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Development status of the integrated tokamak simulator for K-DEMO

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1. Introduction

Korean fusion demonstration reactor (K-DEMO) study has been conducted to investigate the feasibility of an electricity generation, self-sustained tritium cycle, and component test facility. [1] To estimate its capability, the integrated fusion operation simulator called INFRA has been developed by organizing relevant computational codes with standard data models and framework. The different modules of the integrated simulator are chosen among well-validated codes. Standard data models are directly linked with KSTAR experimental data so that the integrated simulator can be used for interpretative simulations but also for predictive simulations. In this study, the current status of code development and some examples of KSTAR interpretative simulations are reported.

2. Code Development Status

2.1 Standard Data Model

ITER integrated modelling and analysis suite [2] is imported to K-DEMO data model to take over ITER experience and to accelerate collaboration with international IMAS community. Standardized rules and guideline have been developed by ITER team for many years. Based on strict policy, this data model has been established and updated. This data model is used for experimental and simulation results. Its tree structure classifies variables and allows re-use of its names. Several computational languages are supported: C/C++, Fortran, Java, Python, Matlab, and IDL. Several versions have been installed and tested on NFRI Sophie cluster.

2.2 Framework

For integrated tokamak simulations, a unified structure which connects the different codes is strongly required. Such system is usually called a framework. Integrated plasma simulator (IPS) [3] framework is adopted for our K-DEMO system. IPS is a script-based framework written in Python. Thanks to its convenient module connection system, rapid coupling of existing simulation codes is feasible. It is also compatible with parallel processing which is suitable for using in supercomputing system.

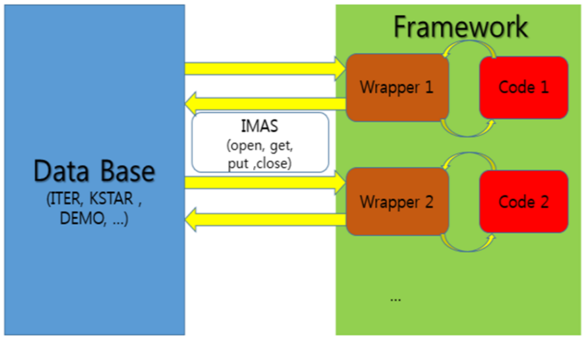

Fig.1. INFRA Module integration on framework

Figure 1 shows integration structure on framework. The wrapper routine is the main connector. It converts experimental and computational results to standard data model (IMAS). The input file for each module is prepared by reading data from IMAS. In this stage, the module is run and computed output data are updated into IMAS. Different computing nodes are allocated for each module run. A calculation algorithm is utilized in this script-based framework;

2.3 Modules

Table I: INFRA Module List

EQ	2D equilibrium	Fixed boundary 2d Grad Shafranov solver
TR	1D Transport	1D Neoclassical & Anomalous transport models
WR	Geometrical Optics	EC, LH ray & beam tracing
NB	Beam injection	Neutral Beam driven current & power
MHD	Stability	Linear core MHD stability analysis

Plasma core analysis is possible now. Table 1 shows the INFRA module list. A fixed boundary code, calculates two dimensional MHD equilibria. A One-dimensional transport module solves the current and particle and heat transport on each magnetic flux surface. A Ray-tracing solver is imported for ECH (Electron Cyclotron Heating), ICH (Ion Cyclotron Heating), and

LH (Lower hybrid Heating) to estimate the current drive efficiency and power absorption. The neutral beam driven current deposition and power are calculated from the particle-based code. Linear core MHD stability checking is available. Korean modules are under-development and current codes will be eventually replaced with Korean codes. Plasma edge, blanket, and divertor modules are also planned to be upgraded to complete our full tokamak simulator.

2.4 Application to KSTAR experiment data

For the test run of INFRA code and its connection with experiment data, KSTAR H-mode shot equilibrium is investigated (Fig. 2).

