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Assessment of Alternative Divertor Configurations as an Exhaust Solution for DEMO

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The European roadmap for fusion energy has identified plasma exhaust as a major challenge towards the realisation of magnetic confinement fusion. To mitigate the risk that the baseline scenario with a single null divertor (SND) and a high radiation fraction adopted for ITER will not extrapolate to a DEMO reactor, the EUROfusion consortium is assessing potential benefits and engineering challenges of alternative divertor configurations.
A range of alternative configurations that could be readily adopted in a DEMO design have been identified. They include the X divertor (XD), the Super-X divertor (SXD) and the Snowflake divertor (SFD). The flux flaring towards the divertor target of the XD is found to be limited by the minimum grazing angle at the target. The characteristic increase of the target radius in the SXD is a trade-off with the increased TF coil volume, but ultimately limited by forces onto coils. Engineering constraints also limit XD and SXD characteristics to the outer divertor leg with a solution for the inner leg requiring up-down symmetric configurations.
Boundary models with varying degrees of complexity have been used to predict the beneficial effect of the alternative configurations on exhaust performance. Desired effects are an easier access to detachment, reluctance of the detachment front to move along the divertor leg and an increase of the divertor radiation without excessive core confinement degradation. Based on the extended 2-point model and achievable geometric variations the SOL radiation required for the onset of detachment decreases in the SXD and SFD with the tolerable residual power ∝(1-f_{rad}) being 30-40% larger than in the SND. Additional improvements are expected from the ability to increase frad without adverse effects on the core performance and through SOL broadening as postulated for the SFD. A systematic study of the alternative configurations and the SND reference using the divertor transport code TECXY confirms that the SFD detaches at a lower f_{rad}, but also shows that the potential gain is modest. The main expected advantage of the XD and similarly of the SXD is an increased reluctance of the detachment front to move towards the X-point. To that end the detachment dynamics are assessed with the SOLPS and SOLEDGE2D-Eirene codes, which use more sophisticated models of the target geometry and neutral particles.

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