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Control system optimization techniques for real-time applications in fusion plasmas: the RFX-mod experience

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Magnetic confinement of fusion relevant plasmas is the target of many devices that are nowadays working towards the achievement of electricity from controlled fusion reactions. Such plasmas constitute a particularly harsh nuclear environment in which violent instabilities can arise [1], causing confinement losses and possible damage to structural materials. Effective control of such instabilities is therefore compulsory for controlled fusion experiments, with active control playing an important role. The RFX-mod experiment is a medium size (R = 2m, a = 0.459 m) toroidal device that has been operating since 2004. It is equipped with a state-of-the-art system for active control of magneto-hydro-dynamic (MHD) instabilities. Such a system, operating with a cycle time T=200µs, is composed of 192 independently fed actuators (saddle coils) and over 600 inputs (magnetic sensors) [2]. The high degree of flexibility of the control system allows virtually switching on or off each single coil, thus different control schemes can be easily implemented [3]. In order to improve the efficiency and effectiveness of the active control system, a series of efforts have been made in optimizing the produced magnetic fields, for example by minimizing the harmonic distortion due to the toroidal geometry [4], or adapting the control scheme to real experimental conditions, such as the fault of single coils [5]. The techniques used to achieve these results, which will be illustrated in the present work, have been tested both in simulations and experiment. A dynamic simulator [6] has been developed for the purpose of testing optimization strategies. It consists of a detailed three-dimensional description of the conducting structures coupled to a two-dimensional plasma magnetohydrodynamic (MHD) model (resulting in the CarMa code [7]) and integrated by a complete representation of the real time control system. The implementation of simple, linear algebra based, real time optimization methods will be described along with proof of the sought beneficial effects. Focus of the work is set on a spurious harmonics reduction technique based on the decoupling of sensors and actuators, a description of its derivation will be given together with the implementation in the control loop. The similar procedure for the compensation of faulted actuators will also be mentioned.

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