TSVV-14 – Multi-Fidelity Systems Code for DEMO

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TSVV-14 Objective

Aim is to create a supported and widely used open-source reactor design tool capable of integrated modelling at multiple levels of fidelity (0-D, 1-D, 2-D, 3-D).

Project team: UKAEA + KIT (2.4 FTE/year)

It isn't a digital twin, "pulse design tool" or "flight simulator". It is a concept design tool (primarily workstation, i.e. not distributed).

Deliverables – Completion level		
Software architecture review and merge of BLUEPRINT and MIRA		2-D magnet winding pack design module
Integration with existing 0-D/1-D systems codes (e.g. PROCESS)		Vertical stability model incorporated into equilibrium solver
Coupled 1.5-D transport solver and free-boundary equilibrium solver		Coupling to open-source 2-D/3-D multi-physics FEA tools for "post run" workflow
Automatic 3-D CAD generation		Plant power balance
2-D deterministic radiation transport		First wall design module taking advantage of integrated tools
3-D radiation transport model integration (e.g. OpenMC)		Implementation of global optimisation solver in bluemira

EU-DEMO Workflow

PROCESS run → PSD-PSDD iteration

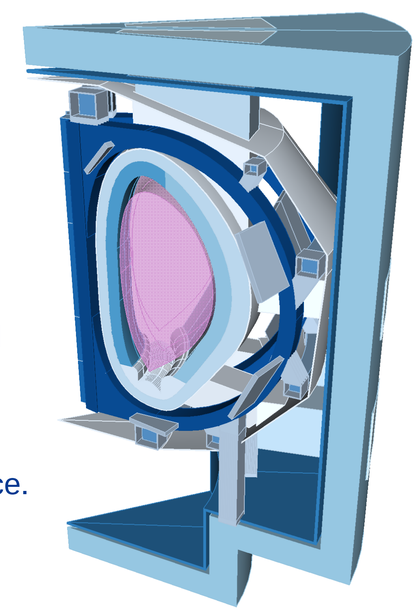
Bluemira run →

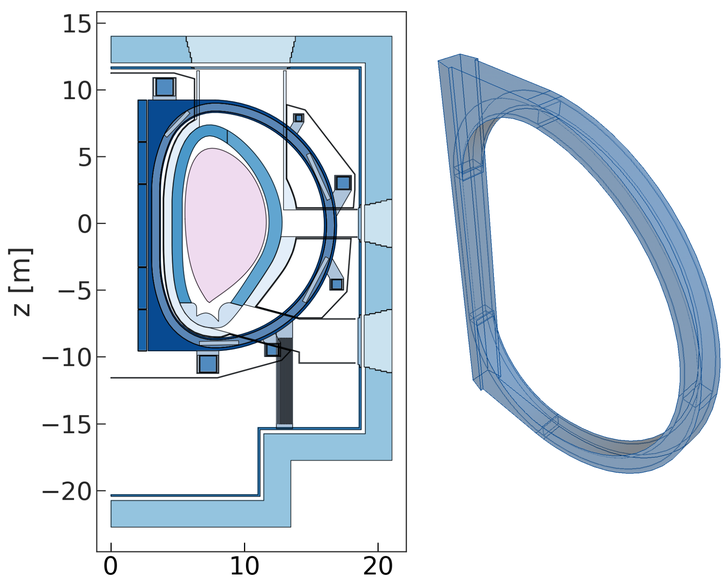
- PSD-PSDD iteration
- TF coil shape algorithm modified (cross-check with 3-D FEA)
- FW shape algorithm adjusted
- Breakdown magnetostatic optimisation modified
- Several subtly different configurations investigated

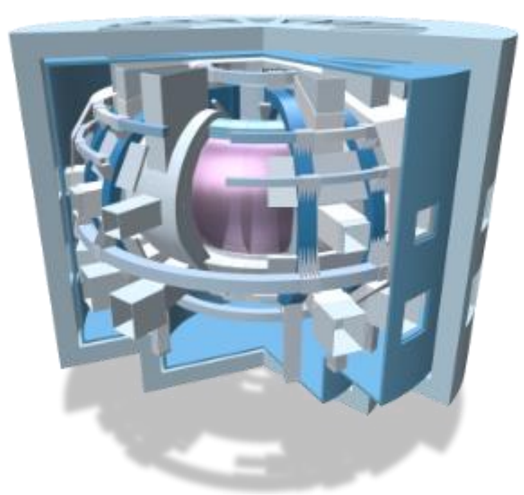
Bluemira outputs then "re-done" and ownership is transferred

- FW shape redone
- The equilibria and PF coil positions are improved by CREATE
- 2-D and 3-D CAD converted into CATIA by the CAD office.

PSD-PSDD workflow continues as normal





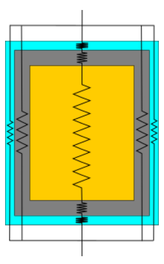


TF Winding Pack

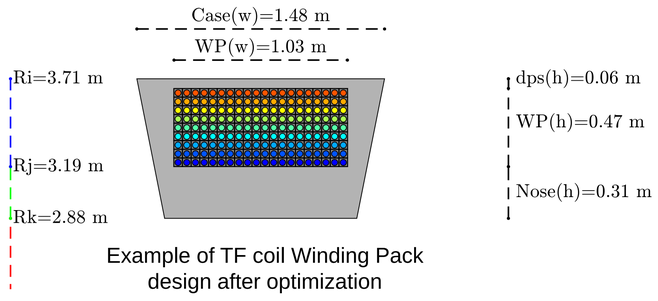
The bluemira magnets module is aimed to provide an initial optimisation of the WP and case dimension for all the magnets following the work of L. Giannini (PMU, Garching).

