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Plasma current and shape control for ITER using fast online MPC

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In a magnetically confined tokamak reactor, the Plasma Current and Shape Controller (PCSC) is the component of Plasma Magnetic Control (PMC) that commands the voltages applied to the poloidal field coils, to control the coil currents and the plasma parameters, such as the plasma shape, current, and position. The PCSC acts on the system pre-stabilised by the Vertical Stabilisation controller, which is another PMC component. The challenge of PMC is to maintain the prescribed plasma shape and distance from the plasma facing components, in presence of disturbances, such as H-L transitions or ELMs, and to changes of local dynamics in different operating points.

Model Predictive Control (MPC) is an established advanced process control technique in the process industry. It has gained wide industrial acceptance by facilitating a systematic approach to control of large-scale multivariable systems, with efficient handling of constraints on process variables and enabling plant optimisation. These advantages are considered beneficial for PCSC, and potentially also for other control systems of a tokamak. The main obstacle to using MPC for control of such processes is the restriction of the most relevant MPC methods to processes with relatively slow dynamics due to the long achievable sampling times, because time-consuming on-line optimization problems are being repeatedly solved at each sample time of the CSC control loop for determining control actions.

In this work we explore the practical feasibility of using MPC for PCSC in the ITER tokamak, employing complexity reduction techniques and recently developed fast on-line quadratic programming (QP) optimization methods. A survey of the available QP methods suitable for the on-line solution of MPC optimization problems is given, with emphasis on first-order methods, which have been recently considered as prime candidates for fast online MPC control. MPC is applied to a simulation model, where PMC makes use of a combination of ohmic in-vessel coils and superconducting poloidal field coils. The prototype MPC controller [1] is based on the control scheme of [2]. Using a modification of the QP solver QPgen [3], a five-fold speed-up compared to the state-of-the-art commercial solver CPLEX was achieved, with peak computation times around 10 ms on a laptop computer with a four-core Intel processor. This is already considered sufficiently fast for the 100 ms sample time estimated to be suitable for the ITER CSC control loop.

[1] S. Gerkšič, G. De Tommasi, “Model predictive control of plasma current and shape for ITER”, 28th Symposium on Fusion Technology (SOFT 2014), San Sebastián, Spain

[2] G. Ambrosino et al., IEEE Trans. Plasma Science, 37(7), 2009, 1324-1331

[3] Giselsson P., Improving Fast Dual Ascent for MPC - Part II: The Embedded Case, arXiv (2014)

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