Title: Power System Simulations to Analyze the Flexible Operation of Small Modular Reactor-Based Nuclear Power Plants for Electricity and Energy Applications (Heating and Hydrogen Production)

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Abstract: Nuclear power has traditionally served as a baseload power source, but the evolving energy landscape demands greater operational flexibility. Small Modular Reactors (SMRs) present a promising solution, not only for power generation but also for enhancing grid stability by complementing variable renewable energy sources. The increasing penetration of intermittent generation, such as wind and solar, shifts the load curve and introduces challenges that require nuclear power plants to dynamically adjust their output. However, frequent control rod adjustments to enable flexible operation can lead to issues such as thermal fatigue, accelerated component aging, erosion and corrosion of hydraulic systems, core power redistribution, and fission product poisoning. These challenges underscore the need for an optimized control rod strategy. This study explores alternative methods to enhance operational flexibility in SMRs, including the integration of bypass systems to manage minor fluctuations and the utilization of variable thermal and electrical loads to balance excess steam generation. One approach involves directing surplus thermal energy toward district heating, ensuring efficient heat utilization while maintaining reactor performance. Another strategy leverages surplus energy for hydrogen production via electrolysis, promoting sector coupling and expanding nuclear energy's role beyond electricity generation. By adopting these approaches, SMRs can play a crucial role in creating a resilient, adaptive and sustainable energy future.