Data for plasma control: from synthetic to real data for design and implementation of plasma control activities

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Fusion devices are nowadays relying on automated control systems to perform the control of a discharge to achieve their experimental goals. ITER, the most ambitious project in fusion under construction in the south of France, will also implement a complex Plasma Control System to achieve its main goal of a Q=10 burning plasma with 500 MW of fusion power production.

The experimental plan to get to full performance in ITER is long and it will follow a sequence of steps aimed at developing a robust route to achieving fusion energy production in the multi-100 MW level. The 15MA pulses with ~50MW of additional power are expected to generate 500MW of fusion power for 300-500s; to achieve and maintain the required plasma performance to reach this fusion power level the Plasma Control System (PCS) is essential. The PCS will manage all the available ITER actuators, from the power supplies driving the superconducting coils to the gas injection and pellet fuelling and additional heating systems to cite a few. The PCS is designed to rise the plasma parameters to achieve the required performance by controlling parameters such as plasma shape and position, temperature profiles and others. The control schemes in PCS will evolve during the operation of ITER operation as knowledge on operation increases and more actuators (e.g. heating systems) and sensors (diagnostics) become available. Additionally, monitoring activities and improved real time plasma prediction modeling are expected to be added to the PCS to improve avoidance and mitigation schemes and for optimization of the discharge.

The PCS control activities will rely on a dedicated set of diagnostics providing measurements' input. ITER will be equipped with about 55 diagnostic systems for a total of ~100 plasma parameters to be extracted. A significant fraction of the diagnostics is expected to work in real-time to provide the necessary input for the PCS. The control schemes require input with a specific performance that is not necessarily the same as that typically required for scientific exploitation. For example, latency is a performance parameter only required for real-time purposes; time resolution, on the other hand, might not be as stringent for real-time control applications as for scientific analyses of experimental results. The specific performance requirement for each diagnostic providing input for PCS is directly linked to the control actions and requirements of the dynamics to be controlled, the allowed reaction time, etc.

The design of the controllers to be implemented in the PCS requires simulations including the necessary plasma models and diagnostics inputs. ITER is not yet in operation and thus no diagnostic data is yet available, therefore a database of synthetic data that simulates diagnostics output needs to be built. For the control purposes foreseen in PCS, a realistic diagnostic measurement should be used thus including noise of various characteristics, uncertainties and the results of diagnostic degradation along its life or partial diagnostic failure (e.g. failure of some channels). This is essential to evaluate, for instance, the robustness of the controller to diagnostic input essential for the basic control functions of the PCS (e.g. plasma current, position, shape control, etc.).

This lecture will describe the role of the ITER diagnostics and their use for the PCS. The requirements for the simulations of diagnostics for ITER control will also be presented with few key examples to illustrate the simulation process. The framework and computation environment used for the development of the PCS and diagnostics simulated data will also be described.