Modeling and Control of a Boiling Water Small Modular Reactor Cogeneration System for District Heating Applications

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This paper proposes a novel approach for modeling and controlling a Small Modular Reactor (SMR) cogeneration power plant for District Heating Network (DHN) applications, aimed at decarbonizing energy systems and enhancing power grid flexibility. Existing studies do not adequately address key aspects of the dynamic modeling and control of SMR-based DHN cogeneration plants, including insufficient representation of piping heat losses, thermal delays, fluctuations in DHN thermal demand, and the lack of multi-timescale dynamic analyses. Thus, this work proposes dynamic models and control strategies for SMR-based DHN cogeneration systems, incorporating detailed thermoelectric modeling that addresses the current modeling shortcomings to allow for the assessment of system stability over both short- and long-term horizons to properly evaluate transient and steady-state performance. Furthermore, the paper assesses the SMR-based DHN cogeneration system by examining its dynamic interactions with the Electric Power Network (EPN) and DHN under realistic scenarios to support industry-driven control design and operational decisions. In this context, the proposed model and controls are validated using the boiling water reactor BWRX-300 being integrated into the power grid of Ontario, Canada, considering a potential DHN deployment in the Darlington region. The results highlight the strong potential of SMRs for cogeneration, demonstrating their operational flexibility in a practical application and illustrating a significant reduction in energy consumption compared to heating systems based on solely Heat Pumps (HPs), considering that existing government policies in Ontario, like in other jurisdictions, are incentivizing the replacement of fossil fuel-based space heating systems with HPs.

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