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Avoidance control of high-density collapse based on data-driven prediction in Large Helical Device

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Avoidance of radiative collapse in high-density plasma has been attempted in the Large Helical Device (LHD) with a real-time control system based on a data-driven predictor model. The predictor model has been developed based on machine-learning techniques and high-density experiment data in LHD.

In stellarator-heliotron plasma, radiative collapse is one of the most critical issues that limit the performance of plasmas, while the stable high-density operation is an advantage of a helical system over a tokamak. In our previous research, low-Z impurities and edge plasma temperature were extracted as the features of radiative collapse with a machine-learning model and sparse modeling. Using these features, the possibility of the occurrence of the radiative collapse was quantified as the collapse likelihood [a].

A single-board computer, Raspberry Pi 4, has been used as a controller that calculates the collapse likelihood in real-time and alarms when the likelihood exceeds the threshold value, which means the plasma is approaching the collapse. The boost ECH is injected and gas puff fueling is turned off while the alarm signal is issued.

The control system has been applied to the density ramp-up experiment in LHD [b]. In the ramp-up in the early phase of discharge, the predictor detected a radiative collapse. Without control, the plasma was shut down immediately after the detection. When the control system is employed, the boost ECH and turning gas puff off were triggered and the collapse was avoided successfully. After avoidance, the plasma density kept developing moderately. In the latter phase of the discharge with control, collapses were avoided by turning gas puff on/off and the electron density was developed above $1.2 \times 10^{20}\mathrm{m}^{-3}$. It has been also attempted to avoid radiative collapse only with boost ECH by tuning the injection setting.

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References
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