Digital Twin Technology to Accelerate Fusion R&D

Jae-Min KWON[1] and V-KSTAR Development Team

[1]*Korea Institute of Fusion Energy, Daejeon, Korea*

Digital twin technology can be defined as a collection of IT technologies which enable a virtualization of the shapes and functions of objects in digital space. Along with the steady progresses in supercomputing technologies, recent advancements in large scale GPU computing enable a digital twining of highly complex objects comprising a large scale plant. In this presentation, we report a recent progress in the development of digital twin technology for fusion, which is aiming to bridge physics-based plasma simulations and engineering-oriented analyses. Several enabling technologies for fusion digital twin are identified: 1) data framework to handle various fusion data and codes, 2) mesh technology to handle complex models, 3) advanced 3D algorithms to handle fusion data in virtual environment, and 4) graphic engine for fast visualization. These technologies are tightly linked with each other in a hierarchical way as shown in Figure 1. In the presentation, their detailed technological elements and interfaces will be discussed. As an application of these technologies, Virtual KSTAR is being developed with two primary goals [1, 2]: 1) real time monitoring of KSTAR experiment and 2) integrated 3D visualization and analysis of KSTAR simulation. As an example for the former goal, the real time monitoring system for the EFIT reconstruction and first wall temperatures is presented. As for the second goal, we introduce the developments of fully 3-dimensional NBI and ECH simulation. We also discuss how these technologies can contribute to both the operation of existing tokamak and the design of future fusion reactor.

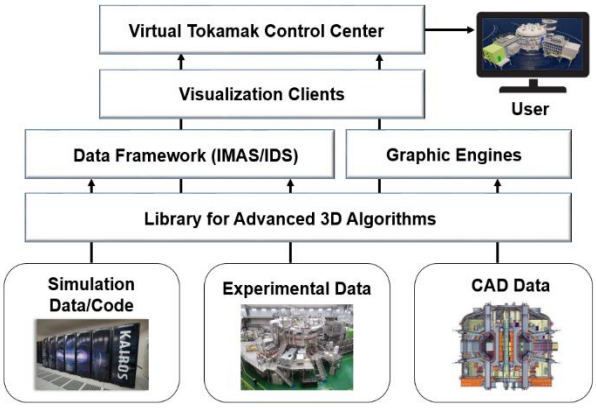

Figure 1. Hierarchical structure of the enabling technologies constituting fusion digital twin.

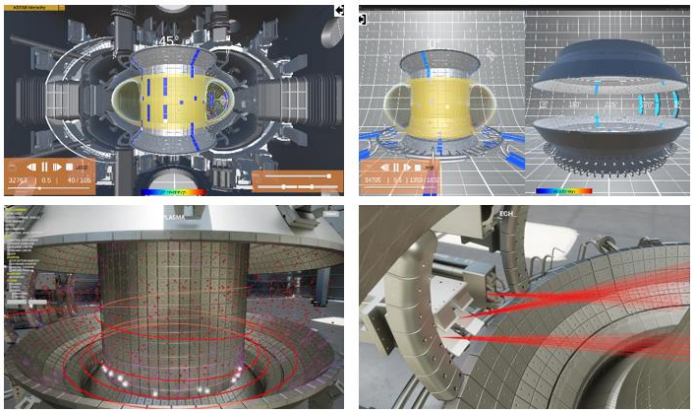

Figure 2. The real time monitoring system of V-KSTAR for plasma equilibrium and machine status (upper left and right), and the post analysis system of V-KSTAR for NBI and ECH (lower left and right).

This work was supported by R&D Program of "High Performance Fusion Simulation R&D (EN2341-9)".

References

[1] Jae-Min Kwon et al, "Development of a Virtual Tokamak platform", Fusion Eng. Des. 184, 113281(2022).
[2] Jae-Min Kwon et al, "Progress in Digital Twin Development of Virtual Tokamak Platform", IEEE Transactions on Plasma Science, doi: 10.1109/TPS.2024.3390159.