TOKAMAK REACTOR DESIGNS AS A FUNCTION OF ASPECT RATIO*

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This paper projects the tokamak technical and economic performance for superconducting (SC) and normal conducting (NC) coil designs as a function of aspect ratio (A). Based on the results from plasma equilibrium calculations, the key physics design parameters of β_N, β_p, β_t, and κ were fitted to parametric equations covering A in the range of 1.2 to 4. The parameters investigated include the physics parameters represented by ARIES-RS (A=4), ARIES-ST (A=1.6) designs and DIII–D D-T equivalent high Q discharges (A=2.74). By using ARIES-RS and ARIES-ST as the reference points, a fusion reactor system code was used to project SC and NC coil reactor designs over the same range of A. A bootstrap current fraction of 90% was assumed in the evaluation. The principle difference between the SC and the NC designs are the inboard standoff distance between the coil and the inboard first wall, and the maximum current density used for respective coil types. For protection from radiation damage, the selected inboard standoff distances for the SC and NC designs are 1.3 m and 0.23 m, respectively. The current densities of 15 MA/m^2 and 31 MA/m^2 were used for respective NC and SC designs. These parameters are similar to the ARIES-ST and ARIES-RS designs. We evaluated the designs at the range of average neutron wall loading (Γ_n) between 2 to 8 MW/m^2 and the electrical power output in the range of 1 to 20 GWe. Using the above key design inputs, results show that at Γ_n in the range of 4 to 8 MW/m^2 and, at an electrical power output of 2 GW(e), the cost of electricity (COE) can be in the respectable range of 78 to 58 mill/kWh. For the NC design, the optimum aspect ratio is A~1.6. A clear design barrier of excessive re-circulating power at A=2.5 resulted for the NC option. For SC designs, at constant power output, higher Γ_n, and higher aspect ratio will lead to lower COE. An aspect ratio of 4 is a reasonable choice for the 2 GWe, Γ_n= 8 MW/m^2 design. Based on the assumptions that we have used, we can consider these results as a technical and economic road map for SC and NC tokamak designs. In summary, we have generated a system code methodology that can be used as a guide for the selection of NC or SC tokamak commercial reactor designs.

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