Contribution ID: **961** Type: **Regular Poster**

Non-linear MHD modelling of Edge Localized Modes suppression by Resonant Magnetic Perturbations in ITER.

Wednesday, 12 May 2021 12:10 (20 minutes)

The intensive experimental and theoretical study of the Edge Localized Modes (ELMs) and methods of their control is of great importance for ITER [1]. The application of small external Resonant Magnetic Perturbations (RMPs) has been demonstrated to be efficient in ELMs suppression/mitigation in present day tokamaks [2]. RMPs are foreseen as one of the methods of ELMs control in ITER [3]. However, a significant progress in understanding of physics of the interaction of ELMs with RMPs is still required to make reliable predictions for next step machines such as ITER and DEMO. The non-linear MHD code JOREK [4] is successfully used to model ELMs mitigation and suppression in the present day tokamaks. Recent modelling results for RMP experiments in ASDEX-Upgrade [5] and KSTAR [6] validated in many aspects the RMPs and ELMs physics models implemented in JOREK code [7]. It was demonstrated in particular that non-linear multi-harmonics approach, realistic tokamak geometry with the X-point and the Scrape-Off-Layer (SOL), realistic geometry and spectrum of RMP coils, toroidal rotation, the bi-fluid diamagnetic effects and neoclassical poloidal friction represent a minimum model which permits to reproduce experimental results.
In the present work the non-linear MHD modelling results of ELM mitigation and suppression by RMPs in ITER are presented for the first time. The realistic ITER geometry including divertor, SOL was used. The parameters of the standard H-mode scenario at 15MA/5.3T modelled by ASTRA code [8] with toroidal flow profiles self-consistently calculated with NBI heating and momentum input documented in ITER IMAS database (short=13102, run=4) were used as initial conditions. The ITER baseline design which includes 27 ELM control coils with three toroidal rows, located at the low field side (LFS) as described in detail in ITER IMAS machine description database (shot=1180, run=17) was used for vacuum modelling with optimized spectrum for main toroidal symmetry n=3 [9-10]. The vacuum RMP boundary conditions were imposed on the computational boundary of the JOREK code similar to [5-7], then the rotating plasma response and interaction of RMPs with ELMs in the core and pedestal plasma were modelled.
For the first time, ELMs suppression by RMPs was demonstrated in multi-harmonics modeling for ITER taking into account main toroidal harmonics n=3 and n=6 in RMP coils spectrum. The threshold for ELM suppression was found to be about ˜60kAt maximum of the current amplitude over all RMP coils versus of capability of 90 kAt. In the ELM suppressed state, previously unstable modes without RMPs, responsible for ELM crash, are stable and only non-linearly driven modes coupled to the imposed (here n=3 and n=6) harmonics of RMPs are triggered and reach saturated state with RMPs, producing continuous turbulent transport at the edge consequently reducing pressure gradient. The 3D divertor magnetic footprints, heat and particle fluxes in stationary RMP phase are characterized.

Acknowledgements: This work has been supported by EUROFUSION CfP-WP19-ENR-01/MPG-03, IO/CT/18/430000. This work benefited from HPC resources from CINECA Marconi-Fusion (project FUA33_JOREK3DE).
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Session Classification: P3 Posters 3

Track Classification: Magnetic Fusion Theory and Modelling