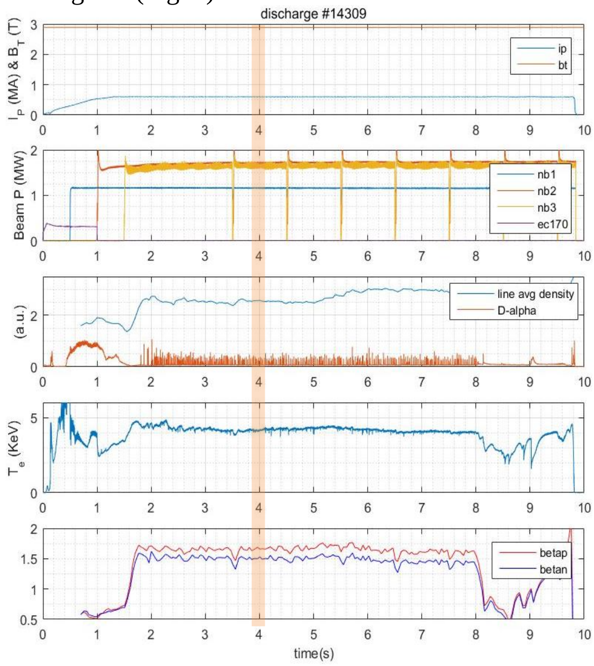

Fig.2. KSTAR H-mode shot #14309, t=4s stationary H-mode point is selected for test run of INFRA equilibrium system. **B_T=2.9 [T] I_P=0.6 [MA] P_{NBI}=4.5[MW] (ne)=2.6 [10^{19} m^{-3}] $T_e \cong 4.22$[KeV]**

Several input formats have been tested to transfer KSTAR data to IMAS database such as ASCII, Ufiles, and MDSplus tree. For its direct connection from experiment data (basic KSTAR experiment data storage system is MDS data), MDSPlus type is chosen. Electron density and temperature from Thomson scattering have been put into IMAS database to solve two-dimensional equilibrium. Fig. 3 shows analysis results. ESC [4], a fixed boundary equilibrium solver, calculates two dimensional MHD equilibria. Thomson raw data are fitted and put into IMAS. Ion temperature is set to be the same as electron temperature. Monotonic q profile is assumed for this analysis. Building kinetic EFIT system [5] in KSTAR is on-going. Equilibrium results will be benchmarked with kinetic EFIT soon.

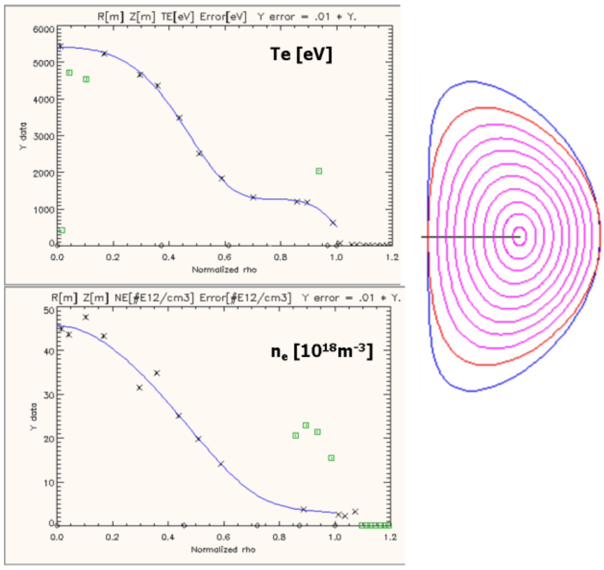

Fig.3. KSTAR #14309 Thomson electron density, temperature fitted profile, and computed flux contour.

3. Conclusions and Future Work

The INFRA system has been utilized to be an alpha version of a KDEMO simulator. Database, framework, and module integration are conducted. A test equilibrium run for KSTAR is done by filling the database with experiment results. More modules will be incorporated in a near future. Validation with KSTAR data and benchmarking previous modelling activity is also planned in order to confirm the feasibility of this system.

Acknowledgement

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REFERENCES

[1] K. Kim et al, Nucl. Fusion, Vol. 55, p.053027, 2015
[2] F. H. Ruddy, A. R Dulloo, J. G Seidel, J.W.Palmour, and R. Singh, The Charged Particle Response of Silicon Carbide Semiconductor Radiation Detector, Nuclear Instruments and Methods In Physics Research, Vol.505, p.159, 2003.
[3] http://ipsframework.sourceforge.net/doc/html/index.html#
[4] J. M. Park, FEST Seminar Jan 6 (2014).
[5] T.H. Osborne, GENERAL ATOMICS REPORT GA-A27666, 2013