Contribution ID: **3** Type: **Oral**

Numerical study of RF power coupling in fusion-relevant single- and multi-driver H^- ion sources

Tuesday, 4 October 2022 10:50 (30 minutes)

ITER’s large and powerful neutral beam injection system is based on a modular concept, where eight cylindrical ’drivers’are attached to one common expansion and extraction region. In each driver, a plasma is sustained via inductive coupling with powers of up to 100 kW at a driving radio-frequency (RF) of 1 MHz to produce fusion-relevant hydrogen beams. These high powers impose great stress on the electric system and hence the ion source’s reliability is decreased. Recent measurements at the single-driver test bed BATMAN Upgrade showed that the RF power transfer efficiency η, which measures the ratio of power absorbed by plasma to total RF power, is only around 50%, leaving room for optimization. In multi-driver test beds such as ELISE η is found to be even further decreased to around 40%. To explain this difference, a previously validated self-consistent 2D RF power coupling fluid model is applied. At the same absorbed power per driver the model shows virtually the same spatial distributions of plasma parameters and power absorption in single- and multi-driver sources. However, the coil current is increased in multi-driver ion sources due to a changed spatial distribution of the magnetic RF field in the region surrounding the drivers. In the exemplary case of the ELISE ion source this results in a slight decrease of η compared to the single-driver setup. Typically, in multi-driver sources conductive shields are applied to cancel the electrostatic interference between drivers. These shields are found to affect the spatial distribution of the RF fields even more severely. In the case of the ELISE ion source, the model calculates a further decrease of η, being in good agreement with experimental measurements. The effect is shown to be highly nonlinear with distance between shield and RF coil, wherefore it is advisable in future multi-driver ion sources to maximize this distance.

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Session Classification: Oral session 5

Track Classification: 12. Numerical simulations of sources or beams