Current ramp-up modelling for STEP

F. Eriksson, F. J. Casson, C. D. Challis, Y. Baranov, S. Bakes, S. Freethy, T. C. Hender, S. S. Henderson, HT Kim, K. Kirov, F. Koechl, H. Meyer, E. Tholerus, C. M. Roach and T. Wilson

CCFE, UKAEA, Culham Science Centre, Abingdon OX14 3EB, UK

The STEP (Spherical Tokamak for Energy Production) program is currently developing a spherical tokamak reactor for producing net electricity. The spherical tokamak concept benefits from a higher beta and elongation than conventional tokamaks but it also has the disadvantage of limited space for a central solenoid and will therefore primarily rely on a non-inductive current. Since a non-inductive ramp to large plasma current has not been demonstrated on a spherical tokamak (ST), STEP relies solely on modelling to demonstrate the feasibility of a non-inductive ramp. The aim of this work is exploratory modelling of current ramp-up for a ST to evaluate the possibility of a non-inductive ramp with very limited magnetic flux from a central solenoid. Predictive non-inductive current ramp-up simulations are performed with the JETTO-ESCO code using simple source and transport models and an evolving fixed boundary equilibrium. More sophisticated codes are used at individual times during the ramp to validate source and transport assumptions. Electron cyclotron (EC) heating will be a main HCD system for STEP and is used in this work to ramp up the current to the flat top operating current. A non-inductive ramp behaves very different compared to a more standard inductive current ramp. It is not limited to diffusion of current from the edge which allows a tailoring of the current density profile. The timescale of the ramp is still set by the resistive timescale which is on the order of 1000s and the current density needs careful optimisation to avoid the development of a current hole in the plasma centre. Furthermore, the EC system mainly heats the electrons resulting in a very high Te/Ti regime which historically has been less explored. Due to the presence of significant auxiliary heating early in the ramp, the maximum elongation of the plasma needs to be reached early to allow the plasma to be diverted. A pathway needs to be optimised which allows the maximum elongation to be reached early to comply with exhaust constraints while remaining MHD stable. The auxiliary power required to reach flat top operating point current depends strongly on current drive efficiency and transport assumptions. In this work the current ramp is performed at a low density to maximize the current drive efficiency. This low density, high electron temperature regime then needs to transition to an alpha dominated high bootstrap current regime for the flat top operation. This talk will summarize modelling results and challenges of a non-inductive current ramp for STEP as well as discuss the transport present in a very high Te, low Ti regime