Integrated Thermal-Electric Energy Management of All-Electric Ship with Advanced Nuclear Reactors

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Program: RC-1.3: Implementation Consideration for Alternative Applications of Advanced Nuclear Reactors

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ABSTRACT:

Maritime shipping is transporting more than 80% of the world's commodities and global trading operating with more than 53,000 active cargo vessels in the oceans. Different solutions to combat global warming as long-term zero-emission plans for maritime transportation have been explored, and nuclear-powered ships have promising advantages in terms of energy efficiency and fuel costs. This project is to explore the novel application of advanced nuclear reactors in future ships to supply the propulsion and other energy demands onboard, which is expected to contribute a low-carbon maritime transport industry by eliminating the use of 5 billion barrels oil every year and reduce the shipping industry's carbon footprint.

With the ship Integrated Power System (IPS) structure, the prime mover, i.e., nuclear reactor, is coupled with the generators being capable of producing large amounts of electric power. A large portion of electric power can be used for electric propulsion and its advanced power electronics drives, and other regular ship service loads. **The overall objective of this project is to** comprehensively model, design, and evaluate the use of advanced nuclear reactors in future nuclear-powered ships with IPS, to enhance the efficiency, reliability, and resilience of shipboard energy distribution systems. **The novelty of the proposed approach lies in** (i) integrated thermal-electric modeling of advanced nuclear-powered shipboard energy system, (ii) novel solutions for total-ship energy management to improve the energy efficiency and prevent catastrophic failures in electric propulsion and other vital systems, and (iii) the integration of advanced nuclear-powered ships with the terrestrial power grid to enhance the power network resilience during disruptive events. To realize these novel contributions, we have outlined a research plan with the following four major research tasks.

- Task 1: Integrated Thermal-Electric Modeling of Nuclear-Powered Ships: This task will focus on model development of the multi-energy nuclear-powered ship energy system considering operation, dispatch, and real-time control of the onboard electrical, thermal, and cooling systems.
- Task 2: Total-ship Optimal Operation and Energy Management: This task is to develop an optimal operation framework for the coupled thermal-electric energy system, to be used in the dispatch engine and supervisory control.
- Task 3: Terrestrial Power Grid Resilience Enhancement via Ship-to-Grid: This task will develop a coordinated framework of connecting advanced nuclear-powered ships with the terrestrial power network to enhance the power network resilience during disruptive events.
- Task 4: Hardware-in-The-Loop (HIL) Test: This task will test the proposed thermal-electric energy system control for the nuclear-powered ship with an HIL system.