interaction of tectonic plates happens mostly in ocean basins and margins, yet the distribution of marine seismic stations is far from their equivalent in land, either because of the technological complexity related with the environment, or the difficulties to access the recorded data. Recent seismic activity associated with the eruption of El Hierro (2011-2012) shows the importance of controlling the seismicity located in the sea that is not covered by the terrestrial monitoring networks.

The integration of real time data generated by marine seismometers will be possible thanks to the development of wireless communication systems, the increasing potential for miniaturization of sensors, storage devices and data processing, which have opened the door to a new generation of distributed intelligent sensor networks that are connected by communication networks.

The energy requirements of low power electronics have steadily decreased with advancements in efficient circuitry such that energy harvesting systems can be considered feasible solutions in providing power to self-powered systems. Among the ocean areas where harvestable energy is available, the most interesting ones are the areas with tidal and ocean currents and the shallow water areas with significantly wave-induced oscillatory currents at the sea bottom. Particular, wave-induced oscillatory currents at the sea bottom are interesting for harvesting devices because of the body dynamics placed in these areas.

The system proposed here draws upon a volcanic seismic acquisition system that can be placed both on land and underwater and can be attached to two different harvesting devices, one based on vertical turbines for land applications and one based on a Bristol pendulum placed inside a floating body. Both energy harvesters are using piezoelectric transducers in order to generate electrical energy from mechanical energy.

II. ACQUISITION SYSTEM

The volcanic seismic acquisition system that has been designed, consists of low-power components to extend the life of the equipment without human intervention. At the same time, the equipment has been designed as a compact system placed in a sealed container in order to obtain greater resistance to the adverse effects of the environment in which there are going to be installed.

The system is divided into four modules: power, control, peripherals and sensors. The power module is formed by a li-ion battery and a voltage regulator system. The control module is composed by a management microprocessor system, an SD memory card for data storage, and three analog to digital converters. In the peripherals module there are included the devices for remote communication of acquired data, and the time synchronization system based on GPS. Finally, the sensor module is composed of the three geophones and a signal matching circuit [3].

Figure 1 Volcanic seismic acquisition equipment

The components are arranged within the sealed casing, as illustrated in Figure 1, in order to improve the distribution of the center of mass, and facilitate the installation. At the bottom there are the batteries and sensors, corresponding to the heavier elements of the system. On top there are the different electronic boards, the power switch and light indicator of activity. Finally, on the side, there are four connectors for external connection to different elements: antenna for data communication, GPS antenna, external sensors and external power supply such as the energy harvester.

III. ENERGY HARVESTING

A. Land energy harvester

It has been designed and developed a prototype of a turbine comprising a vertical turbine and two piezoelectric transducers, in order to generate electrical energy from mechanical energy produced by the wind turbine. The energy harvester has been developed to increase the energy supply to the volcanic seismic monitoring system.

For the EH design it has been considered that the seismic station is located in areas with an average wind speed between 4.67 to 6.05 m/s. Based on this, the design goals are to ensure the stability of the turbine, to ensure the necessary energy for the seismic station and the ability to pass unnoticed to prevent vandalism.

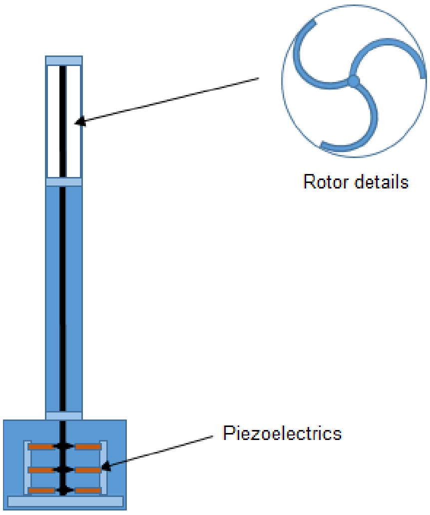

Figure 2 Configuration of turbine energy harvester device

The design of the vertical axis turbine shown in Figure 2 has been done based on a system of Savonius blades type [4], consisting of three blades with 40° angle and located at 120° around the axis of rotation of the turbine. Based on this design a prototype, illustrated in Figure 3, has been built and experimentally has been demonstrated the operation of this.

Figure 3 Energy Harvester prototype

The wind energy for the projected turbine at an average wind speed of 4.67 m/s is 2.02W. Given this potential, corresponding experiments have been conducted to optimize energy production, using planked piezoelectric converter [5] based on impacts between the piezoelectric and plectra's attached on the shaft of the turbine system.

