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Nonlinear 3D simulations of Vertical Displacement Events in tokamaks

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Vertical displacement events (VDEs) where the plasma moves rapidly towards the wall can cause large electromagnetic forces on the vessel structures with possible damaging effects for large tokamaks. Non-axisymmetric modes developing during the VDE can lead to asymmetric, sometimes rotating forces on the vessel which can be even more severe. Large-scale 3D simulations play a crucial role on the path towards assessing and preventing the damaging effects of VDEs on vessel components in future large tokamaks like ITER.

We use the high-order finite element code M3D-C^1 [1] to perform 2D and 3D nonlinear MHD simulations of VDEs in tokamaks including a resistive wall model [2]. In order to develop predictive capabilities, the simulation results are benchmarked with other codes as well as validated against existing experimental measurements.

2D and 3D nonlinear MHD simulations of VDEs are based on and validated against discharges in NSTX [3] as well as DIII-D. The results of a set of axisymmetric VDE calculations based on NSTX discharge #132859 show the sensitivities of the early VDE evolution to different parameters, in particular the halo resistivity. 3D simulations show how non-axisymmetric modes arise in the late VDE phase and lead to a stochastization of the magnetic field lines which allows for an efficient release of thermal energy into the wall. The thermal quench is followed by a fast decay of the plasma current and rise of the wall current.

A detailed benchmarking activity between the M3D-C^1 code and the 3D nonlinear MHD code NIMROD [4] based on an NSTX discharge is being performed. The comparison of axisymmetric VDE calculations is focused on the early VDE growth and the wall forces. We plan to extent this benchmark to 3D simulations with a 2D wall. In addition, an axisymmetric benchmark between the M3D-C^1 code and the CarMaONL code [5] based on a standard ITER scenario using a simplified 2D model of the ITER first wall is in progress.

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