7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Control of resistive wall mode in STEP

Guoliang Xia, Tim Hender, Ruben Otin, Morten Lennholm, Elisee Trier, Hendrik Meyer
UKAEA, Culham Science Centre, Abingdon, OX14 3DB, UK
e-mail (speaker): Guoliang.Xia@ukaea.uk

The Spherical Tokamak for Energy Production (STEP) is a UKAEA programme that aims to deliver a prototype compact fusion energy plant and a commercial pathway to fusion energy.[1] The low aspect ratio spherical tokamak is attractive because of its potential to achieve high-β (where β is the ratio of the volume averaged plasma pressure to the magnetic pressure), since fusion power is $\propto \beta^2$. To fully exploit this, and maximize economic attractiveness, operation above the no-wall beta limit is desirable, where either passive or active control of the resistive wall mode (RWM) is needed, to avoid possible disruptions.

The RWM can be viewed as a residual instability from the ideal external kink (XK) mode, which is a global magnetohydrodynamic (MHD) instability driven by plasma current and/or pressure.[2] For a pressure-driven XK, the stability is determined by the normalized beta β_N. The XK becomes unstable when β_N exceeds the so-called Troyon no-wall limit.[3] A close-fitting perfectly conducting wall can stabilize the XK, resulting in increased β_N. However, in practice the wall will have a finite conductivity and the resulting RWM grows on a timescale characteristic of the field penetration time through the wall. An unstable RWM can potentially reduce the beta limit back to the no-wall Troyon limit.

Understanding and controlling the RWM is a key issue for the optimization of plasma pressure and improving the economic benefit. It was found that passive stabilization of the RWM in STEP gives a relatively small increase in β_N above the no-wall limit, relying on toroidal plasma flow and drift kinetic resonance damping (from both thermal and energetic particles). In order to optimize performance in STEP from an MHD viewpoint, active control of the unstable RWM appears to be a necessity. We use MARS-F[4] code to calculate how to stabilize the resistive wall mode, including different controllers, sensor signal noise and low-frequency filtering.

References
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