Optimisation based on:

1. Amount of superconducting material
2. Amount of stabilizing material (considering hot spot temperature criteria)
3. Steel thickness (consideration on the allowable stress using an equivalent spring system approach)



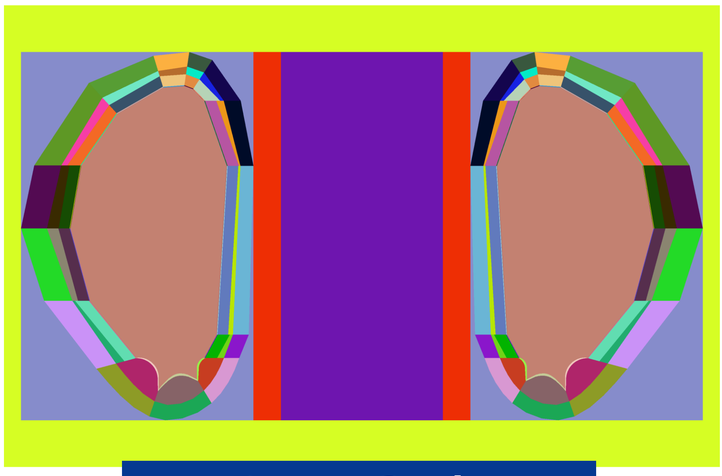
Equivalent spring system for a conductor



Example of TF coil Winding Pack design after optimization

Neutronics

- Automatic axisymmetric OpenMC (CSG) model generation from the Bluemira CAD
- Seamless integration from CAD to calculation of neutronics quantities such as the TBR and heat loads on various components.
- Simplified neutronics model runs fast enough to be used within optimisation problems



Remote Maintenance

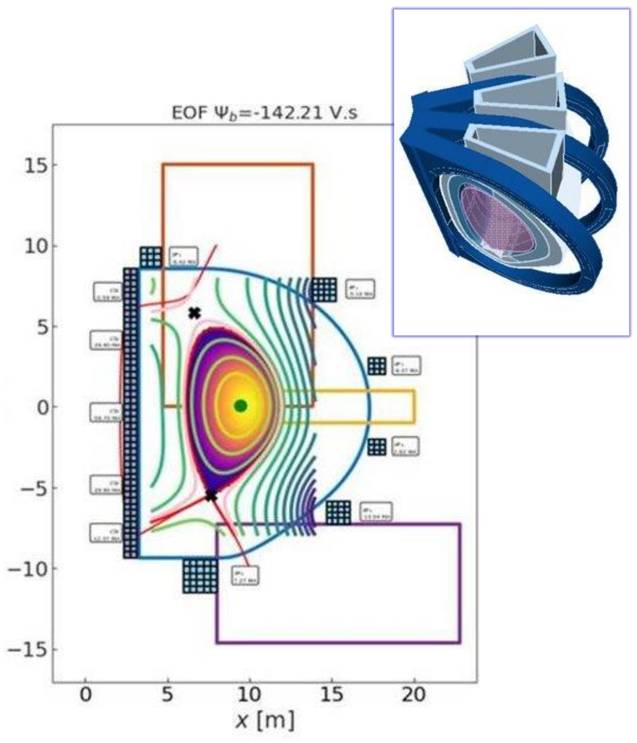
Specification of constraints on remote maintenance:

- Space availability and with optimisation constraints.
- Manipulator constraints (eg. mass).

Early concept stage integration of RM considerations

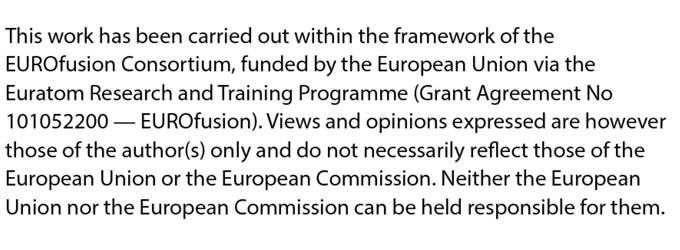
- Integrated with all other systems
- 2D Keep out zones for ports part of automated PF coil positioning and blanket segmentation
- Access restrictions respected

Immediate generation of space claim CAD expedites further analysis.



Power Cycle

- (**Net Power Loads**) Accounting tool to represent & sum power loads of major plant systems.
- (**Magnetics**) Coil Power Supply model for fast estimation of coils active/reactive power demands.
- (**ss-BoP**) Modelling of major thermodynamical processes for consistent BoP characterization based on an identified minimal set of design requirements.
- (**tt-BoP**) Dynamic 0D modelling of heat capacity for selected components, for fast estimation of impact of transients to BoP.



Next Steps → finalise coupling with 3-D FEA (OS dependency), "Gap" constraints for equilibria, Toroidal harmonics (WIP), Fuel cycle re-vamp (+ generalisation of load accounting architecture to both Power and Fuel Cycles), Improve 2-D WP design tool (e.g. 2-D FE stress calculation, higher fidelity quench models), surrogate neutronics models and generic surrogate tools, PROCESS <-> BLUEMIRA feedback/convergence loop.

UK Atomic Energy Authority

Karlsruher Institut für Technologie

Bluemira

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