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# Thermal Energy Storage System Proposal for DEMO Fusion Power Plant

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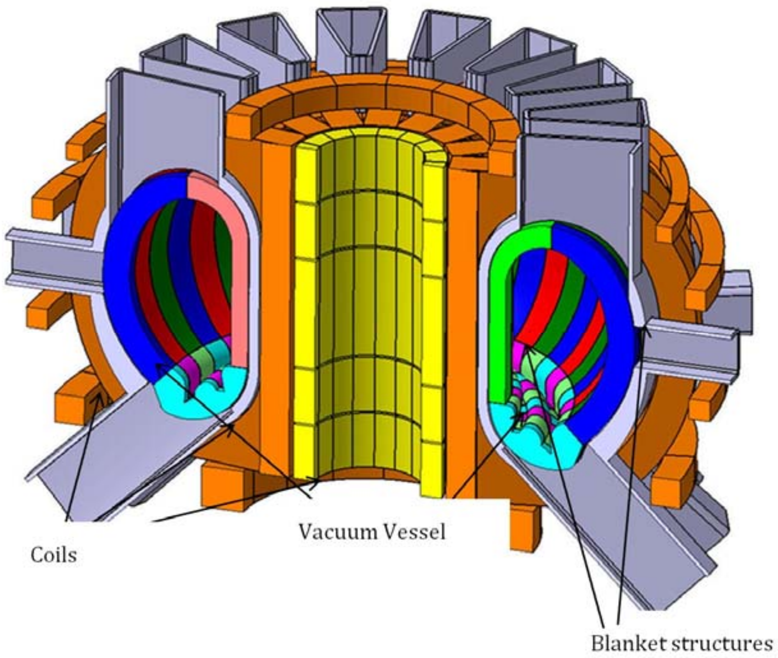
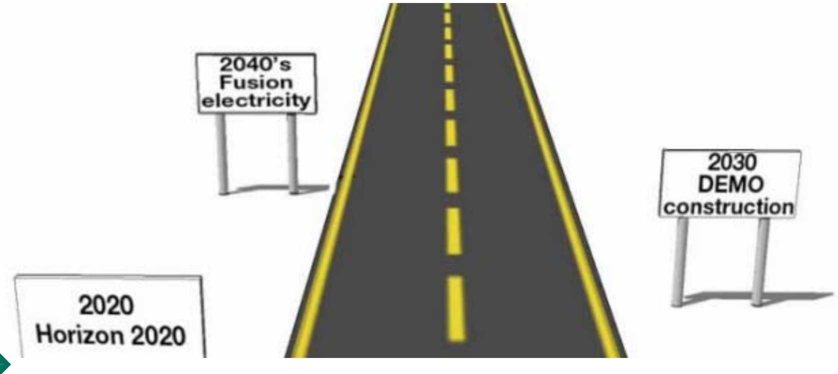
The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Institute for Neutron Physics and Reactor Technology

# Outline

- Introduction
- Available heat sources
- Objective of presentation
- Selected coolants for DEMO BoP
- Conceptual design configuration for DEMO intermediate heat storage loop:
  - water cooled BB case
  - He cooled BB case
- Conclusions (water & He cooled BB cases)




Conceptual design

Ref: https://www.euro-fusion.org/eurofusion/the-road-to-fusion-electricity/

# Introduction

- The EUROfusion Consortium within its Power Plant Physics and Technology (PPPT) work programme is currently focused on the conceptual design of a demonstration fusion power plant (DEMO) to be constructed in 2030.
- As the operation of DEMO fusion power plant consists of different phases – charging of poloidal field (PF) coils, plasma burning time, shutdown of PF coils and Dwell time between pulses, the power output is not constant.
- Also internal needs to start up magnet fields lead to the conclusion to add an energy storage to the DEMO system.
- Due to the high efficiency, the energy storage will be a thermal energy storage (TES) system, which would allow a constant production of power and would increase the lifetime of power conversion system (PCS).
- Presented here is a proposal for such a TES system for DEMO fusion power plant.

