Dynamic Modelling of the Helium-cooled DEMO Fusion Power Plant with an Intermediate Loop and Energy Storage System (Indirect Cycle)

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Introduction

The DEMO (DEMOnstration Power Station) is a conceptual design for a future fusion power plant utilizing experience from the ITER project. DEMO is designed to produce electricity and one key challenge relates to the pulsed operation of the machine and adopting a conventional power conversion systems. The DEMO balance-of-plant systems have to be designed to manage a periodical drop in fusion heat production during a foreseen cycling between a 2 hours power (burn) period and a 10 min dwell period while keeping relatively stable conditions in the PCS to avoid excessive cyclic loads on components.

Concept, model and aims

- 16 sector Helium-Cooled Pebble Bed Breeding Blanket (HCPB) configuration.
- A molten salt Intermediate Heat Storage System (IHTS) equipped with an Energy Storage System (ESS) between the Primary Heat Transfer System (PHTS) and the Power Conversion System (PCS) – Indirect Cycle, see Figure 1.

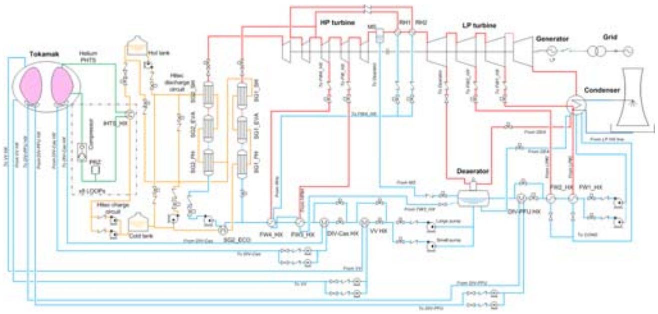

Figure 1. Layout of the helium-cooled primary heat transfer system (green lines) with a molten salt intermediate heat transfer and energy storage system (orange) and the power conversion system (red – steam; blue – water)

- KIT has, with the support from Siemens and KAH, developed and optimized the PCS scheme and performed steady-state balance analysis for power and dwell operations with the simulation tool Ebsilon.
- VTT has made a model of the same configuration with the system code Apros for dynamic analyses.
- Dynamic analyses including pulse and dwell transitions have been performed to verify that the developed balance-of-plant concept is feasible.

Power source	Pulse (2h) [MW]	Dwell (10') [MW]
Breeding blanket, BB	2101.7	21.017
Divertor plasma facing unit, DIV-PFU	136.00	1.42
Vacuum vessel, VV	86.00	1.00
Divertor casette body, DIV-CAS	115.20	1.07

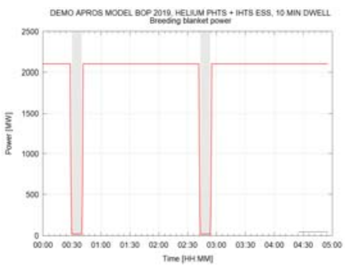

Figure 2. Source power levels and transition power behavior.

Results

- BB PHTS temperature variations can be kept relatively low with proper timing for stopping the circulators (Figure 2).
- Molten salt charging flow from cold to hot tank is 100 % during burn and 0 % during dwell (5 % bypassing hot tank). Molten salt discharge flow (hot to cold tank) is 90 % during burn and 104 % for 30 min after start of dwell.

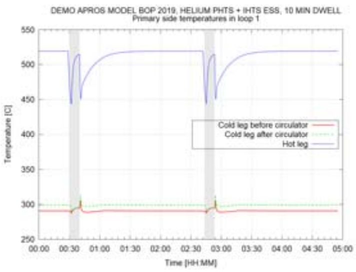

Figure 3.

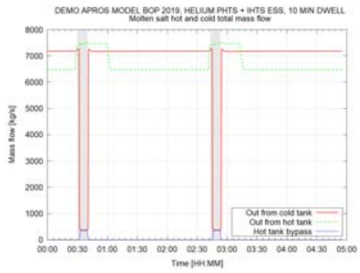

Figure 4.

- The mass inventory variations of the molten salt tanks are considerable during a cycle (Figure 5). The volume averaged molten salt temperature variation can be considered acceptable. (Figure 6).

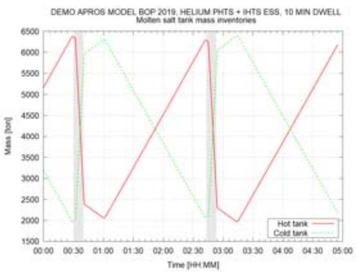

Figure 5.

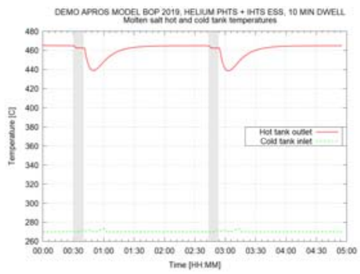

Figure 6.

- Temperature and pressure variations in the PCS are inevitable, but can be controlled to acceptable (Figures 7-8).

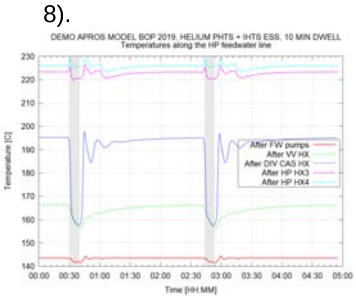

Figure 7.

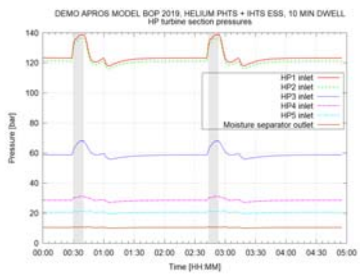

Figure 8.

Conclusions

- **The helium cooled concept with an intermediate heat storage system and energy storage is feasible from a technical performance aspect**
- **The energy storage system requires huge molten salt tanks**

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