Contribution ID: **60** Type: **Oral**

Mitigation of AE induced ICRF fast-ion losses using deuterium NBI in the ASDEX Upgrade tokamak

Friday, 10 December 2021 14:00 (30 minutes)

The confinement of fast-ions, such as those generated by neutral beam injection (NBI), ion cyclotron resonance heating (ICRH) or fusion products, is of paramount importance for future fusion reactors to ensure a good plasma heating efficiency and the device integrity. Toroidicity induced Alfven Eigenmodes (TAEs) have been shown, both experimentally and numerically, to increase the radial fast-ion transport, eventually causing deleterious fast-ion losses [1].
In this work we present the mitigation of TAE induced fast-ion losses of ICRH origin using deuterium NBI in the ASDEX Upgrade tokamak. The experiment is carried out in deuterium plasmas with Bt=2.5 T and Ip=0.7 MA. The TAEs are driven by a fast-ion population generated by the application of 3.7 MW of on-axis hydrogen minority ICRH, together with up to ˜4 MW of ECRH power in counter-ECCD configuration. These TAEs are observed to cause coherent fast-ion losses, as measured by a scintillator based fast-ion loss detector (FILD1). Phases of up to 900 ms and 2.5 MW of NBI heating are added. In these phases, either partial or full suppression of the TAE induced fast-ion losses is observed, depending on the level of applied ECRH power, while the TAE activity is maintained. An overall reduction in the total fast-ion loss level is also observed. The mitigation/recovery of the coherent fast-ion losses appears with a time delay of the order of tens of ms with respect to the NBI on/offset. Such an effect has been observed for NBI sources Q3 and Q8, with a main injection energy of 60 and 93 keV respectively. Tomographic reconstructions of the FILD signal reveal clear changes in the velocity-space of the losses during the mitigation phase. During the NBI on/off phases, FIDA and NPA measurements show changes in the H and D distribution functions, while a clear increase in the ion temperature and toroidal rotation of the plasma is measured, as well as a change in the frequency and toroidal mode numbers of the TAEs.
Measurements point out two possible effects that might explain this mitigation: (a) a modification of the hydrogen and deuterium fast-ion distribution functions during the NBI phases due to the 2nd harmonic D ICRF absorption and (b) a modification of the TAE structure due to changes in the kinetic profiles. In order to clarify which plays the dominant role, modelling of the hydrogen and deuterium fast-ion distribution functions with and without NBIs has been performed with the PION code, while the effect of the NBIs on the TAEs will be studied by means of the LIGKA code.
These experimental results show that, by an appropriate arrangement of the auxiliary heating systems, AE induced fast-ion losses could be mitigated or suppressed even in the case in which the control of the AE activity is not possible.

[1] M.Garcia-Munoz et al, Plasma Phys. Control. Fusion 61 054007 (2019)

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Session Classification: Control of Energetic Particle Confinement

Track Classification: Control of Energetic Particle Confinement