# Available heat sources

- There are three main heat sources to be taken into account when designing the BoP system for DEMO fusion power plant: heat coming from blanket, divertor and vessel cooling circuits.
- Divertor and vessel are cooled by water, and these two heat sources are implemented into the power conversion system (PCS) of DEMO.
- Blanket cooling might be done by water or helium. This work analyze both: the DEMO BoP with water cooled blanket and DEMO BoP with helium cooled blanket. Blanket cooling circuit is part of DEMO primary heat transport system (PHTS).
- The link between PHTS and PCS is the intermediate TES system, where the coolant is proposed to be solar salt, which transports heat from the blanket cooling circuit to the PCS, where steam is being produced and supplied to the steam turbine for electricity production.

## Objective of presentation

- ✓ This presentation will highlight the design peculiarities of the TES system, when applied to DEMO BoP with water cooled blanket and DEMO BoP with helium cooled blanket.
- ✓ A proposal for TES system for DEMO BoP will be presented for the two above mentioned cases of blanket cooling.
- ✓ Differences between the two options are being discussed and conclusions drawn.

# Selected coolants for DEMO BoP

- Coolant for the intermediate heat storage loop of DEMO PHTS system was chosen to be molten salt, or saying more exactly solar salt (60% $NaNO_3$, 40% $KNO_3$).
- Solar salt is well established in concentrating solar power technology and has a wide applicability range, however, the freezing temperature is rather high (~220 °C).
- Working fluid for the PCS was selected to be water (Rankine Cycle).

# Conceptual design configuration for DEMO intermediate heat storage loop (water cooled BB case)

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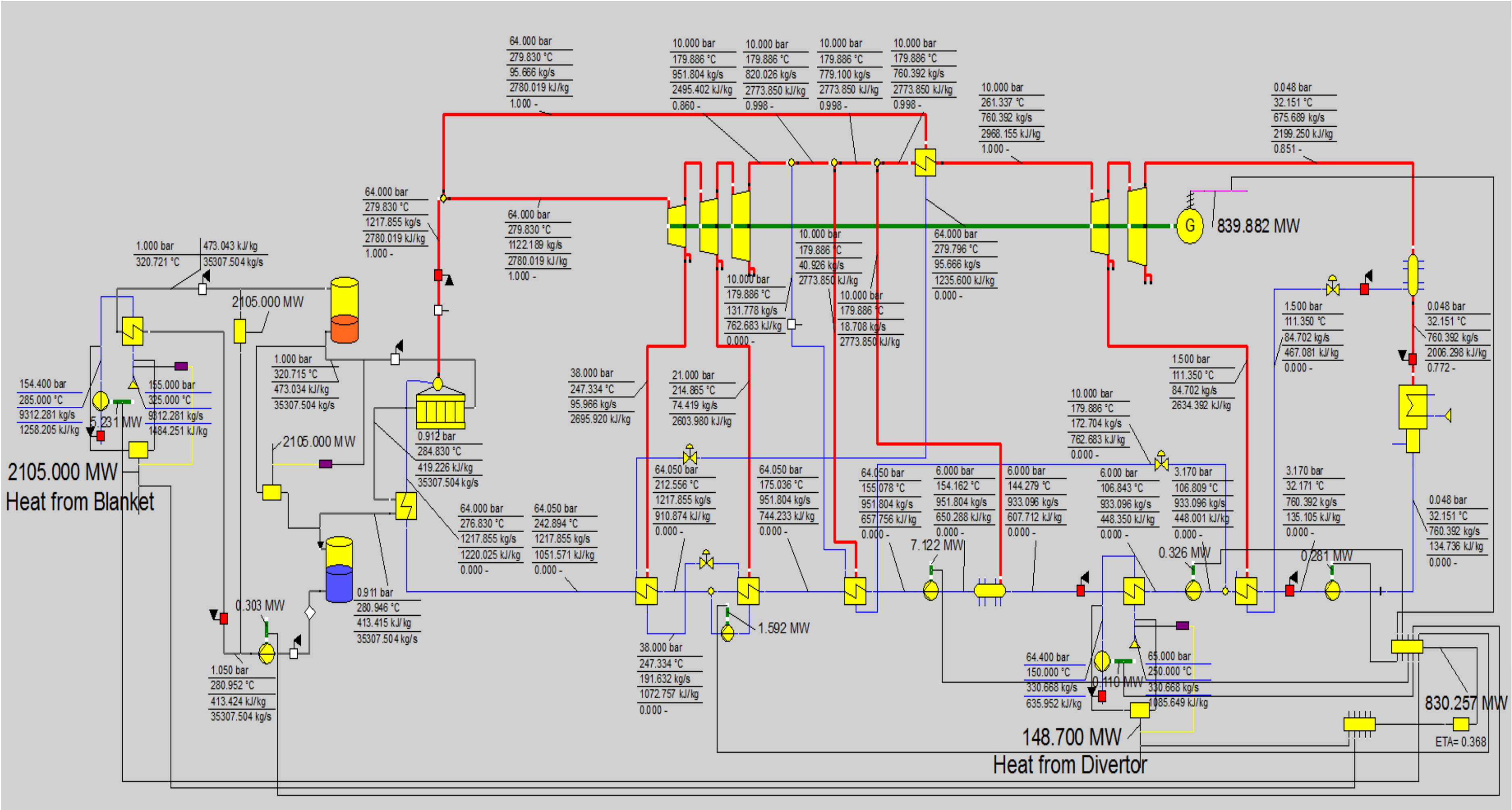




