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NBImag: a useful tool in the design of magnetic systems for the ITER Neutral Beam Injectors

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NBImag is a code suitable for the design and optimization of complex magnetic field configurations, such as that of a multi-aperture, multi-stage negative ion source and accelerator. The NBImag code has been developed for the design of the ITER Neutral Beam Injector (NBI), whose full-size prototype, MITICA, is presently under construction in Padova, Italy. The ITER injector shall produce a focused beam of neutral particles (H or D) having an energy of about 1 MeV and a total power of 16.5 MW, for 3600 s continuous operation.

The accelerator is constituted by a system of 7 conductive grids having different potential (from -1 MV to ground), each including 1280 apertures, with the purpose of forming a bundle of accelerated H- or D- beamlets with a total current up to 46 A or 40 A, respectively.
Since none of the available commercial (or freeware) codes was suitable for efficiently modelling such a complex magnetic field configuration with acceptable detail level and computation time, the code has been developed and used for optimizing the magnetic field configuration in the ion source and accelerator, so as to comply with the constraints existing in different regions:

- minimal magnetic field in the RF drivers for effective plasma start-up in the plasma source;
- reduction (filtering) of the fast electrons in the plasma source for efficient production and extraction of negative ions in proximity of the plasma-facing grid;
- optics quality (aiming and focusing) of 1280 negative ion beamlets ;
- disposal of co-extracted and stripped electrons and minimization of the heat loads on accelerator grids (by early deflecting co-extracted and stripped electrons).

A combination of a weak horizontal “long range” magnetic field produced by currents flowing in the plasma facing grid and in suitably arranged bus-bars, and of a strong vertical “local” magnetic field, produced by 5616 permanent magnets embedded in the accelerator grids, proved to be the most efficient configuration on the basis of an automated optimization procedure.

The NBImag code is based on an integral formulation and allows an efficient calculation of any static magnetic field configuration on the basis of the geometry of the magnetic sources, with linear material and permanent magnets. NBImag also includes magnetic force and inductance calculation, based on the same formulation. Thanks to the capability of efficiently describing a large number of permanent magnets with limited computational effort, NBImag has also been integrated with different automatic optimization procedures for the solution of inverse magnetic problems.

This paper describes the formulation of the code and of the optimization algorithms, the validation against analytical models and experimental measurements, and the application to the design of MITICA.

Eligible for student paper award?

No

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