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Control and protection challenges in fully metallic tokamak WEST for long pulse operation

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WEST is a tungsten tokamak designed for long pulse operation. It is now fully equipped with actively cooled components especially, the lower divertor is made of 456 ITER like Plasma Facing Units (PFU) that are being qualified in a tokamak environment. The main missions of WEST address high fluence plasma divertor exposure and the demonstration of long pulse H-mode in a full tungsten environment. In particular, thanks to the actively cooled plasma facing components (PFC), the fluence of a single ITER discharge can be obtained in a few long WEST discharges while several months of operation would be necessary on tokamaks equipped with inertial PFCs. Achieving long duration and high performance plasma discharges while ensuring the protection of the machine requires specific features such as dealing with unexpected events that may occur at any time. As a result, the WEST Plasma Control System (PCS) addresses the plasma discharge as a set of sequences also called segments [Nouailletas 2019] each of them being triggered by an event. For example, several segments have been designed to deal with the discharge soft landing to address runaway mitigation, flux swing flux limit etc. In addition, each controlled parameter can vary in a preset range defined by an envelope that allows an acceptable deviation from the preset value without generating an event resulting in triggering a new segment. The development of plasma scenarios is also relying on specific controls. The simultaneous controls of the loop voltage and the plasma current, using respectively the voltage applied to the central solenoid and the power of the lower hybrid current drive system is available and used for long pulse operation. An important mission of WEST consists in testing the ITER-like PFUs submitted to a constant and controlled heat load. Recently the real time evaluation of this load has been implemented permitting its control through the auxiliary heating power. In parallel to the performance and duration, the machine protection must be guaranteed at any time. This function is ensured by an extensive set of diagnostics, coupled with advanced controls and cross diagnostic functions. Among them, the infrared system that monitors all critical in-vessel components plays a central role. Indeed, the accurate conversion to surface temperature from the infrared radiance maps is complex due to various phenomena that must be considered in a metallic environment such as reflections, and low and varying emissivity. Finally, even more advanced control functions based on artificial intelligence are under development. They offer a greater adaptability to different scenarios, while being more robust with respect to the uncertainties on the plasma characteristics and the non-linearity of involved dynamics. At present, they are tested on a simulator of the WEST tokamak.

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