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# Conceptual design configuration for DEMO intermediate heat storage loop (water cooled BB case)

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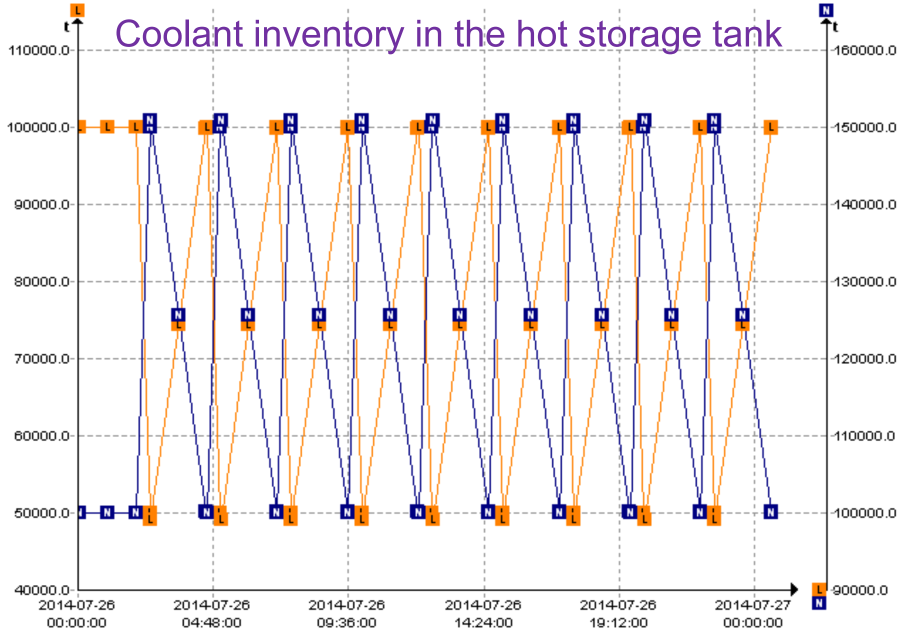
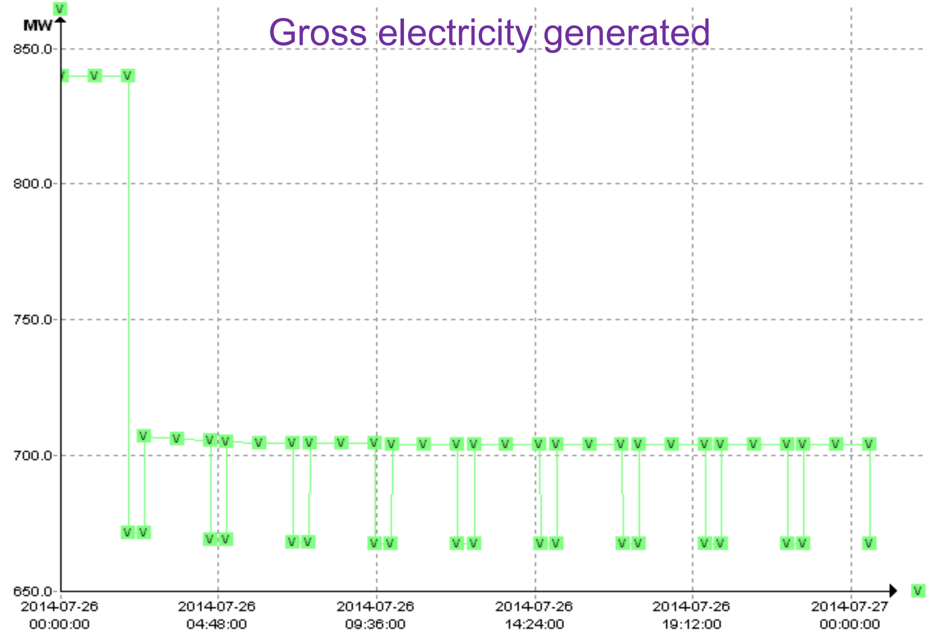
Assumptions made:

