Active Control of Alfvén Eigenmodes in Fusion Plasmas

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Alfvén waves are magnetohydrodynamic fluctuations inherent to magnetized plasmas. Gradients in the energetic particles' distribution determine the resonant wave-particle energy and momentum exchange. Burning plasmas in magnetically confined fusion devices are prone to develop Alfvén Eigenmodes (AEs) that, if allowed to grow unabated, can cause an important degradation of fusion performance through fast-ion redistribution. To obtain a self-maintained burning plasma, fusion-born alpha particles must, however, be well-confined. Recent breakthroughs in the diagnosis of the temporal evolution of the energetic particles' phase-space have allowed the identification of wave-particle interactions that lead to a net fast-ion transport enabling the development of dedicated control techniques. Several external actuators have shown their potential to mitigate or even suppress the AE activity and associated fast-ion transport in tokamaks and stellarators. Most control techniques aim at modifying the background kinetic and current profiles. Recent experimental results have shown, however, that an active control of the fast-ion distribution, i.e. AE drive directly, can be a robust and promising technique towards future burning plasmas. Externally applied 3D fields and heating systems provide an excellent tool to tailor the fast-ion distribution in phase-space, thus modifying their drive/damping through local wave-particle interactions. Non-linear 3D hybrid kinetic-MHD simulations help to identify the wave-particle resonances responsible for the observed AE drive/transport improving our ability to develop robust control techniques for future burning plasmas. Recent experimental and modelling results from a worldwide effort focused on addressing this important problem will be presented. The prospects of each technique towards ITER will be discussed.