Merging/Compression start-up in ST40: Comparison between the first experimental results and numerical model

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Tokamak Energy Ltd. is presently commissioning ST40 [1], a relatively small ($R = 0.4\,\mathrm{m}$) spherical tokamak which has been designed to operate with a high toroidal field ($B_T \sim 3\,\mathrm{T}$) and high current density ($I_p \sim 2\,\mathrm{MA}$). The aim of this commissioning has been to test all sub-systems and to integrate them into the Plasma Control System (PCS). During this phase ST40 operated with a toroidal field of $0.7\,\mathrm{T}$ at $R = 0.4\,\mathrm{m}$ ($I_{\mathrm{rod}} = 1.38\,\mathrm{MA}$) and have achieved a plasma current of $I_p \sim 300\,\mathrm{kA}$.

Start-up in ST40 uses a technique called Merging/Compression which involves [2, 3]: inductively forming plasma around two internal poloidal field coils, when the current within the internal poloidal coils is close to zero the two plasma rings are attracted towards each other and merge, and through magnetic reconnection $\sim 5\%$ of the poloidal flux is converted into thermal energy.

To manage forces within ST40 the vacuum vessel is relatively thick, consequently, substantial eddy currents (up to $700\,\mathrm{kA}$) are induced into the vessel during Merging/Compression start-up. This adds two complications: firstly, it makes magnetic reconstruction more challenging and secondly, the eddy currents have a large impact on the Merging/Compression technique - therefore they must be accounted for when designing Merging/Compression start-up scenarios. In this presentation both of these issues are discussed and addressed. During this commissioning phase ST40 had the following magnetic diagnostics: 5 Rogowski coils, 36 flux loops and 70 poloidal field pickup probes, and we have developed and tested a new magnetic reconstruction code in which the vessel is approximated by the 20 longest lived eigenmode excitations and the plasma is approximated by a set of orthogonal basis functions. Later, this code will be integrated into the PCS to allow real-time control of the plasma current, plasma current centroid position (RI_p and ZI_p) and plasma shape. We have included the effects of these eddy currents in our predictive modeling of the Merging/Compression start-up technique, and find good agreement with experimental results.

References

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