Autonomous Wireless Heat Energy Meter Based on Piezoelectric Energy Harvester for Heat Energy Measurement in Building Complexes

Siamak Jafarpisheh[1], Ahmadreza Tabesh[2], Nasrin Rezaei-Hosseinabadi[3*], Mohammad Amin Latify[4], Hamid Reza Karshenas[5]

[1] Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran
siamak_jafarpisheh@yahoo.com,
[2] Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran
a.tabesh@iut.ac.ir
[3] Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran
n.rezaei@iut.ac.ir
[4] Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran
latify@iut.ac.ir
[5] Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran
karshen@iut.ac.ir

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Extended Abstract

Introduction: This paper presents a platform for a power-autonomous wireless energy meter device using piezoelectric energy harvesters. This device can mainly be used for measuring the share of heat energy consumption in a fair manner in building complexes with central heat energy systems. In the suggested device, the piezoelectric energy harvester is also used as a flow-meter to reduce the power consumption of the device. Such event facilitates power autonomous operation of the device. The performance of the devices is investigated based on a prototype which has been used under a test condition with a flow rate from 100 up to 200 liters per hour. Comparing the test results with those having been recorded based on a standard hall-effect flow meter, as a reference sensor, verifies the multi-function operation of piezoelectric energy harvester as a flow sensor within the device.

Materials and Methods: The suggested device in this paper consists of six parts: piezoelectric fluid flow energy harvester and flow meter, a storage circuit, low-power temperature sensors, a processor, and a wireless transmitter. The energy harvester consists of a turbine in the inlet water path with an even embedded number of permanent magnets (PMs) with opposite polarities in its hub, which interact with the PMs at the tip of piezoelectric beams. The arrangement of PMs in the hub, with opposite polarities, applies an almost sinusoidal force at the tip of the piezoelectric beam, which generates electrical power. Because the vibrating frequency of the piezoelectric beam is proportional to the flow in the inlet water path, the frequency of generated piezoelectric voltage is proportional to the fluid flow rate required for calculation of heat energy consumption.

In this device, the following algorithm is proposed to reduce the power consumption of the heat energy meter: inlet and outlet temperatures as well as flows are measured every minute to calculate heat energy. Then, the average heat energy of 20 minutes is calculated; by activating the transmitter for a short time of 3.7 seconds, the average value is transmitted by the wireless transmitter.

Results: To evaluate the performance of the suggested device, a Tec1-12710 thermoelectric cooling element and two radiators were used to produce hot and cold water simultaneously. The function of the thermoelectric element is such that if a voltage is applied to it, one side of it will be heated, and the other side will be cooled. Therefore, by placing two radiators on either side of the thermoelectric element, the water passing through one of the radiators was cooled due to contact with the hot surface; and the other radiator was cooled due to contact with the cold surface of the thermoelectric. This prototype was used for experimental measurement with a flow rate of 100 to 220 liters per hour.

The test results showed that the average power consumption in the proposed design with the piezoelectric flow meter, compared to the case in which the hall-effect sensor had been used for the flow meter, was reduced from 53μW to 44μW. Also, based on the test results, with a piezoelectric energy harvester of a resonant frequency of 82.6 Hz, the flow rate from 100 to 220 liters per hour could be measured with less than one percent error.

The test results illustrated that the maximum extracted power from the piezoelectric energy harvester at the flow rate of 127 liters per hour was about 227μW, which provided stable energy sources for the wireless heat energy meter.

Discussion and Conclusion: This paper has presented an autonomous wireless heat energy meter based on a piezoelectric energy harvester. The following can be considered as innovations of the research:

- Simultaneous use of piezoelectric beam as an energy harvester and flow meter in the suggested device has led to a reduction in power consumption and in cost of the device. It should be noted that the proposed design is such that the circuit related to the flow meter does not affect the performance of the piezoelectric beam as an energy harvester. Also, the operation range of piezoelectric beam in the flow meter's role is wide (100-220 liters per hour). It is also possible to use an array of piezoelectric beams mounted around the fluid tube to harvest more electrical power and to increase the flow meter's operating range.

- This device has low power consumption due to low-consumption equipment and optimal operation mode selection.

- The use of piezoelectric beams, as harvesters and flow meters, makes it possible to generate electrical power and measure fluid flow at low fluid flows. Low flow rate operation is not possible in an electromagnetic harvester because the amplitude of output voltage decreases as the flow rate decreases.

- The device presented in this paper can calculate the actual share of heating energy consumption (instead of calculating it by area) and provide a bill for each unit in residential and commercial complexes that use a central heating system.

Although energy harvesting technologies have not yet been integrated into the commercial applications of commercial wireless heat energy meters, experimental test results have shown that implementing self-power wireless heat energy meters is feasible. It leads to reduction or elimination of batteries and long-term environmental problems. Also, continuous reading of the amount of heat energy consumed by each household and storing the resulting data make it possible to predict the amount of hot water consumed with seasonal changes through using statistical analysis and machine learning. These analyses can also be used to extract guidelines for an optimal use of hot water by the households and the efficient operation of central heating systems.

Keywords: Heat measurement, piezoelectric energy harvesters, piezoelectric flow-meters, smart buildings.

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