1. As related to the **two** heat sources (blanket and divertor), coolant flowrates are 100 % during the ~2 h time period and 0 % during the ~0.5 h shutdown (Dwell) time period. Coolant temperatures during the ~ 2 h time period are: blanket 325 °C in the inlet line and 285 °C in the return line, divertor 250 °C in the inlet line and 150 °C in the return line. Coolant temperatures during the ~0.5 h shutdown time period drop down: to 285 °C for the blanket and to 150 °C for the divertor;
2. In the PHTS coolant flowrate is 100 % during the ~2 h time period and 0 % during the ~0.5 h Dwell time period;
3. In the intermediate heat storage loop coolant flowrate from the cold storage tank to the hot storage tank is 100 % during the ~2 h time period and 0 % during the ~0.5 h Dwell time period, while coolant flowrate from the hot storage tank to the cold storage tank is always ~80 % nominal flow;
4. In the PCS coolant flow is always ~80 % nominal flow.

# Conceptual design configuration for DEMO intermediate heat storage loop (water cooled BB case)




- Pulsed power operation of DEMO (~2 h on, ~0.5 h off – 4:1 cycle) reduces the cycle efficiency from 36.8% down to 29.7% and requires the heat storage capacity for ~50000 t of solar salt (two equivalent tanks for hot and cold salt) for the Dwell time period of the DEMO. This big amount of the required heat storage capacity results in huge additional costs related to the purchase of the solar salt itself and also to the cost of these huge salt storage tanks

