Reinforcement Learning-Based Control of Integrated Energy Systems using ModelicaGym

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The concept of integrated energy systems (IES) is gaining popularity owing to energy efficiency and security imparted by coupling different forms of energy sources and services. Concurrently, the energy industry has also been transitioning towards green resources such as nuclear, wind, and solar. Traditional nuclear reactors function as base load centralized plants and are not considered as a suitable source for localized energy production. However, with the development of advanced reactor technology such as the small modular reactors (SMRs), the utilization of nuclear for distributed energy production is attaining momentum. Considering the multi-domain interactions in such systems, Modelica language is a suitable tool for model development and designing the control infrastructure. The physical system is driven by suitable control mechanisms on valves and pumps, which is further overseen by a supervisory controller. Conventional PID controllers are used in these models, which are known to be reliable and exhibit simple control strategies. These controllers, however, perform poorly during large perturbations in operating state during disturbances, and in systems with high non-linearity. In view of the complex interactions in the IES, and the uncertainty associated with operating conditions, it may be more suitable to adopt an intelligent control scheme which is adaptive to variations in both plant and environment. Reinforcement learning (RL) based controllers have been garnering attention in this regard, and can be employed for IES control. Additionally, the RL control mechanism is autonomous, and can be deployed online for real-time control of the IES.

In this study, we will implement an RL control for the IES management, by using the open source ModelicaGym toolkit [1] as a bridge between the physics-based model and the artificial intelligence module. The plant here is an IES encompassing nuclear as the energy source, with electricity and hydrogen as end products. The model is developed using the Modelica language in the Dymola platform. The core of the RL framework is developed in python using the OpenAI Gym. The functional mock up interface (FMI) standard is used to derive a compatible representation of the physical model. The proposed control framework will be used for controlling the valves in two specific subsystems, namely the balance of plant and the industrial plant, to meet the power grid and hydrogen plant demands.

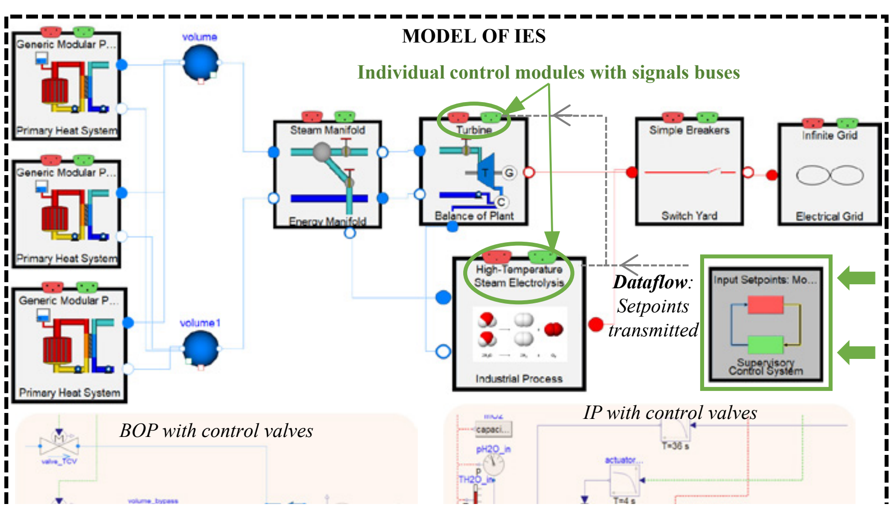

Figure 1. The control infrastructure of the IES modeled in Dymola. Individual control modules are assigned for each subsystem and the overall control objective is achieved by the supervisory controller. Lower level PI controllers are used for valve control.