A New Approach for Exploration of Tokamak Power Plant Design Space

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Detailed and integrated design and assessment of fusion concepts as power plants is important in guiding the research programs and illuminating the fusion development paths. An important tool in conceptual design studies is comprehensive systems code which have been utilized to optimize a specific design point, typically with the cost-of-electricity (COE) as the optimization parameter. This produces the most favorable power plant for a set of constrained parameter choices, but it is often difficult to justify or understand why that point was optimal because: 1) Experience indicates that “optimum” design points are usually driven by the constraints. In some cases, a large design window is available when the constraint is slightly relaxed, allowing a more robust and credible design, 2) Experience indicates that the power plant parameter space includes many local minima and the optimum region is quite shallow, and 3) The systems code identifies the mathematical optimum. There is a large optimum region when the accuracy of the systems code is taken into account, requiring human judgment to choose the operating point.

For these reasons, the USA RRIES Team is exploring a new approach to use the ARIES systems code as a scanning tool rather than a design point optimization tool in which the systems code scans a wide operating space of possible design solutions instead of focusing on one point. The ultimate goal is to more accurately understand the tradeoffs between the available systems parameters and constraints and to identify where the parameters and constraints have a strong or weak impact. This is an important contribution to define R&D goals as in some case a small change in the constraint in an adverse manner may lead to a tradeoff in other more stringent or costly areas. Alternatively, one may want to stay away from certain constraints that might have a minor influence on the design and cost of electricity (COE) in order to achieve a robust design.

The new systems code consists of newly revised physics, engineering, and costing modules that can be updated as required. At present, our systems code can scan any of the 55 input parameters to any resolution. The output of such a detailed scan with the systems code could consist of millions of possible operating points. Hence, we utilize modern visualization tools to uncover the dependence of the multi-dimensional parameters on one another, to extract meaningful data, and to provide direction to focus on more meaningful regions of the operating space. Such a visualization method must be able to identify trends and provide insight into the tradeoffs of the parameter space and ultimately the COE.

In this paper, I will discuss our new systems code and the visualization tool, as well as results for several tokamak power plant embodiments.