# Conceptual design configuration for DEMO intermediate heat storage loop (He cooled BB case)

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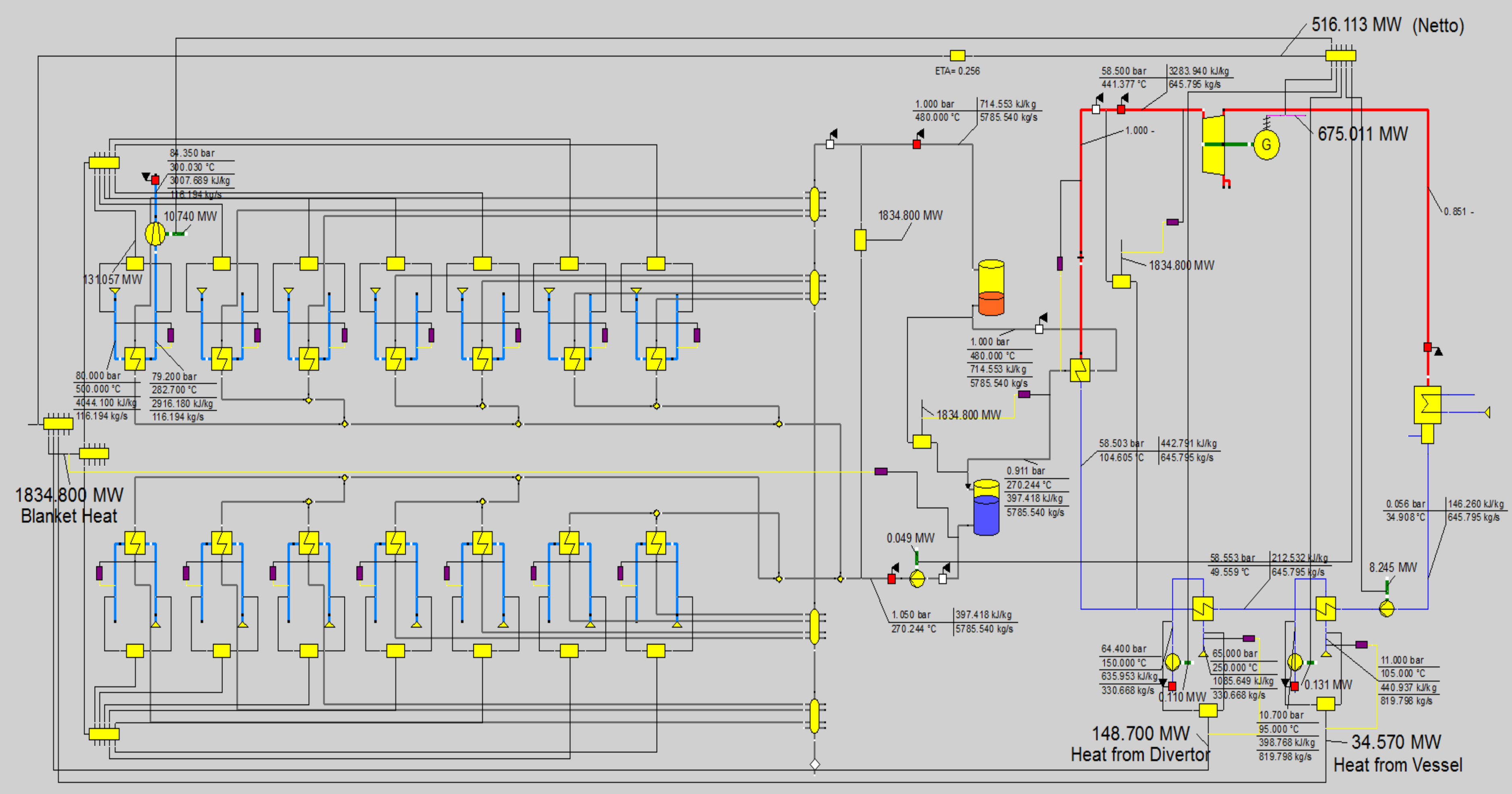




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# Conceptual design configuration for DEMO intermediate heat storage loop (He cooled BB case)

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Assumptions made:

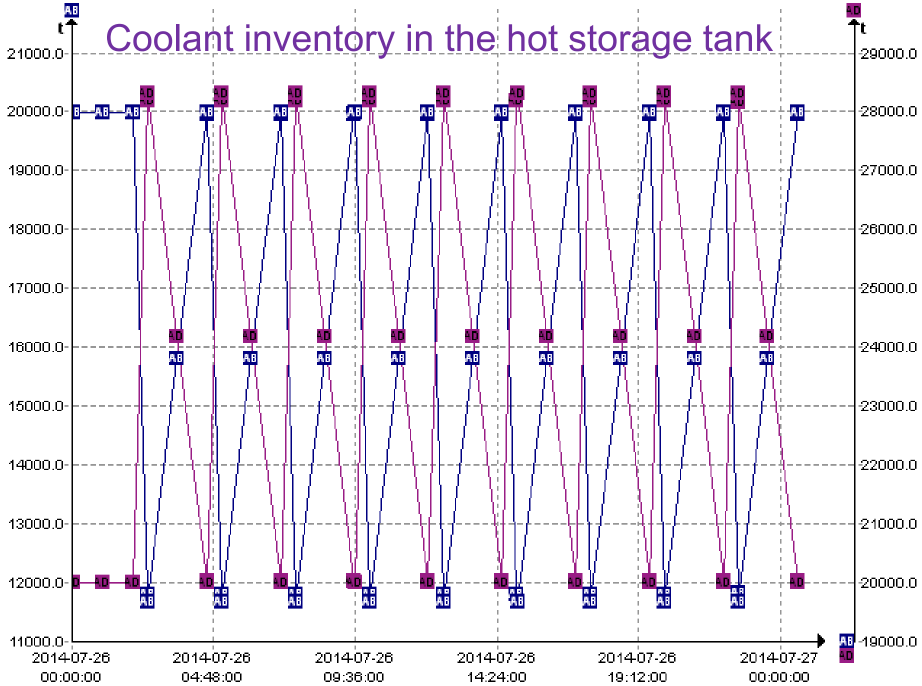
1. As related to the **three** heat sources (blanket, divertor and vessel), coolant flowrates are 100 % during the ~2 h time period and 0 % during the ~0.5 h shutdown (Dwell) time period. Coolant temperatures during the ~ 2 h time period are: blanket 500 °C in the inlet and 300 °C in the return line, divertor 250 °C in the inlet and 150 °C in the return line, vessel 105 °C in the inlet and 95 °C in the return line. Coolant temperatures during the ~0.5 h Dwell time period drop down: to 300 °C for the blanket, to 150 °C for the divertor and to 95°C for the vessel;

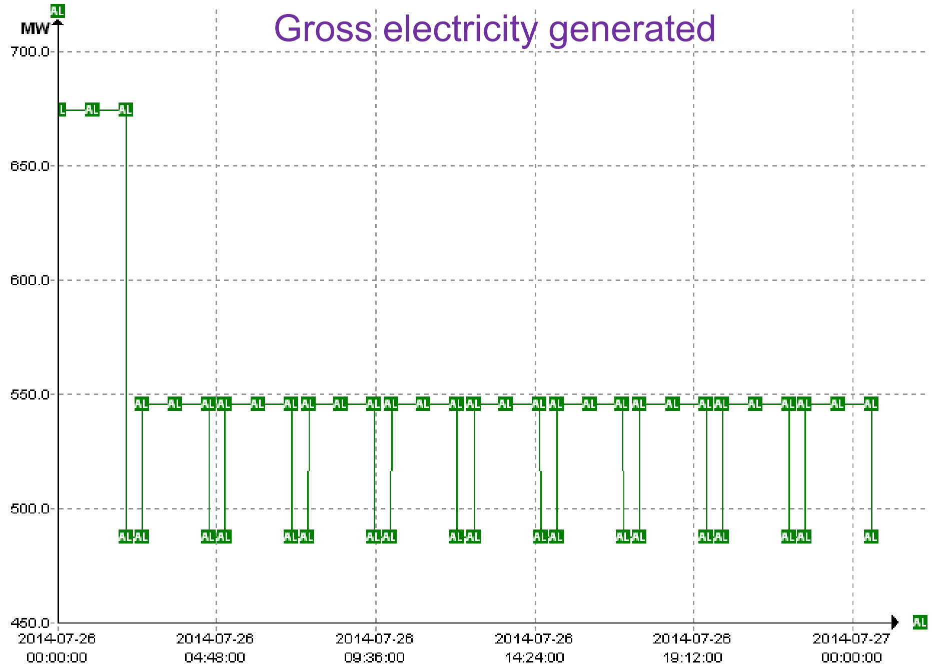
2. In PHTS coolant flowrate is 100 % during the ~2 h time period and 0 % during the ~0.5 h Dwell time period;

