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Effective Piezoelectric Energy Harvesting for Self-Supplied IoT Gadgets

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Abstract

Information and Communication Technology (ICT) are integral to Smart Cities (SC). Smart sensor gadgets will leverage 5G and the Internet of Things (IoT), facilitating secure and prompt communication. The demand for sustainable energy sources and autonomous active detectors will persist as a significant challenge in this field. Since their inception, Piezoelectric (PE) Energy Harvesting (EH) devices have exhibited considerable efficacy in powering wireless sensor nodes and their utilization across various systems, such as autonomous vehicles, intelligent healthcare, interfaces between humans and machines, and safety devices, which have been thoroughly examined. PE-EH devices are viable options for sustainably feeding wireless sensor nodes and creating intelligent, self-sustaining sensors applicable in various fields. This study reviews multiple uses of PE-EH for feeding IoT devices and gadgets in SC.

Keywords: Piezoelectric, Energy Harvesting, Internet of Things, Analysis.

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Introduction

Smart Cities (SC) (Kuru & Ansell, 2020) are significant catalysts for innovation across many sectors, including healthcare, environmental sustainability, and Information and Communication Technology (ICT) (Aceto et al., 2019). The future SC utilizes innovative ecosystems to enhance its residents' overall quality of life. SC aims to transform rural and urban areas into democratic creativity centers, where innovation ecosystems enhance user-citizen groups' shared intelligence and collaborative capabilities to create inventive homes and work environments. SC is at the forefront of open, user-driven development to showcase the advantages of future internet-enabled services. SC is constructed and enhanced with modern ICT infrastructure and Internet of Things (IoT) (Ivushkina et al., 2019) gadgets. The IoT is recognized as a fundamental component of ICT, defined as an extensive network structure that facilitates information sharing and connectivity with physical entities, such as electric vehicles or drones, and virtual "objects."

The IoT comprises digital technology, semantic tongues, and virtual identity (Sethi & Sarangi, 2017). The IoT improves the reliability and efficiency of the functioning and management of intelligent environments. Implementing smart monitors enabled patrons to receive immediate data while awaiting a parking space, decreasing wait times. Intelligent sensors gather information that can be transmitted to gadgets via a wireless connection and special software. A smart grid that can manage variable power sources will be essential for future SC. One of the primary objectives is to utilize local Renewable Energy Sources (RES) (Ang et al., 2022) to the greatest extent possible.

RES and batteries can be implemented on a broader scale in urban areas as an integral component of a system like this. They will be capable of interfacing with the grid to supply and store electricity in response to fluctuations in demand. Small-scale Energy-Harvesting (EH) structures (Amer et al., 2020), particularly vibration-based cultivators, have garnered significant academic interest in recent decades. Due to the intricacy of energy networks in urban centers, managing energy is a primary process challenge. SC seeks to improve inhabitants' quality of life by employing technology to handle resources. The principal function in SC is fulfilled by advanced and innovative systems that streamline and enhance urban processes. Such systems can employ sophisticated gadgets capable of automatically monitoring and controlling urban facilities. Over the previous decade, several applications have been implemented alongside solutions to associated issues. Renewable EH machines are technologies used in these cities, reducing the negative impact on the natural world. Studies have devised numerous techniques for extracting energy from various sources, including sunlight, wind, thermal, kinetic, and vibrational energy. Researchers have investigated converting kinetic energy from external sources, including humans, wind or airflow, and water currents or waves.

Related Works

Some scientists have endeavored to affix Piezoelectric (PE) materials (Klimiec et al., 2020) onto human skin or wearing garments. At the same time, other groups have sought to develop an EH gadget capable of generating vibrations from various bodily movements. The study assessed PE uses, focusing on methods that yield high-power outputs while ensuring a broad operational spectrum.

