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Real-time detection of overloads on the plasma facing components of Wendelstein 7-X

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Wendelstein 7-X (W7-X) is the leading experiment on the path of demonstrating that stellarators are a feasible concept for a future power plant. One of its main goals is to prove quasi-steady-state operation in a reactor-relevant parameter regime. To this end, the surveillance and protection of the water-cooled plasma-facing components (PFCs) against overheating is fundamental to guarantee a safe steady-state high-heat-flux operation. The fast reaction times required to prevent damage to the device makes imperative to fully automate the analysis of the thermographic images to timely interrupt operation through the interlock system if a critical event is detected. This imaging system, being the last line of defence, must be based on highly reliable real-time image and risk analysis techniques to guarantee the integrity of the device.

During the past operation phases, W7-X was equipped with inertially-cooled test divertor units and although the system still required manual supervision, several concepts to deal with the intrinsic three-dimensional geometry of stellarators were put under test. With the experience gained, a new PFC protection system has been designed based on advanced image segmentation techniques. In order to achieve the steady-state operation, however, a feedback control system able to prevent unnecessary interruptions of plasma operation is needed. The feedback control shall be guided by the image analysis, requiring a high-level scene understanding through computer vision and machine learning algorithms. Based on this analysis, the feedback control can then take the most effective countermeasures to prevent the PFCs overloading by acting on the heating systems, the strike-line shape and positioning or plasma detachment.

In this work, we present the design of the real-time image analysis system for the protection of the PFCs of W7-X through the Interlock, and its validation results based on the analysis of the existing experimental data. Additionally, we present the roadmap towards a feedback control system for the protection of the device in long high-performance plasmas.