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Fast optimization of the central electron and ion temperature on ASDEX Upgrade based on Iterative Learning Control

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Tokamak scenarios are governed by actuator actions that can be either pre-programmed in feedforward or requested by feedback controllers based on actual plasma state. Actions requested by feedback controller have the advantage that they can react on unpredictable events that happen in the system. On the other hand, the reaction comes always with a delay. For that reason, it is required to prepare the feedforward trajectories such that they bring the system as close as possible to the desired state and feedback controllers provide correction of disturbances.

In tokamak research, the feedforward trajectories are typically found by trial and error approach, which is not very effective in terms of convergence and can lead to violation of operational and actuator limits. This approach is not applicable to future devices such as ITER or DEMO. In our contribution, we propose to use Iterative Learning Control (ILC) [1], which is a common technique for optimization of repetitive processes in control engineering world and demonstrate its use on optimization of central ion (Ti) and central electron temperature (Te) using NBI and central ECRH as actuators on ASDEX Upgrade.

The ILC is based on a linearized actuator response model along the initial system trajectory, which was in our case obtained from RAPTOR [2] simulation matched to existing experimental data. After the tokamak discharge is executed, the quantities of interest are evaluated and the new actuator trajectories are computed to minimize error between the desired and actual behavior while avoiding operational limits, and penalizing too large deviations from the initial actuator trajectory as well as the trajectory in previous trial. This method is also applicable to quantities that can not be measured in real time (Ti in our case).

We have successfully applied this method on optimization of central Ti,e as well as the Te/Ti ratio at constant WMHD. In the first case, we increased Ti while keeping Te constant and in the second case we have ramped the ratio of Te/Ti while keeping WMHD constant. These quantities can be quickly evaluated after every discharge using IDA [3] and IDI [4] integrated analysis. We propose a method for effective bringing of the improved actuator trajectories to the pulse schedule. We also summarize our experience and give several recommendations for future usage of ILC: the method can be effectively used only with good shot-to-shot reproducibility, which can be largely improved for example by an effective actuator management.

References:

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Speaker's Affiliation

Max Planck Institute for Plasma Physics, Garching

Member State or IGO

European Union

Primary authors: Dr KUDLACEK, Ondrej (IPP Garching); Mr VAN MULDERS, Simon (SPC Lausanne); Dr FELICI, Federico (SPC Lausanne); Dr SAUTER, Olivier; Dr FISCHER, Rainer (IPP Garching); Dr BONANOMI, Nicola (IPP Garching); Dr ANGIONI, Clemente (IPP Garching); Mr GRÄTER, Alexander (IPP Garching); Dr TREUTTERER, Wolfgang (IPP Garching); Mr ZEHETBAUER, Thomas (IPP Garching)

Presenter: Dr KUDLACEK, Ondrej (IPP Garching)

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