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Editorial

The New Techniques for Piezoelectric Energy Harvesting: Design, Optimization, Applications, and Analysis

Wael A. Altabey [1,2,*] and Sallam A. Kouritem [2,*]

1 International Institute for Urban Systems Engineering (IIUSE), Southeast University, Nanjing 210096, China
2 Department of Mechanical Engineering, Faculty of Engineering, Alexandria University, Alexandria 21544, Egypt
* Correspondence: wael.altabey@gmail.com (W.A.A.); sallam.kouritem@alexu.edu.eg (S.A.K.); Tel.: +86-1736-8476-644 (W.A.A.)

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The importance of energy harvesting is considered when harvesting the neglected ambient energy that graduated from different systems and dissipates around us, such as electromagnetic waves, heat, vibration, etc., and thus converting it into useful, and easy electrical energy. This can be used to supply critical devices such as sensors, that work in remote and inaccessible areas, with the energy needed to work. This can include oil and gas pipelines, long-distance transmission lines, remote forests and oceans areas, etc. Therefore, enhancing the sustainability of these devices and expanding the opportunities for IoT utilization and possible wireless operation of the sensors in sensor networks. This special issue aims to gain new, unique knowledge of energy harvesting technology that is now attracting attention as it enables technology to expands their uses and possibilities. Another goal is the gather the main contributions of academics and practitioners in mechanical, aerospace, and civil engineering to provide a common ground for improvements in approaches to piezoelectric energy harvesting including design, optimization, applications, and analysis. Moreover, the studies concerning sensor technologies, vibration-based techniques, artificial intelligence, and related fields are all welcome, both numerical and experimental.

Researchers and industry have been interested in piezoelectric energy harvesting because it has a great ability to provide self-powered operations of wearable devices, wireless sensor networks, and medical implants. The piezoelectric converts mechanical energy to electricity with a high efficiency and ease of operation. The harvested power can be employed in many medical and industrial applications such as pacemakers, bridges, building monitoring, and tire pressure monitoring techniques. Many energy sources can be harvested using a piezoelectric device such as the mechanical vibration energy of buildings, bridges, mechanical systems, structures, and vehicles. Piezoelectric energy harvester displays only a sharp peak voltage near the natural frequency which means low efficiency in harvesting ambient vibrations so broadband natural frequency energy harvesting techniques are highly recommended. Many broadband energy harvesting techniques have been introduced such as the nonlinear properties of the structure, using an array of harvesters, and Automatic Resonance Tuning (ART). A typical Integrating structural control and health monitoring system including energy harvesting is shown in Figure 1.

For more general knowledge for understanding of the state of the art, we suggested the reader see the review paper of Mitra et al. [1], it has several works discussed the SHM various components system (see Figure 1). Moreover, we can see in Mitra et al. [1], various techniques of monitoring based on ultrasonic guided waves (UGW) generated by piezoelectric techniques. Furthermore, that work will give you experience of what research and development exists for advanced SHM systems. As you may know, the SHM techniques based on UGW generated by piezoelectric transducers are the most common and most developed as well as having a longer history [2] than the other techniques, in particular Fiber Bragg Grating (FBG) sensors. The piezoelectric materials development for establishing transducers for generation UGW sensors and construction of the integrated components and systems with low-power consumption are good additions to the research of providing new design methodologies and technologies in the field the SHM. Moreover, we suggested the reader see another interesting report presented by Dennis Roach of Sandia National Labs [3] for the testing of SHM systems in the aerospace industry, this report shows the objectives and implementations of SHM systems for airplanes and includes several examples with piezoelectric sensor applications for monitoring impacts, deformations, debonding, delamination. Moreover, it solves the drawbacks of SHM techniques due to the complexity of the installation of the sensors on a target structure, the real-time signal acquisition and processing, and the replication of the real-life environmental conditions.

