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Inertial fusion reactor system modeling: precursor to a digital twin

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An Inertial Fusion Reactor (IFR) is an extremely complex system on multiple aspects. On the engineering side, most of the promising candidate's components for such reactor are still at very low in Technology Readiness Level (TRLs). This leads to the combination of technological blocks that must be integrated together as a system while the evolutions of such subsystems influence all others. This highly risked task must be perfectly tracked through a robust and rigorous system architecture.

We started to model the system using an open-source python library called CoSApp [1] (for Collaborative System Approach). It allows the representation of the different subsystems as elementary bricks that can be connected to each other and exchange information (inputs/outputs). CoSApp is a very versatile library that makes possible, among things, the design of a complex system by solving nonlinear systems of equations imposed by the system and its subsystems. It also allows running time simulation through imposed conditions and presents standardized interfaces such as fmu/fmi.

The model presented is a preliminary result based on the work performed with our collaborator Assystem, a French engineering company specialized in nuclear and system engineering. We built with them a functional analysis, which is in a way, transcribed into our digital twin precursor.

We integrated into it a cost model developed by Woodruff Scientific LTD [2]. It provides a costing framework, which follows the Cost Accounting Structure (CAS) preconized by the GENIV Economics Modeling Working Group for the 4th generation of nuclear energy systems [3]. If the laser CAS is particularly relevant for FOAK and NOAK (Fist and Nth Of A Kind), as it is based on detailed National ignition Facility (NIF) costs, some other CAS such as the ones relevant to targetry, have to be refined.

In the future, this tool could handle other complex matter flux, such as fuel inventory or cycle, which could be updated according to a given design.

References

[1] Lac *et al.* (2024), CoSApp: a Python library to create, simulate and design complex systems, Journal of Open Source Software 9(94), 6292.

[2] Woodruff-Scientific-LTD, PyFecons, (2023), GitHub repository.

[3] W. Rasin, "Cost estimating guidelines for generation iv nuclear energy systems revision 4." The Economic Modeling Working Group Of The Generation IV International Forum, Tech. Rep. GIF/EMWG/2007/004, Sep. 2007. [Online Ressource]