Increasing NTM stabilization efficiency using modulated ECCD in ASDEX Upgrade

A. Manini, M. Maraschek, G. Gantenbein*, Q. Yu, H. Zohm, S. Günter, F. Leuterer and the ASDEX Upgrade Team
Max-Planck-Institut für Plasmaphysik, EURATOM Association, Boltzmannstr. 2, 85748 Garching, Germany
**Forschungzentrum Karlsruhe, Association EURATOM-FZK, IHM, 76021 Karlsruhe, Germany*

The active control of core magneto-hydro-dynamic (MHD) activity in fusion plasmas plays a very important role for increasing the performance of a reactor. Recently, in ASDEX Upgrade a significant effort has been undertaken with the aim of optimizing the control of MHD stability using its electron cyclotron heating (ECH) system, which up to 2006 included three gyrotrons with f = 140GHz, P = 3°ø0.5MW and T = 2s. Particular attention was put on the optimization of the control of the neoclassical tearing mode (NTM). NTMs normally appear in plasmas with high normalized pressure $\beta_N = \beta/(I_p/aB_t)$, with $\beta = \langle p\rangle/[B_0^2/(2\mu_0)]$ being the ratio between the plasma kinetic and magnetic pressures. The flattening of the pressure profile within the magnetic island leads to a hole in the bootstrap current profile, which is the main drive for the growth of the NTM, therefore to a significant reduction of the plasma performance. In future devices such as ITER, the appearance of a NTM could lead to a reduction of the fusion power by up to 50%. Moreover, the formation, at high plasma current and pressure, of in particular (2/1)-NTMs could lead to a plasma disruption potentially very dangerous for the structure of the device. Once NTMs are excited, electron cyclotron current drive (ECCD) aimed at the resonance surface can be used to minimize their negative impact on the performance. The NTM suppression efficiency using ECCD has been thoroughly studied experimentally in several devices, including in particular ASDEX Upgrade. It has been found that, for continuous CD operation, the suppression effectiveness drops drastically as the deposition width d of the driven current becomes larger than the island width W. However, theory predicts that by modulating the ECCD in phase with the rotating island's O-point, the high efficiency can be recovered [1]. The experimental demonstration of this theoretical prediction has been obtained for the first time in ASDEX Upgrade [2], where (3/2)-NTMs were fully stabilized using modulated ECCD in conditions for which nonmodulated ECCD does not. These results are in good agreement with theoretical calculations taking into account the equilibration of the externally driven current on the island flux surfaces. These results are very important for large next-step fusion devices, such as ITER, where 2d > W I expected to be unavoidable during NTM suppression, pointing out that modulation capabilities of the ITER ECH system should be foreseen. Presently, ASDEX Upgrade is being enhanced with a new ECH system, which will include four new gyrotrons delivering 1MW for 10s, one 2-frequency at f=105/140GHz and three step-tuneable with four frequencies between 105 and 140GHz. The new system, will provide more flexibility for the control of core MHD activity, and in particular, with the increased power, the possibility of extending the stabilizing possibilities to the (2/1)-NTM.

[1] Q. Yu et al., Phys. Plasmas 11 (2004) 1960
[2] M. Maraschek et al., Physical Review Letters **98** (2007) 025005