Optimal Sizing of Marine Renewable Energy Microgrids under Resource Uncertainties.

Oluwabunmi Iwakin[1,4], Mehregan Gilani Nejad[3,4], Daniela Villacres[1,4], Faegheh Moazeni[*,1,4], Javad Khazaei,[2,4], and Arindam Banerjee[3,4]

[1] *Department of Civil and Environmental Engineering, Lehigh University, Bethlehem, 18015, PA, USA*
[2] *Department of Electrical and Computer Engineering, Lehigh University, Bethlehem, 18015, PA, USA*
[3] *Department of Mechanical Engineering and Mechanics, Lehigh University, Bethlehem, 18015, PA, USA*
[4] *Atlantic Marine Energy Center, Lehigh University, Bethlehem, 18015, PA, USA*
[*] moazeni@lehigh.edu

Abstract:
Coastal microgrids powered by renewable energy sources offer sustainable and resilient solutions for meeting energy demands in geographically disadvantaged coastal regions. Their high complementarity makes them a cost-effective alternative to conventional energy sources, particularly with the growing interest in harnessing coastal wave energy through wave energy converters (WECs) to enhance renewable energy penetration. However, the inherent variability of solar, wind, and wave resources introduces significant uncertainty in system design and operation, particularly at high penetration. This study presents a stochastic optimization framework for the optimal sizing of a hybrid solar-wind-wave coastal microgrid, accounting for resource intermittency and system constraints. The framework integrates a multi-period optimization strategy with a techno-environmental economic analysis to minimize the expected levelized cost of energy (LCOE) while ensuring system reliability and environmental sustainability via emissions costs. Key constraints, including resource availability, energy storage capacity, and operational limits, are incorporated to enhance the microgrid performance under diverse conditions. The effectiveness of the proposed methodology is demonstrated through case studies on a coastal microgrid in New Jersey Shore subject to varying climatic conditions. The findings highlight critical trade-offs between cost, reliability, and renewable energy utilization, providing valuable insights into the design of robust and adaptive microgrid systems. This study contributes to the development of resilient coastal energy infrastructures with well-informed technical specifications that can withstand uncertainties while promoting sustainability and reducing dependence on fossil fuels.