Thermophotovoltaic (TPV) System Design for Terrestrial Ghost Core Reactors

Introduction

"Ghost Core" reactors are a hypothetical class of high-temperature, grid-scale reactors (100-500 MW_e) that produce intense thermal radiation for power generation. Instead of conventional steam turbines, these systems use thermophotovoltaic (TPV) converters to directly convert heat to electricity. TPV systems offer direct, emission-free, high-efficiency power with cogeneration potential for water and agriculture.

Maximizing TPV Conversion Efficiency

Selecting the right photovoltaic material is crucial to match the Ghost Core's thermal emission spectrum. The reactor's core emits in the infrared, so TPV systems must tune the semiconductor bandgap accordingly. Multi-junction TPV cells can convert multiple wavelength bands, boosting total efficiency beyond 40%. Spectral filtering, photon recycling, and selective emitters ensure unused photons are reflected back to the core instead of lost as heat.

Coastal Deployment Configuration

A coastal Ghost Core TPV plant uses ocean water for efficient cooling and desalination. The warmed seawater from TPV cell cooling is routed into a multi-effect distillation system to produce fresh water. This enables a single facility to supply clean electricity and potable water with no carbon emissions.

Inland Deployment Configuration

Inland TPV plants use air and ground-based cooling methods, supplemented by underground heat exchangers. Additionally, reactor waste heat is used to warm greenhouses, allowing year-round agriculture in cold climates. This model combines energy and food production, supporting resilient local ecosystems.

Feasibility and Outlook

TPV conversion is now viable at grid-scale due to advancements in multi-junction cells, spectral management, and thermal materials. With proper design, a Ghost Core reactor can provide not just electricity but water and heat, making it a next-generation clean energy ecosystem. Further development could bring these systems to life in both coastal and inland regions, directly impacting energy and climate resilience.