SIMULATION, CODE BENCHMARKING AND OPTIMIZATION OF THE MAGNETIC FIELD CONFIGURATION IN A NEGATIVE ION ACCELERATOR

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SPIDER is a full-size Negative Ion Source and a multi-beamlet 100 kV Accelerator, presently under construction in Padova as part of the test bed for the full development of the Heating Neutral Beam system for ITER [1].
The magnetic field configuration in the Ion Source and in the Accelerator has a considerable impact on the performances of a Negative-Ion-driven Neutral Beam for several reasons:

- the "Filter" magnetic field inside the Ion Source reduces the number of co-extracted electrons entering the Accelerator and also affects the Negative Ion production efficiency;
- the "Suppression" magnetic field, produced by permanent magnets in the Accelerator extraction grid, deflects the co-extracted and secondary electrons, but also causes an undesired alternate horizontal deflection of the Ion beamlets;
- any lack of field uniformity from beamlet to beamlet results in a non-uniform deflection of the beamlets and in an increased divergence of the entire Beam.

These aspects have driven the final design of the magnetic configuration of SPIDER, which has been optimized for increasing the Ion Extraction and Acceleration efficiency in a wide range of Beam operating parameter. This goal has been achieved with the introduction of a current flowing through the Plasma Grid and along suitably-shaped busbars, and also with the addition of a ferromagnetic layer located on the downstream side of the Grounded Grid.
The numerical simulation and optimization of the final 3D magnetic configuration has required to develop numerical models capable of representing with sufficient accuracy the magnetic field features on different scales of magnitude, from the local configuration inside a single aperture to the global non-uniformity effects near the external edges of the device.
Being the magnetic field produced by a combination of busbars and permanent magnets, together with a current-carrying grid and a ferromagnetic grid (both having complex geometry with 1280 beamlet apertures) the development and verification of the models was not straightforward.
Different numerical models, based both on commercial and non-commercial codes, including a FEM "mixed" formulation, have been thoroughly benchmarked against each other in order to verify their accuracy and reliability, as a prerequisite to the optimization. The good accuracy of the numerical models (also confirmed separately by comparison against experimental data measured on a real device), also allows to establish an acceptance criteria for permanent magnet positioning and residual magnetic field to be applied during the construction of the Accelerator.
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[1] P. Sonato et al. Fusion Engineering and Design Vol. 84 269-274 (2009)

Topic B: Plasma Heating and Current Drive