Modelling-based high β_N RMP spectrum optimization for ELM mitigation

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Edge Localised Modes (ELMs) are a repetitive MHD instability prevalent in modern tokamaks, which may be mitigated or suppressed by the application of resonant magnetic perturbations (RMPs) [1]. The applied spectrum of the RMPs can be tuned for optimal ELM control, by introducing a toroidal phase difference $\Delta\Phi_{ul}$ between upper and lower rows of RMP coils. This flexibility may be critical for ITER in view of the requirement of robust ELM control across a wide range of plasma parameters, notably the normalised pressure β_N and the safety factor q. This motivates a study of the dependence of the optimal coil phase difference $\Delta\Phi_{ul}$, on plasma parameters β_N and q_{95}. Using calculations of the plasma response to the applied RMPs, criteria may be devised for the optimization of the RMP spectrum, which have had some success in interpreting ELM mitigation experiments in MAST [2,3] and ASDEX Upgrade [4]. In this work, a set of tokamak equilibria spanning a large range of (β_N, q_{95}) is produced, based on a reference equilibrium from an ASDEX Upgrade RMP experiment. The MARS-F/K code [5,6] is then used to compute the optimal $\Delta\Phi_{ul}$ across this equilibrium set, using stochasticity-based and plasma displacement-based optimisation criteria. It is found that for a given plasma boundary shape, the optimal $\Delta\Phi_{ul}$ is determined mainly by β_N, q_{95}, and toroidal mode number n of the applied RMP. For fixed β_N, the optimal $\Delta\Phi_{ul}$ increases with q_{95}, whereas for fixed q_{95}, the optimal $\Delta\Phi_{ul}$ decreases with β_N. It is also found that the shift in $\Delta\Phi_{ul}$ caused by the inclusion of the plasma response, is robustly between 60° - 90°, which may allow the optimal $\Delta\Phi_{ul}$ to be approximately predicted without requiring a plasma response computation.

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