DPP17-2017-001055

Abstract for an Invited Paper
for the DPP17 Meeting of
the American Physical Society

The ins and outs of modelling vertical displacement events

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Of the many reasons a plasma discharge disrupts, Vertical Displacement Events (VDEs) lead to the most severe forces and stresses on the vacuum vessel and Plasma Facing Components (PFCs). After loss of positional control, the plasma column drifts across the vacuum vessel and comes in contact with the first wall, at which point the stored magnetic and thermal energy is abruptly released. The vessel forces have been extensively modelled in 2D [1] but, with the constraint of axisymmetry, the fundamental 3D effects that lead to toroidal peaking, sideways forces, field-line stochastisation and halo current rotation have been vastly overlooked. In this work, we present the main results of an intense VDE modelling activity using the implicit 3D extended MHD code M3DC1 and share our experience with the multidomain and highly nonlinear physics encountered. At the culmination of code development by the M3DC1 group over the last decade, highlighted by the inclusion of a finite-thickness resistive vacuum vessel within the computational domain [2], a series of fully 3D non-linear simulations are performed using realistic transport coefficients based on the reconstruction of socalled NSTX frozen VDEs, where the feedback control was purposely switched off to trigger a vertical instability. The vertical drift phase, the evolution of the current quench and the onset of 3D halo/eddy currents are diagnosed and investigated in detail. The sensitivity of the current quench to parameter changes is assessed via 2D nonlinear runs. The growth of individual toroidal modes is monitored via linear-complex runs. The intricate evolution of the plasma, which is decaying to large extent in force balance with induced halo/wall currents, is carefully resolved via 3D nonlinear runs. The location, amplitude and rotation of normal currents and wall forces are analysed and compared with experimental traces. [1] Miyamoto, S., et al., Nuclear Fusion 54 (2014) 083002 [2] Ferraro, N., et al., Phys. Plasmas 23 (2016) 056114