Through mathematical modeling and experiments, the research demonstrated the efficacy of PE-EH devices utilizing non-linear and linear vibrating drivers. The power produced was proportional to the variations in stimulation and reaction phases. The investigation assessed a prototype of PE vibration-based EH utilizing ceramics or polymeric as foundational materials and examined the consequences of this research (Mishra et al., 2019). The research focused on the non-linear resonance wavelengths and the expansion of the spectrum of PE-EH, in addition to analyzing the non-linear effects in vibration systems. The study introduced a method for improving ambient energy conversion and adjusting the resonant resonance. Frequency synchronization is essential to enhance the efficacy of EH systems. Utilizing electrical properties assessed under diverse bending situations, the study illustrated the application of the longitudinal PE action to develop an impermeable and self-sustaining sensor. The findings indicate that electrical properties exhibit a linear relationship with voltage and a reverse square root relationship with power.

To illustrate energy conversion management, researchers conducted tests to ascertain the fundamental principle of dipole motions in polymer-based PE substances. The internal resistance of equipment and the devices' sampling frequency significantly influenced the energy transfer mechanism. Several investigations were conducted in the past year to enhance power generation and optimize the efficiency of harvesting machinery. Three primary methodologies have been utilized to develop PE-EH machines. The initial task involved selecting an appropriate working mode, the subsequent task entailed modifying substances, and the final task was changing the harvester's architecture. PE harvesting machines operate in two distinct modes: style 33 and style 31. The study examined the distinctions between two operational modes of a cantilever-based PE elements device. The Method 31 devices exhibited more significant

power generation and open-circuit average value than the Mode 33 devices; however, they demonstrated a minor frequency of resonance and maximal voltage in open circuits compared to the Style 33 gadgets.

Uses of PE Technology in SC

Numerous sources of vibrations and movement in SC are utilized to collect energy. The kinetic energy generated by human motion, wind and atmospheric pressure in automobiles, waves from the sea, and pressure from the water, construction sites, bridges, and highways can be directly transformed into electrical energy by PE-EH devices. This section will go over and debate several studies of the sources above.

Human emotions are a potential power source in SC. The study examined the applicability of PE-EH systems in the biomedical field. The motionless force generated by humans through muscular unwinding, physical activity, circulation of blood, lung expansion, and heart motion can be transformed into electricity utilizing the designs they create. The investigators asserted that, in certain instances, obtaining a maximum current of 10 V and an energy density of 0.25 W/cm² is feasible. PE harvesters can be utilized in wearable devices, including footwear, apparel, and timepieces. Several harvesting machines have been developed to generate electricity from arm movements. The kinetic energy generated by motion components can be transformed into electrical energy retained by the wristwatch's integrated micro-generators. Walking is a prevalent activity among humans as it results in significant displacement.

PE substances have been engineered to capture energy generated by ambulation, either by integrating them into footwear to collect energy from the weight of humans or by affixing the energy source to a foot or leg to be stimulated by the motion of walking or swinging. Future applications of generated energy include charging mobile phones and sterilizing devices. The double-pendulum device is utilized as an example to enhance the efficiency of energy collecting from human ambulation. A study examined an energy source integrated into a shoe comprising three harvesting units.

A wearable gadget extracts power from a shoulder bag by replacing the bag's harness with a harness. The electrodes placed on the strap's surface were fabricated utilizing an electrostatic self-assembling technique, ensuring the strap's capacity to endure substantial loads. The findings indicated that this gadget could capture around 41.2 mW. A flight of stairs was constructed separately from human activity to EH. The excitement was contingent upon the walking surroundings and the individual's characteristics. A study devised a PE power harvester to capture power from bikes during operation in SC. The investigation examined the feasibility of harnessing human walking power in the libraries. They concentrated on the building sections exhibiting the highest levels of activity. The optimal sites for electricity generation were identified as the café, unconventional meeting rooms, and the main entryway. Pave Gen panels EH from people walking on the pathway.

Their dimensions and installation method dictated the quantity of tiles. The optimal deployment approach was selected depending on the extent and duration of the paths since the ceramic tiles were configured in longitudinal and lateral orientations. The research investigated the incorporation of PE cymbal harvesters into 28-cm-diameter pavement for the first time. Every cymbal was found to generate up to 15 W of power from the path of a single heavy vehicle. Upon the incorporation of 31k cymbals along a 120 m segment of roadway, the resultant energy output ranged from 45 to 60 MW h/m, approximately translating to 80 MW annually. The findings indicate that vehicular movement on spans can produce sufficient vibrations to serve as a source of motion energy. A study demonstrated that these devices can capture up to 14.2 mW of energy. Experiments were conducted to demonstrate the functionality of wireless devices utilizing energy captured from the vibrations of a low-traffic rural roadway bridge. Research on road energy collecting has examined the electrical conversion characteristics of PE materials used in roadways, demonstrating its feasibility.