3. In the intermediate heat storage loop coolant flowrate from the cold storage tank to the hot storage tank is 100 % during the ~2 h time period and 0 % during the ~0.5 h Dwell time period, while coolant flowrate from the hot storage tank to the cold storage tank is always ~80 % nominal flow;

4. In the PCS coolant flow is varying between ~73 % and ~83 % nominal flow, depending on the availability of the heat sources from divertor and vessel.

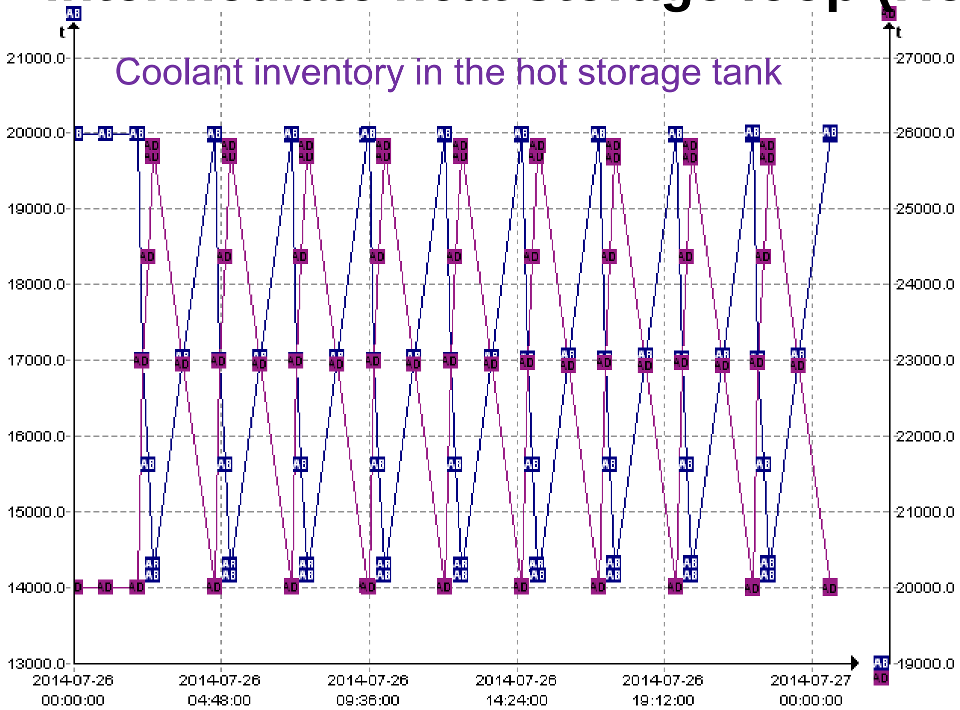
# Conceptual design configuration for DEMO intermediate heat storage loop (He cooled BB case)

