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Optimized controllers for stabilizing the frequency changes in hybrid wind-photovoltaic-wave energy-based maritime microgrid systems

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HIGHLIGHTS

- Maritime Microgrid system is designed for investigations with RE & storage units.
- PV, Wind, MBG, AWPG, SOFC, and battery storage units are considered.
- 2DOF-TIDN controller is developed to mitigate the changes in the system.
- The AOA method is proposed for optimal gains of the 2DOF-TIDN under uncertainties.
- Sensitivity analysis, Time delay analysis, and stability analysis are performed

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ABSTRACT

Reducing the dependence on traditional energy sources and shifting towards the utilization of renewable energy sources (RES) of energy in the maritime sector is imperative for reducing greenhouse gas emissions. Inherently, RES sources like solar and wind are intermittent and variable, resulting in inconsistent power availability and hence leading to energy supply fluctuations and potential shortages. In this respect, an efficient control strategy to maintain system stability and address intermittency effectively is essential. This work considers a hybrid marine microgrid with various energy sources like photovoltaics (PV), wind energy conversion system (WECS), marine biodiesel generator, Archimedes wave power generation, solid oxide fuel cell, and batteries. A 2-degree of freedom (2DOF) structure is designed and implemented with the tilt-integral-derivative filter (TIDN) to address frequency variations. Furthermore, an Archimedes optimization algorithm (AOA) is used to optimize the 2DOF-TIDN controller. The stability of the proposed microgrid system is assessed under various combinations of RES availabilities, including real-time data from WECS and PV. The AOA-based 2DOF-TIDN performance is compared to the following algorithms: genetic, Jaya, bat, grasshopper optimization, particle swarm optimization, and moth flame optimization. Simulation results obtained show that the AOA-based 2DOF-TIDN control strategy achieves shorter settling times in mitigating the changes of marine microgrid systems under different dynamic conditions as compared to the other algorithms. Finally, the controller being proposed in this paper was tested for robustness with parameter deviations of +25%, −20%, and − 40% from the nominal values, and proved to be the proposed 2DOF-TIDN controller parameters demonstrate significant robustness in effectively managing the uncertainties and parametric variations.

1. Introduction

Air pollution results from burning fossil fuels in ship engines, which discharges contaminants into the atmosphere. Ship emissions, which include greenhouse gases (GHGs) such as carbon dioxide (CO2), Sulphur oxides (SOx), particulate matter (PM), and nitrogen oxides (NOx), can have a detrimental effect on ecosystems and human health. The maritime sector contributes to 2.9% of the global greenhouse gas emissions [1]. Ocean acidification, fluctuating ocean temperatures, rising sea levels, and altered weather patterns are all impacts of climate change

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