28th IAEA Fusion Energy Conference (FEC 2020)

Contribution ID: **1229** Type: **Regular Poster**

Development of Integrated Suite of Codes and Its Validation on KSTAR

Friday 14 May 2021 18:25 (20 minutes)

Due to complex non-linear interactions of various phenomena in the tokamak plasmas, integrated modelling is a proper tool to understand physics behind them. TRIASSIC (Tokamak Reactor Integrated Automated Suite for SImulation and Computation), which is a flexible integrated suite of codes for interpretive/predictive analyses, is under development for this purpose by exploiting merits of the standardized data model, IMAS [1]. Its structure is depicted in figure 1.

Figure 1: The structure of the integrated suite of code, TRIASSIC. Equilibrium, transport, H&CD, grid, neutral modules separately access to the IMAS data structure via the Python interface. Each plasma analysis codes originally coded in the Fortran language was wrapped by the F2PY wrapper which enabled direct access via Python interface.

For easy maintenance, plasma analysis codes contained in this integrated modelling tool are designed to be fully independent and modularized, so that the integration of a new code or model is simple. Based on the Python framework, modularized analysis code can dynamically be called without losing fast computation speed and unnecessary file IO. The Python based graphical user interface (GUI) was also developed, which lowers the entry barrier to integrated modelling and enables users to easily conduct integrated simulations without loss of consideration on delicate modelling options.

Figure 2: Validation of interpretive simulations of TRIASSIC. (a) Comparison of plasma stored energy calculated from integrated suite of codes, and EFIT. (b) Histogram of Winterpret/WMHD and (c) histogram of Winterpret/WMHD without high β_P discharges with TAE.

For the validation of this integrated suite of codes, a database of ~50 stationary discharges of various KSTAR scenarios was established. First, we conducted interpretive simulations to compare plasma stored energy which can be calculated by using plasma density, temperature, and fast ion energy by TRIASSIC or by EFIT [2] relying on magnetic diagnostics. As shown in figure 2, comparison of energy calculated from TRIASSIC with EFIT yields significant overestimation of the plasma stored energy from TRIASSIC in high β_P discharges with TAE, which indicates that the additional fast ion transport model is needed in addition to the classical fast ion model [3]. The calculation on remnant majority of discharges, however, showed good agreement with experiments.

Figure 3: Validation of predictive simulations of TRIASSIC with TGLF. (a) Histogram of predicted volume averaged electron density with respect to the experimental value, (b) histogram of predicted plasma stored energy with respect to the experimental value. Expectation values of prediction with and without gas puff modeling are indicated as black and gray dashed line, respectively.

To test predictive capabilities of the integrated suite of codes, comparison of electron density and plasma energy was conducted. Using anomalous transport model, TGLF [4], significant amount of electron density and stored energy reduction was observed. It was found that this underestimation was due to the absence of neutral gas puff modelling [5]. Systematic scans on absolute amount of cold neutral inward flux could resolve experimental electron density and stored energy level. The electron density and stored energy was able to be predicted accurately, mostly within 10% deviation from its experimental values as shown in figure 3.

References:
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Session Classification: P8 Posters 8

Track Classification: Magnetic Fusion Theory and Modelling