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Nonlinear Power Flow Control Design Methodology for Navy Electric Ship Microgrid Energy Storage Requirements

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As part of the U.S. Navy's continued commitment to protecting U.S. interests at home and abroad, the Navy is investing in the development of new technologies that broaden U.S. warship capabilities and maintain U.S. naval superiority. In particular, NAVSEA is supporting the development of power systems technologies that help the Navy realize an all-electric warship. In support of this effort new nonlinear power system controls approaches are being developed to improve system performance in light of new electrically powered weaponry that behave as pulsed loads. Preliminary advancements include the identification of pulse load profiles that have aided in guiding the identification of energy storage requirements. A dynamic optimization engine has been developed and serves as the feedforward receding horizon control portion of the HSSPFC (Hamiltonian Surface Shaping and Power Flow Control) feedback controls for the energy storage portion of the networked microgrid system. Several numerical simulation experiments were conducted that contrasted the trade-offs between conventional energy storage available on the bus EM (Energy Magazine) versus individual energy storage associated with each mission load. The identification of an experimental definition of a CWP (Coalition Warfare Program) exemplar test scenario has been selected. Both detailed and Reduced Order Models (ROM) Simulink simulation models have been created that include multiple mission pulses load profiles. These models support the determination of energy storage system requirements. Multiple pulse load shaping optimization techniques have been created to reduce oscillations or ringing incurred during overlapping mission load profiles and minimize power/energy storage requirements on the electrical side. This optimization development is utilized in the feedforward planning of the HSSPFC feedback controls for the energy storage portion of the CWP single DC microgrid system. Several numerical simulation experiments demonstrate the contrasts and trade-offs between conventional energy storage available at each mission load versus energy storage on the bus EM. The main goal is to minimize energy storage size and weight while maintaining power system performance. This includes real-time simulator validations as a proof-of-concept.