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FTP/P1-17: Feasibility and R&D Needs of a Negative Ion Based Neutral Beam System for DEMO

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The R&D requirements of a heating and current drive (H&CD) system for a demonstration fusion power plant (DEMO) are presently assessed within the EFDA 3PPT activities. The requirements of the H&CD system will strongly depend on the DEMO scenario; the most demanding requirements are defined by a steady state tokamak. For such a cw CD system with several 100 MW power, the key issues are the achievement of adequate plug-in efficiency, availability and reliability. The neutral beam injection (NBI) system, at present a key system H&CD of magnetic fusion devices including ITER, is also a candidate for DEMO, due to its high current drive efficiency.

A DEMO cw CD NBI system will be based like the ITER NBI system on production, acceleration and neutralisation of negative deuterium ions. For sufficient current drive neutral particle energies of several 100 kV at minimum are required. The neutralisation efficiency of negative ions is still about 60% at these high energies whereas the efficiency of positive ions is below a few percent.

The paper concentrates on two issues which are presently addressed by IPP R&D activities:

(i) the enhancement of the overall wall plug efficiency from approx. 25% for the ITER system to more than 50%; and (ii) the reliability and maintainability of the negative deuterium ion source.

At present, the only promising technology to enhance the plug-in efficiency to the required values above 50% is a laser neutraliser system with neutralisation efficiency of almost 100%. Among other benefits, a laser neutralizer does not require high heat flux components, i.e. a residual ion dump, in the beamline, so that the negative ion source and the accelerator will be the most crucial parts for the reliability of the system. Both parts are exposed to local power densities of several 10 MW/m2 in the present ITER design. The operation at reduced source filling pressure (below 0.3 Pa, the ITER requirement) and a Cs-free source are identified to be very beneficial by reducing the local power loads and removing the need for a regular maintenance. On the other hand, NBI systems with energies above 1 MeV for enhanced current drive efficiency seem to be unfeasible with the present technology.

Details and concepts will be discussed in more detail in the paper, highlighting the feasibility and R&D needs from the present available ITER technology.

Country or International Organization of Primary Author

Germany

Primary author: Ms FANTZ, Ursel (Germany)

Co-author: Dr FRANZEN, Peter (Max-Planck-Insitut fuer Plasmaphysik)

Presenter: Ms FANTZ, Ursel (Germany)

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