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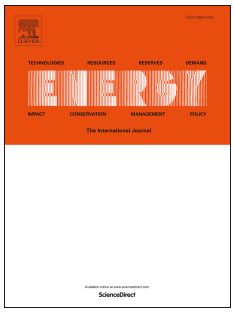

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Optimal Sizing of Hybrid Energy Storage Sub-systems in PV/Diesel Ship Power System Using Frequency Analysis

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***Abstract*—Owing to the increasing concerns about the release of pollution by traditional ships, the use of the renewable energy in ships' power systems is attracting much attention. However, an improperly designed renewable generation system and energy storage system (ESS) will increase costs and greenhouse gas emissions. This paper proposes a mathematical model of a photovoltaic (PV) power generation system for a ship, taking into account the effects of ship rolling. A PV system on the shipboard, unlike one on land, has to confront dramatic power fluctuations that are caused by the motions of the ship and bad weather, so hybrid ESSs play a significant role in a ship's power system. In this work, the discrete Fourier transform (DFT) is employed to decompose the required balancing power into various time-varying periodic components, which are utilized to calculate the maximum required power of the hybrid energy storage systems. A cost analysis is performed using particle swarm optimization (PSO) algorithm to optimize the size and capacity of various types of energy storage systems. Simulation results reveal the efficiency of the optimal allocation of the ESSs.**

***Index Terms*—Hybrid energy storage system, photovoltaic generation, ship rolling, discrete Fourier transform, particle swarm optimization.**

Nomenclature

Acronyms

CRF	capital recovery factor
DFT	discrete Fourier transform
ESS	energy storage system
FFT	fast Fourier transform
GA	genetic algorithm
HESS	hybrid energy storage system
IMO	international maritime organization
PSO	particle swarm optimization
PV	photovoltaic

Variables