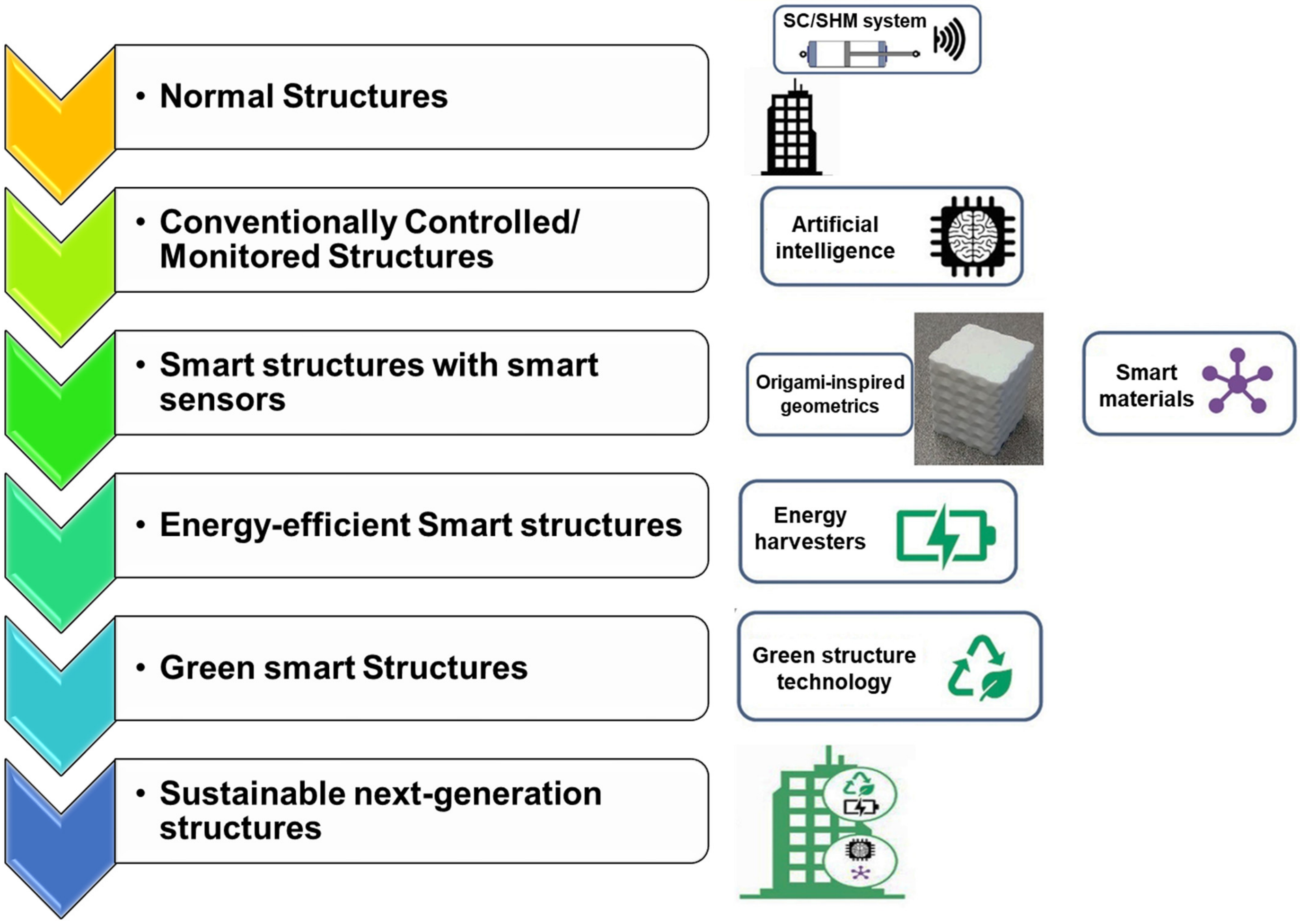

Figure 1. A typical Integrating structural control and health monitoring system including energy harvesting.

The piezoelectric sensors commonly used for reproducing the impact stress waves in passive mode are typically based on PZT piezoelectric materials [2,4–6]. According to the choice of piezoelectric material, the sensor design or selection is completed by the definition of the fabrication technology and the dimension/shape that must accomplish several system-level target parameters, such as:

(1) bandwidth;
(2) sensitivity/Gain/signal to noise ratio (SNR);
(3) input Impedance;
(4) input signal dynamic;

(5) temperature range;
(6) mechanical features: Stress/Strain/Brittleness/Flexible/Stretchable;
(7) bonding/Embedding;
(8) electrical connection/wiring;
(9) cost.

Design, optimization, applications, and analysis of piezoelectric energy harvesting is a vital and attractive research topic: Advances in the design of energy harvesters [7], using FEM and hybrid methods [8,9]; Broadband energy harvester techniques [10,11]; Optimization techniques for piezoelectric energy harvesters [12]; Nonlinear-vibration-based piezoelectric energy harvesting [13]; Advances in materials for energy harvesting [14,15]; Piezoelectric energy harvesting [16], surrogate models [17]; Piezoelectric energy harvester applications in industry [18]; Piezoelectric energy harvester applications in structural health monitoring (SHM) [19]; Advanced energy harvesting technologies for predictive maintenance [20]; Piezoelectric energy harvester applications in advanced sensing technologies [21]; Artificial-intelligence-based methods for piezoelectric energy harvesters [22]; New sources of piezoelectric energy harvesters (acoustics, random vibrations, impact, simple harmonic) [23].

As the knowledge of the guest editors of this special issue, the piezoelectric energy harvesting technology can be used in a multitude of applications; therefore, each implementation needs to optimize the technique for its own needs. Moreover, the development of energy harvesting will play an important role in developing technologies of Structural health monitoring (SHM) by providing energy for the devices such as sensors network which enhances the sustainability of these devices and expands the opportunities for IoT utilization and possible wireless operation of the sensors in sensor networks. Moreover, entering the artificial intelligence (AI) techniques into the procedure of designing, optimization, applications, and analysis of piezoelectric energy harvesting will highly affect the improvement of the modeling and simulation of piezoelectric energy harvesting and overcoming the main drawback in harvesting (low level of harvested power and the need for rectification, maximum power extraction, and output voltage regulation). In this special issue, we collected contributions from active researchers in the field of Piezoelectric Energy Harvesting in mechanical, structural, electrical, materials, and other engineering fields. It will act as a platform for sharing. Furthermore, researchers may give transparent views and indices for their research areas through the challenges and opportunities. In short, this sharing can help researchers to develop new ideas, particularly in the early stages of this research field.

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