B. *Underwater energy harvester*

To harvest the energy produced by the sea motion in the bottom we start to develop a prototype based on a Bristol cylinder which can generate electrical voltage using vibration piezoelectric. These vibrations are generated by plectrums impacts, such as in the wind EH device, which create continuous free vibration in piezoelectric after impacting them [5].

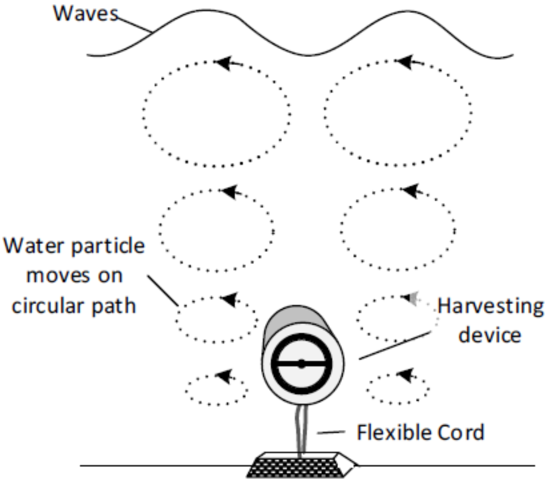

Figure 4 Configuration of motion energy conversion device

The configuration presented in Figure 4, takes advantage of the oscillating motion of a cylindrical floating body produced by the circular motion of the water particles induced by waves. The oscillating force created by the sea motion, destabilizes the pendulum based system creating continuous impacts in the piezoelectric elements.

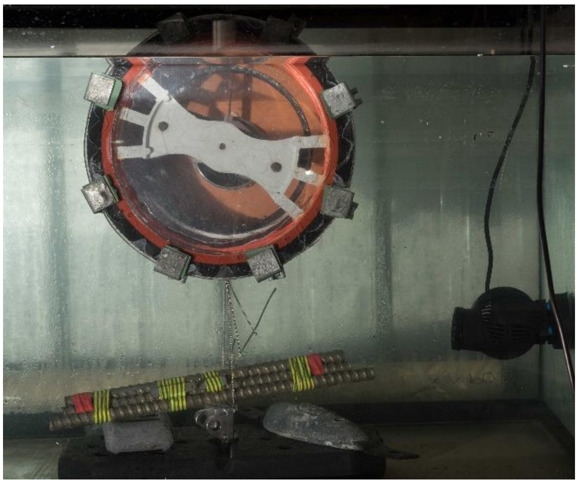

Figure 5 Sea motion electrical energy generator prototype

Once manufactured the prototype illustrated in Figure 4, we begun the experiments based on waves and currents magnitudes usually found at OBSEA observatory.

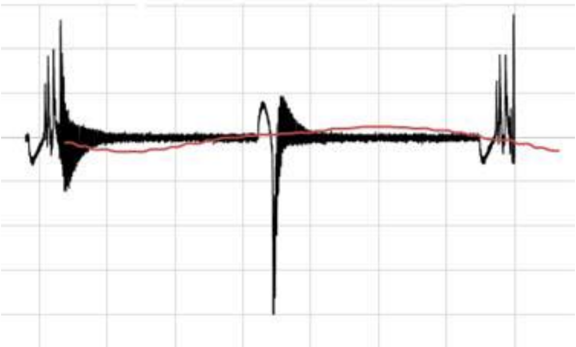

Figure 6 Output voltage of a single piezoelectric plotted versus

Figure 6 plots the instantaneous output voltage of a single plunked vibration piezoelectric beams for a driving rotation of the harvesting device with a wave height of 0.5 meter and wave period of 4 seconds and with a single plectra facing of the piezoelectric beam. The maximum peak-to-peak voltage is 32V. Experimental results shows that the proposed energy harvester achieves a maximum power density of 350µW/cm3.

IV. RESULTS & CONCLUSIONS

From the different laboratory tests we have obtained that the seismic acquisition system consumes about 150 mW. This power consumption was obtained for continuously data recording in the SD memory without remote data transmission.

For the experiments regarding the power generation system, we use two piezoelectric (MEAS VOLTURE v21b) and four spikes (located at 90 ° around the axis of rotation). Then, simulating a constant wind speed of 7 m/s, the total power obtained by the EH to supply the seismometer was 0.868 mW. This means that if we have the system working for a period of 30 days at this constant speed, it would get a total of 0.625 Wh. Therefore, the prototype could allow an operation of four hours of the seismic acquisition system working in continuously data recording without remote data transmission.

The results of testing this novel power generating system have demonstrated the possibility to obtain energy from wind using piezoelectric transducers, and can also be used for underwater currents. Although, the power generated by this first prototype is small, these tests provide a good basis for further work in this field.

ACKNOWLEDGMENT

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