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Plasma Control Requirements for Commercial Fusion Power Plants: A Quantitative Scenario Analysis with a Dynamic Fusion Power Plant Model

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One aspect of fusion power plant engineering with little insight is the plasma control for electric power generation. At the moment, no model can simulate the behavior of the fusion power plant from the plasma to the turbine generator. Whether the future fusion power plant operation would be load-limit or load-follow, or pulsed or steady state, it is very important to study the relation of the plasma behavior and the plant power output.

In order to obtain fundamental knowledge on the plasma control requirements for the future fusion power plant, the authors constructed a multi-domain dynamic simulation model of a nuclear fusion power plant on Modelica with Thermopower library. This is the first model of its kind that can simulate the power system behavior of a fusion power system.

The model plant was designed to have a tokamak reactor with solid breeder blanket cooled by supercritical water, with the output of 3,627 MWt (thermal) and 1,209 MWe (electric). A steam generator, two steam turbines (higher and lower pressure turbine), a turbine by-pass and a series of condensers were modeled as the power system (1st loop: 323/287 oC 6.85 MPa, 2nd loop: 274/81 oC 1.06 MPa). The power system was controlled by a closed-loop single-input-single-output (SISO) governor and a steam-regulating valve. The power system model was adjusted against the RELAP model of an existing PWR power plant.

The blanket and the diverter of the reactor were modeled as a transfer function of the neutron flux and the heat energy, based on experimental results by JAEA. This model simulates the thermal energy from the neutron flux as well as the decay heat of the system. It should be noted that plasma simulation is not within the scope of this study; the neutron flux was simply handled as an input signal.

The authors simulated several plasma patterns on this model. The plasma operation scenarios were created based on the load-limit and load-follow operation scenarios of SSTR; both short-term (< 10 sec) and long-term (~ 600 sec) fluctuations of the neutron flux were simulated.

Simulation results suggested requirements of the plasma operation in order to control the electric output within +/- 3% of the target for the first time, which is crucial for the commercialization of a nuclear fusion output.

Eligible for student paper award?

Yes

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