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Model-based vertical position control design and optimization for CFETR tokamak

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The vertical displacement instability is an inherent characteristic of tokamaks using elongated configurations. The uncontrolled growth of this instability will lead to plasma disruption, resulting in discharge termination and damage to the device. Therefore, it is necessary to control this instability. Due to the shielding effect of the vacuum vessel on external coils, full superconducting tokamaks typically use in-vessel coils to produce a horizontal magnetic field for controlling vertical displacement. The control requirements for vertical displacement are strongly related to the plasma current, elongation, and the passive structure of the tokamak. The CFETR tokamak aims for a configuration with a high elongation and plasma current, leading to high vertical displacement control system requirements. In the preliminary design phase [1], analyses were conducted based on the rigid model, and the position of the passive structure and in-vessel coils was determined. Based on the further simplification of the response model [2], a method to estimate the control requirements has been proposed in this work. It provides an estimate of the minimum power required to control a given vertical displacement and its corresponding voltage and current values. Based on this method, combined with optimal control algorithms and ITER-like speed control algorithms, the CFETR vertical displacement controller has been optimized. For the same control of 10% minor radius vertical displacement, the power requirement of the controller, requiring the highest power of 598 MW, has been reduced to 164 MW. Optimized designs of the controller significantly reduce the control requirement, allowing for robust control at lower power levels, which can effectively lower the overall cost of the device.

References:
[1] Li B , Liu L , Guo Y ,et al. Preliminary assessment of vertical instability with blanket in CFETR. Fusion Engineering and Design, 2019, 148:111295.
[2] Humphreys, D.A. et al. Experimental vertical stability studies for ITER performance and design guidance. Nuclear Fusion, 2009, 49 115003.

Speaker's Affiliation

Institute of Plasma Physics, Chinese Academy of Sciences, Hefei

Member State or IGO

China, People's Republic of

Primary author: WANG, Yuehang (ASIPP)

Co-authors: LUO, Zhengping (Institute of Plasma Physics, Chinese Academy of Sciences); HUANG, YAO (ASIPP); Dr YU, Qingze (ASIPP); RUI, Wangyi (ASIPP); XIAO, Bingjia (Institute of Plasma Physics, Chinese Academy of Sciences)

Presenter: WANG, Yuehang (ASIPP)

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