Karlsruhe Institute of Technology

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Parameter study and dynamic Simulation of current DEMO Intermediate Heat Transfer and Storage System design via MATLAB/Simulink

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Introduction

State:

- ✓ Nuclear fusion is expected to offer limitless fuel reserves
- ✓ Steady energy supply needs development of effective technical solutions
- ✓ For the DEMOstration Fusion Power Plant (DEMO FPP) an Intermediate Heat Transport and Storage System (IHTS) is developed
- ✓ The HITEC molten salt is proposed to be used as a heat transfer fluid in the IHTS two-tank direct system

Scope:

Study of parameters and simulation of dynamic model for intermediate heat transfer and storage system (IHTS) via MATLAB/Simulink

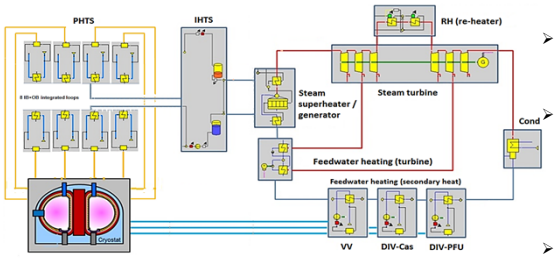
Tasks:

- ➢ Evaluation of dynamic behavior of DEMO-IHTS through the simulation via MATLAB/Simulink
- ➢ Calculation of thermodynamic parameters of HITEC molten salt and their involvement into the dynamic IHTS model via MATLAB/Simulink
- ➢ In due course simulation of temperature decay inside the hot and cold IHTS tanks and calculation of the tanks filling level during the Tokamak burn and dwell phases

DEMOnstration Fusion Power Plant

DEMO Balance of Plant (BoP) 2019 concept

- ➢ **Design:** Helium Cooled Pebble Bed Breeding Blanket
- ➢ **Steady state conditions:** Thermal power of ~2 GW generated in 8 inner and outer breeding loops during pulse operation of DEMO FPP with 100% power transfer
- ➢ **Gross electrical power value:** ~ 987 MW

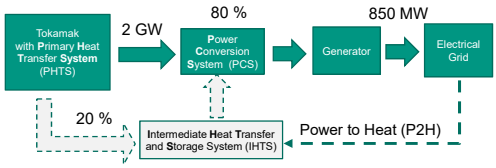


Conceptual State of Balance of Plant (BoP)

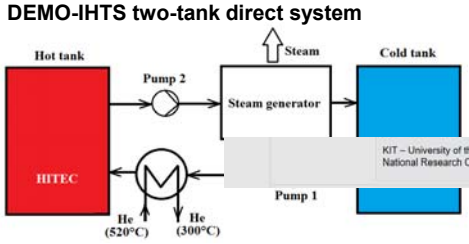
- ➢ **Pulsed operation:** burn phase of 120 min and dwell time of 10 min for dust/ash cleaning and loading of central solenoid
- ➢ **Intermediate Heat Transfer and Storage System (IHTS):** Coupling of Primary Heat Transfer System (PHTS) and Power Conversion System (PCS) with a two-tanks direct thermal storage
- ➢ **HITEC molten salt:** as heat transfer fluid for IHTS

Intermediate Heat Transfer and Storage System Model (IHTS)

Energy Transfer Chain for DEMO FPP



DEMO-IHTS two-tank direct system



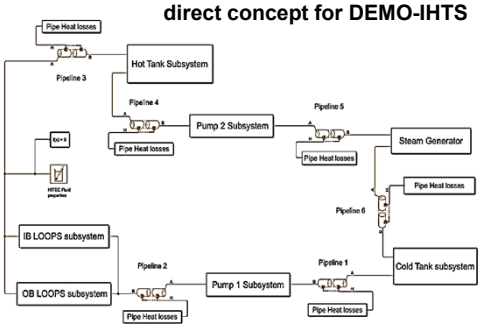
IHTS

- ➢ IHTS is coupled to PHTS, PCS and infrastructure
- ➢ It receives thermal energy from PHTS Inner Blanket and Outer Blanket loops
- ➢ Bounded critical temperature: 473.15 K to avoid HITEC molten salt crystallization

HITEC molten salt parameters

Specification	HITEC molten salt
Composition	7% $NaNO_3$, 53% KNO_3, 40% $NaNO_2$
Min/Max. Temperature	142°C / 535°C
Total mass of salt per tank	5040 t
Size / Volume	Ø: 23.8m / H: 7.8m / V: 3000m³
temperature	
Operational pressure	1.0 bar – 2.0 bar

Dynamic model for two-tank direct concept for DEMO-IHTS

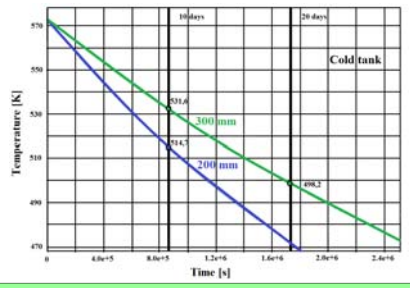


Dynamic Simulation using MATLAB/Simulink to improve the Current [illegible] Design, J.Oliveira, Master thesis, INR, KIT, 2018

- ✓ use same design blocks
- ✓ Simulation includes regulation of volume, tank level, temperature, height & heat losses

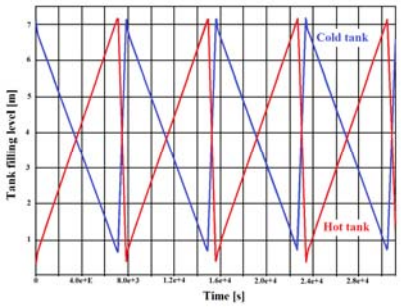
Results of dynamic simulation

Influence of thermo-insulation thickness on temperature of HITEC during stand-by



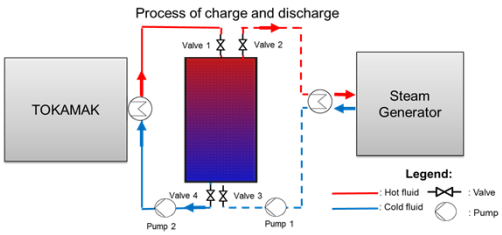
- ➢ During stand-by operation, no trace heating in DEMO-IHTS tanks is required
- ➢ For cold tank, with the insulation thickness of 200 mm and 300 mm, it takes for HITEC molten salt 20 and 30 days to reach the critical temperature of 473.15 K
- ➢ For hot tank it takes 27 and 40 days, correspondingly

Filling level of IHTS hot and cold tanks for 4 fuel cycles



- ➢ During pulse time, molten salt level in tanks changes in gradual way
- ➢ During dwell time, the change takes place in a steep slope

Single tank thermocline DEMO-IHTS concept



Dynamic Simulation of single-tank thermocline storage system using MATLAB/SIMULINK, C. Pasquet, international internship, INR, KIT, 2019

Single thermocline tank design concept:

- ✓ Lower costs in comparison with two-tank concept
- ✓ Less material and construction elements demand
- ✓ Reduced volume of heat transfer fluid
- ✓ Enhanced pumping system

Conclusions

- ✓ Successful development of the dynamic simulation of DEMO-IHTS design
- ✓ Use of HITEC molten salt as heat transfer fluid
- ✓ First results of simulation with dynamic two-tanks IHTS model

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