World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:11, No:10, 2017

Experimental Proof of Concept for Piezoelectric Flow Harvesting for In-Pipe Metering Systems

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Abstract : Intelligent networking of devices has rapidly been gaining importance over the past years and with recent advances in the fields of microcontrollers, integrated circuits and wireless communication, low power applications have emerged, enabling this trend even more. Connected devices provide a much larger database thus enabling highly intelligent and accurate systems. Ensuring safe drinking water is one of the fields that require constant monitoring and can benefit from an increased accuracy. Monitoring is mainly achieved either through complex measures, such as collecting samples from the points of use, or through metering systems typically distant to the points of use which deliver less accurate assessments of the quality of water. Constant metering near the points of use is complicated due to their inaccessibility; e.g. buried water pipes, locked spaces, which makes system maintenance extremely difficult and often unviable. The research presented here attempts to overcome this challenge by providing these systems with enough energy through a flow harvester inside the pipe thus eliminating the maintenance requirements in terms of battery replacements or containment of leakage resulting from wiring such systems. The proposed flow harvester exploits the piezoelectric properties of polyvinylidene difluoride (PVDF) films to convert turbulence induced oscillations into electrical energy. It is intended to be used in standard water pipes with diameters between 0.5 and 1 inch. The working principle of the harvester uses a ring shaped bluff body inside the pipe to induce pressure fluctuations. Additionally the bluff body houses electronic components such as storage, circuitry and RF-unit. Placing the piezoelectric films downstream of that bluff body causes their oscillation which generates electrical charge. The PVDF-film is placed as a multilayered wrap fixed to the pipe wall leaving the top part to oscillate freely inside the flow. The warp, which allows for a larger active, consists of two layers of 30µm thick and 12mm wide PVDF layered alternately with two centered 6µm thick and 8mm wide aluminum foil electrodes. The length of the layers depends on the number of windings and is part of the investigation. Sealing the harvester against liquid penetration is achieved by wrapping it in a ring-shaped LDPE-film and welding the open ends. The fabrication of the PVDF-wraps is done by hand. After validating the working principle using a wind tunnel, experiments have been conducted in water, placing the harvester inside a 1 inch pipe at water velocities of 0.74m/s. To find a suitable placement of the wrap inside the pipe, two forms of fixation were compared regarding their power output. Further investigations regarding the number of windings required for efficient transduction were made. Best results were achieved using a wrap with 3 windings of the active layers which delivers a constant power output of 0.53µW at a 2.3MΩ load and an effective voltage of 1.1V. Considering the extremely low power requirements of sensor applications, these initial results are promising. For further investigations and optimization, machine designs are currently being developed to automate the fabrication and decrease tolerance of the prototypes.

Keywords : maintenance-free sensors, measurements at point of use, piezoelectric flow harvesting, universal micro generator, wireless metering systems
Conference Title : ICEHS 2017 : International Conference on Energy Harvesting Systems
Conference Location : Bangkok, Thailand
Conference Dates : October 26-27, 2017