Contribution ID: **214** Type: **Poster**

Integrated Concept Development of Next-Step Helical-Axis Advanced Stellarators

Friday, 21 October 2016 08:30 (4 hours)

One of the high-level missions of the European Roadmap for the realisation of fusion energy is to bring the helical-axis advanced stellarator line (HELIAS) to maturity. The near-term focus is the scientific exploitation of the Wendelstein 7-X experiment in order to assess stellarator optimization in view of economic operation of a stellarator fusion power plant.
Meanwhile, the understanding of the physics and technology of stellarators has made significant progress in recent years. Essential contributions came from the design process of W7-X, from the construction experience itself, and from the ongoing theoretical work during the construction phase. However, even with the achieved progress it is not straightforward to extrapolate to a HELIAS power plant. Therefore, the need arises to study and develop concepts of next-step HELIAS devices.
In order to facilitate such an approach, HELIAS-specific systems-code models were developed and implemented in the European systems code PROCESS. Following this, systems studies have been carried out for HELIAS reactor concepts in order to assess the available design window. As the confinement properties have a great impact on such studies, transport simulations were included in this study and iterated back and forth with the systems studies.
Based on the definition of a HELIAS power plant design window, gaps in physics and engineering with respect to current understanding have been revealed. It turns out, that the step from W7-X to a HELIAS power plant is significant for several important physics and engineering parameters (e.g. alpha-particle pressure, heating power, P/R, confinement time). This leads to the concern, that a direct step from W7-X to a HELIAS reactor bears undue scientific and technological risks.
If W7-X demonstrates the success of stellarator optimization, the European strategy foresees a review point at which it should be decided if an intermediate-step stellarator is necessary to study the dynamics of a burning-plasma in 3D geometry. In preparation of this review-point, the properties of an intermediate-step stellarator are assessed. Following the integrated design analysis approach, different options for such a device have been studied. In particular, a fast-track, cost-efficient device without blanket and a DEMO-like machine requiring a full set of reactor systems were investigated.

Paper Number

FIP/P7-9

Country or International Organization

Germany

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Session Classification: Poster 7

Track Classification: FIP - Fusion Engineering, Integration and Power Plant Design