Modeling and Control of Nuclear-Renewable Integrated Energy Systems for Electricity and Hydrogen Production

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The rapid depletion of fossil fuels along with the phenomenon of climate change has intensified the need for green resources to produce various forms of energy for daily consumption. Nuclear and renewable resources are important players in this global effort towards minimizing the carbon footprint. Additionally, energy security and resilience are also critical in a developed society where economy and quality of life rely on energy availability. Diversification of energy resources along with decarbonization is hence the future of sustainable energy. In this context, in an integrated energy system (IES), the different sectors of energy are coupled to exploit the full potential of the clean energy mix. Besides flexibility, energy efficiency is yet another benefit of integrating the different sectors. Physics based modeling and simulation are used to evaluate the behavior and response of the individual units and overall system to varying parameters. Considering the different forms of energy and material transfer within the IES, it is pertinent to utilize a modeling tool which is suitable across different domains and represents the physical system with sufficient fidelity.

The Modelica language is deemed to be suitable for capturing the IES behavior and evaluating the control strategy of the IES to follow the demand while satisfying the safety limits.

In this study, we will present one such IES where the nuclear reactor, particularly the small modular reactor, functions as the primary heat supply system for various end uses, and the renewable generation in the form of wind and solar plants supply variable electricity. The utilities of the IES include electricity supplied to the power grid and an industrial plant producing hydrogen. As is evident, the IES requires modeling of different components in the thermal, hydraulic, and electrical domains. The Dymola environment is utilized for the IES model development using the Modelica language. Further, the control strategy of the overall system and the individual control units is tested for different case studies. The simulation results which provide a close-to-real characterization of the system behavior can be used to analyze the impact of varying parameters (such as electricity demand, renewable generation, and hydrogen demand) on the dynamic performance of the IES.

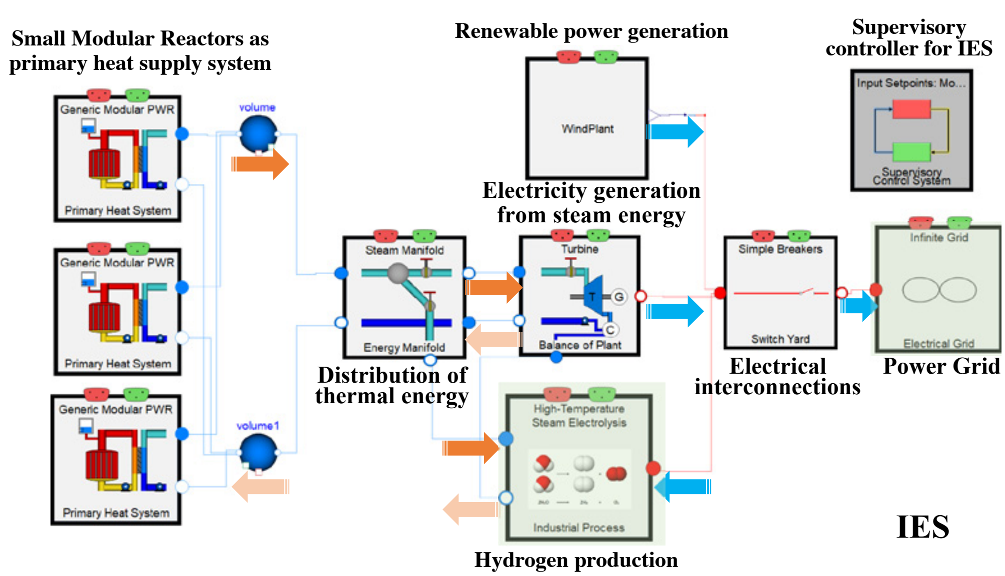

Figure 1. Top level view of the multi-domain IES model architecture in Dymola with component description