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A Hybrid System for Converting Thermal and Optical Energy to Power Internet of Things Nodes

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Abstract

Efficient power supply for Internet of Things (IoT) devices remains a challenge, demanding innovative solutions for sustainable and self-sufficient operation. This article presents a comprehensive exploration of a hybrid energy harvesting system designed to convert both thermal and optical energies into electrical power for IoT nodes. By integrating thermoelectric and photovoltaic technologies, this system harnesses diverse energy sources, enabling continuous, reliable, and environmentally friendly power generation for IoT applications. The review encompasses the working principles, design considerations, and potential applications of this hybrid system, highlighting its transformative potential in powering IoT nodes in various environments.

Keywords: Energy harvesting • Hybrid system • Thermal energy

Introduction

The proliferation of Internet of Things (IoT) devices across various domains necessitates sustainable and autonomous power solutions to ensure uninterrupted operation. Traditional power sources often fall short in meeting the energy demands of these devices, prompting the exploration of innovative energy harvesting systems. This article introduces a hybrid energy harvesting system that converges thermal and optical energies to power IoT nodes, addressing the challenges of sustainability and self-sufficiency in powering these devices. The system incorporates thermoelectric generators (TEGs) to harness thermal gradients and convert waste heat into electrical power using the Seebeck effect. Optimization of TEG materials and configurations enhances energy conversion efficiency. Photovoltaic cells integrated into the hybrid system capture optical energy from ambient light, converting it into electrical power. Enhancements in photovoltaic technologies focus on improving efficiency and adapting to varying light conditions [1].

Literature Review

The core of the system involves a hybrid unit that intelligently combines the outputs from thermoelectric and photovoltaic modules. This synergy optimizes power generation by effectively utilizing both thermal and optical energy sources. Efficient power management circuits and energy storage solutions, such as supercapacitors or rechargeable batteries, ensure steady power supply to IoT nodes. Adaptive algorithms regulate energy flow to match device requirements and storage conditions [2]. The hybrid energy harvesting system finds application in IoT sensor networks deployed in remote or harsh environments, enabling self-sufficient and long-term operation without relying on external power sources.

The compact and adaptable nature of the hybrid system facilitates its integration into wearable IoT devices or embedded sensors, ensuring continuous power supply from ambient heat and light. Deployment in environmental monitoring systems and smart infrastructure allows for sustainable, autonomous operation in remote or infrastructure-challenged areas, facilitating data collection and analysis [3]. Advancements in nanomaterials and nanostructuring techniques enhance the performance of both thermoelectric and photovoltaic components, boosting energy conversion efficiency and scalability.

Further advancements focus on maximizing energy conversion efficiency, especially in low-grade thermal environments, and scaling up production for commercial viability. Miniaturization efforts aim to reduce the footprint of the hybrid system, enabling seamless integration into small IoT devices and expanding its applicability [4].

Discussion

Advanced hybrid systems explore the integration of multiple energy sources beyond thermal and optical, such as kinetic or vibrational energy, enabling more diverse and robust power generation for IoT devices. Tandem or cascade configurations combining multiple energy harvesting mechanisms, like thermoelectric and photovoltaic, enhance overall efficiency by sequentially capturing different energy spectra and reducing energy loss [5].

Innovations in energy harvesting systems aim to enable self-powered sensing and actuation in IoT devices. This involves developing mechanisms to efficiently utilize harvested energy for both data collection and device operation. Hybrid systems are optimized to harvest energy from diverse ambient sources, including body heat, sunlight, indoor lighting, and environmental heat gradients, ensuring a continuous power supply for IoT devices across varied settings [6]. Integration of hybrid energy harvesting systems contributes to the development of energy-aware IoT networks. These networks optimize power consumption and distribution, ensuring prolonged device operation without manual intervention. Deployment in extreme or remote environments, such as industrial plants or rugged terrains, showcases the robustness and reliability of hybrid energy harvesting systems, enabling sustained IoT operations in challenging conditions.

Conclusion

The integration of thermal and optical energy harvesting in a hybrid system presents a promising solution to the power challenges faced by IoT nodes. This

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innovative approach offers sustainability, autonomy, and reliability, unlocking new possibilities for uninterrupted operation in various IoT applications. Continued research, technological advancements, and interdisciplinary collaboration will drive the evolution of hybrid energy harvesting systems, paving the way for a more energy-efficient and interconnected IoT landscape. Hybrid energy harvesting systems hold immense promise in addressing the power challenges faced by IoT devices, ensuring sustainable and uninterrupted operation. Innovations in materials, system designs, and integration methodologies are driving the advancement of these systems, paving the way for a future where IoT devices operate autonomously and efficiently in diverse environments. Continued research endeavors and technological innovations are expected to further strengthen the role of hybrid energy harvesting systems in powering the next generation of IoT ecosystems.

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Conflict of Interest

None.

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