In a separate instance, PE generators energize the transmitters, monitoring insect motions. The study used a diminutive PE power gatherer, a battery-free 5.6 GHz sender, and a compact antenna on 92 mg bees. The gatherer generated over 2 V, sufficient to power the communication device. A study developed and constructed a compact PE power harvester capable of extracting energy through the wing movements of green June bugs. The microgenerator was a non-resonant PE bimorph functioning in d31 mode. They asserted that an ultimate power draw of 115 W could be obtained from insect motion. A direct link between the bugs' flight musculature and the microgenerator can enhance power production. Employing harvesters that produce PE energy enables the monitoring of insect activities in prospective SC.

Conclusion

Contextual EH resources in SC have generated significant interest due to their ability to supply power for small micro-electronic gadgets and real-time IoT sensors. PE substances are excellent choices for this application. The present

study examines and evaluates contemporary PE-EH technologies for kinetic power sources. Research concentrating on harvesting PE power from diverse sources, including wind, sea, vehicles, transportation facilities, and individual and animal motions, was elucidated to validate the feasibility of employing electric power harvesting machines to energize sophisticated IoT uses in SC. The settings for operation and mechanical structures of different sources of energy were explained. Enhanced construction, suitable supplies, and efficient power management circuitry are empirically demonstrated to augment output power. Recent developments in SC assistance services have been achieved through IoT sensors and uses, potentially enhanced by superior PE-EH equipment.

References

Kuru, K., & Ansell, D. (2020). TCitySmartF: A comprehensive systematic framework for transforming cities into smart cities. *IEEE Access*, *8*, 18615-18644. https://doi.org/10.1109/ACCESS.2020.2967777.

Aceto, G., Persico, V., & Pescapé, A. (2019). A survey on information and communication technologies for industry 4.0: State-of-the-art, taxonomies, perspectives, and challenges. *IEEE Communications Surveys & Tutorials*, *21*(4), 3467-3501. https://doi.org/10.1109/COMST.2019.2938259.

Ivushkina, E. B., Alieva, N. Z., Kushnir, I. B., & Kalmykova, O. M. (2019). The internet of things as a precondition of development of the ICT global infrastructure. *Ubiquitous Computing and the Internet of Things: Prerequisites for the Development of ICT*, 1003-1009. https://doi.org/10.1007/978-3-030-13397-9_104.

Sethi, P., & Sarangi, S. R. (2017). Internet of things: architectures, protocols, and applications. *Journal of electrical and computer engineering*, *2017*(1), 9324035. https://doi.org/10.1155/2017/9324035.

Ang, T. Z., Salem, M., Kamarol, M., Das, H. S., Nazari, M. A., & Prabaharan, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. *Energy strategy reviews*, *43*, 100939. https://doi.org/10.1016/j.esr.2022.100939.

Amer, A. A. G., Sapuan, S. Z., Nasimuddin, N., Alphones, A., & Zinal, N. B. (2020). A comprehensive review of metasurface structures suitable for RF energy harvesting. *IEEE Access*, *8*, 76433-76452. https://doi.org/10.1109/ACCESS.2020.2989516.

Klimiec, E., Kaczmarek, H., Królikowski, B., & Kołaszczyński, G. (2020). Cellular polyolefin composites as piezoelectric materials: Properties and applications. *Polymers*, *12*(11), 2698. https://doi.org/10.3390/polym12112698.

Mishra, S., Unnikrishnan, L., Nayak, S. K., & Mohanty, S. (2019). Advances in piezoelectric polymer composites for energy harvesting applications: a systematic review. *Macromolecular Materials and Engineering*, *304*(1), 1800463. https://doi.org/10.1002/mame.201800463.