NTM control – radial location of the NTM
NTM control – mode frequency and phase

M. de Baar

Dutch Institute for Fundamental Energy Research, Eindhoven, Netherlands

NTM control

Reactor relevant tokamak plasmas are performance limited by Neoclassical Tearing modes. These resistive MHD modes can develop after a magnetic perturbation, e.g. a swatooth crash and can lead to plasma disruption. The instability mechanism is the non-linear reduction of plasma pressure, the boot-strap current and the island dynamics: the island reduces the pressure, this reduces the bootstrap current, and this tends to grow the island size. For reactor operation at high plasma beta, the NTMs must be actively suppressed. From a physics perspective, this means that the lack of bootstrap current needs to be compensated by a local source of current-drive. Electron Cyclotron Current Drive is most suited for this.

The NTM suppression challenge is twofold. The first challenge is to deposit the Electron Cyclotron power at the exact location where the mode-rational flux surface intersects the power absorption condition. Second, the power must be deposited in the O-point of the island. This means that both the radial location of the mode as well as the frequency and phase of the mode must be estimated in real-time.

Lecture 1: Radial location of the NTM

The instability physics of the NTM will be addressed and the Generalized Rutherford Equation for the NTM dynamics will be introduced as well as the possibilities to sense and actuate the NTM using magnetics, electron cyclotron emission and current drive.

The control problem will be specified and the complications of the radial power deposition control will be discussed, including mechanical motion control of the EC launcher and real-time estimation of the equilibrium and the EC wave-propagation. Various realizations of NTM control systems, including the ITER reference scheme will be presented. Special emphasis will be put a dedicated sensor that aims to eliminate insecurities of the equilibrium and wave propagation and on plasma, actuator and sensor models to synthesize the controllers.

Lecture 2: Mode frequency and phase

In this lecture we will investigate the problems associated with the real-time estimation of the mode frequency: such as sensor noise, non-ideal wave-forms, higher harmonics and frequency and amplitude dependent sensitivity.

We will present to methods to deal with these complications: the first is the Phase Locked Loop, a proven method that will give a reliable estimate in a predefined frequency band. The second is the Kalman filter. We will derive various Kalman filters, and discuss their merits and performance.