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Machine Learning model for real-time SPARC vertical stability observers

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Given the demanding requirements of the SPARC high-field tokamak (B_{0}=12.2 T) and its operation with high elongated plasma (\kappa_{sep}=1.97), robust real-time-compatible vertical stability observers are paramount. In this work, we present the fast surrogate-based modeling approach for observers (such as energy functional, VDE *n*=0 growth rate, stability margins (m_s), inductive stability margins (m_i), max-Z, and frequency components), integrating advanced 2D electro-mechanical circuit and dynamic plasma response models [1]. These surrogate observers employ transformer-based machine learning techniques; trained to replicate and predict the results of the filamentary semi-rigid body MEQ-RZIp and deformable free boundary MEQ-FGE (and its linearized version FGElin) code suite, as detailed in Carpanese et al. [2]. The training dataset incorporates simulated SPARC primary reference discharge scenarios and the Alcator C-Mod (hot VDEs) 2012-2016 disruption warning database. To enhance robustness, these observers will also be trained over a range of simulated L- and H-mode SPARC plasma scenarios, including periods without and with ELM triggering (via artificial vertical kicks [2]). We will report on the assessment of observers'sensitivity to the underlying RZIp & FGE models and their proximity to stability boundaries; thereby supporting disruption prediction and avoidance.

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References

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