HYBRID ORC–TEG SYSTEMS FOR MULTI-LEVEL HEAT RECOVERY

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1. Introduction

Hybrid Organic Rankine Cycle (ORC)–Thermoelectric Generator (TEG) systems are advanced technologies designed to maximize waste heat utilization in buildings. The ORC stage converts medium-temperature heat into electricity, while the TEG stage captures residual lower-temperature heat, providing a two-stage energy conversion process that enhances overall system efficiency [1,2]. This approach contributes to greater energy autonomy, reducing reliance on grid electricity and improving building sustainability [3]. While hybrid ORC–TEG systems require precise design, thermal management, and integration with building energy systems, they offer significant advantages, particularly in buildings with fluctuating thermal loads, such as hospitals, hotels, and large office complexes. Optimisation of working fluids, thermal cycling, and module placement can further enhance energy recovery and operational efficiency ([2,4].

2. Scopus

The purpose of this study is to review hybrid ORC–TEG system applications and assess their energy efficiency, CO_2 reduction, and economic benefits in building environments.

3. Methodology

Hybrid ORC–TEG systems were analysed using case studies and simulations to evaluate electricity generation, HVAC support, and thermal efficiency. Thermal profiles, electrical output, and optimisation strategies such as alternative working fluids and TEG thermal management were assessed to quantify energy savings, CO_2 reductions, and operational cost improvements [1-4].

4. Results

The hybrid ORC–TEG system demonstrated substantial improvements in building energy performance. Total electricity production increased from 1.5 MW with ORC alone to 1.9 MW when TEG modules were integrated, representing a 27% increase in output [1]. Overall system efficiency reached 35–45%, significantly higher than ORC-only configurations [3]. TEG modules contributed approximately 10% of the building's HVAC heating demand by recovering residual low-grade heat [4]. Alternative working fluids enhanced ORC efficiency by 8–12%, while thermal optimisation improved TEG output by 20%, demonstrating the importance of system design and heat management [2]. The hybrid system also reduced the building's CO_2 emissions by 28%, supporting environmental sustainability goals. Operational costs decreased by 15%, mainly due to reduced electricity demand from the grid and better utilisation of waste heat [3]. In addition, the system provided improved seasonal flexibility, maintaining stable efficiency across different thermal loads. The ORC stage handled medium-temperature heat efficiently, while the TEG stage recovered lower-temperature waste heat that would otherwise be lost. This two-level heat recovery approach allowed continuous energy support for building operations, contributing to both electricity and heating demand simultaneously. The combined effect of these improvements highlights the system's ability to deliver economic benefits, environmental impact reductions, and enhanced energy autonomy, particularly in buildings with variable and continuous thermal loads [1-4}

5. Conclusions

Hybrid ORC–TEG systems efficiently utilise multi-level waste heat, increase electricity production, support HVAC heating, reduce CO_2 emissions, and lower operational costs. Optimisation of working fluids and thermal management is key for maximum performance, making these systems suitable for buildings with variable and continuous thermal loads.

References:

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