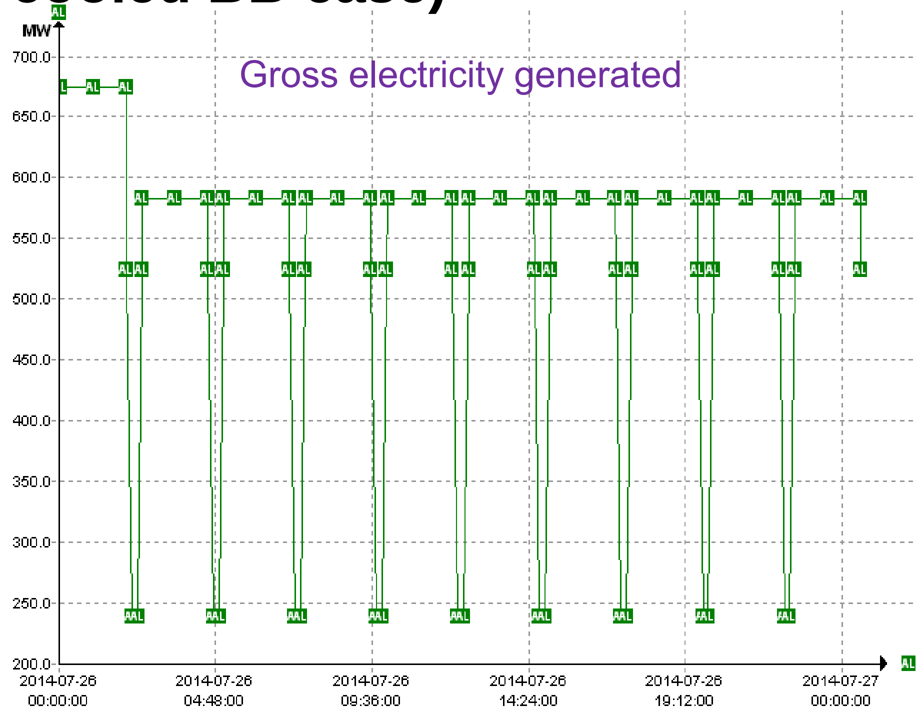



- Pulsed power operation of DEMO (~2 h on, ~0.5 h off – 4:1 cycle) reduces the cycle efficiency from 25.6% down to 19.1% and requires the heat storage capacity for ~8000 t of solar salt (two equivalent tanks for hot and cold salt) for the Dwell time period of the DEMO. This amount of the required heat storage capacity is much (~6 times) less than the required heat storage capacity for the case when blanket is cooled by water.

# Conceptual design configuration for DEMO intermediate heat storage loop (He cooled BB case)




- Additionally, ~30 % economy on the solar salt itself is possible, if DEMO BoP would reduce its electrical power production down to ~54% during the Dwell time period, thus smoothly going down in produced power in the first 10 min of the Dwell time period of the total of 30 min, staying at ~54% power production for 10 min, and then smoothly going up in produced power in the last 10 min of the Dwell time period.

# Conceptual design configuration for DEMO intermediate heat storage loop (water & He cooled BB cases)

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Conclusions:

- In the case of DEMO BoP scheme for water cooled blanket concept, pulsed power operation of DEMO requires the heat storage capacity for ~50000 t of solar salt (two equivalent tanks for hot and cold salt), in order to constantly produce steam for constant operation of the steam turbine, even during the Dwell time period of the DEMO. This big amount of the required heat storage capacity results in huge additional costs related to the purchase of the solar salt itself (~25 M$) and also to the cost of these huge salt storage tanks.

- **Alternative solution:**

  Phase change materials with Tc ~ 310°C, but requires additional research to investigate response times.

# Conceptual design configuration for DEMO intermediate heat storage loop (water & He cooled BB cases)

Conclusions:

- In the case of DEMO BoP scheme for helium cooled blanket concept, pulsed power operation of DEMO requires the heat storage capacity for ~8000 t of solar salt (two equivalent tanks for hot and cold salt), in order to constantly produce steam for constant operation of the steam turbine, even during the Dwell time period of the DEMO. This amount of the required heat storage capacity is much (~6 times) less than the required heat storage capacity for the case when blanket is cooled by water, and thus the cost for the solar salt itself is much less (~4 M$) and the cost for the salt storage tanks would be much less.

# Conceptual design configuration for DEMO intermediate heat storage loop (water & He cooled BB cases)

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Conclusions:

- This huge difference in the required heat storage capacity between the two options of DEMO BoP (between water cooled blanket and helium cooled blanket options) is mainly due to the usable different coolant $\Delta T$ of the main heat source (heat coming from the blanket cooling): in the first case $\Delta T$ ~ 40°C, in the second case $\Delta T$ ~ 200°C. Having lower coolant $\Delta T$ one needs more salt to store the same amount of heat, while having higher coolant $\Delta T$ one needs less salt to store the same amount of heat, in order to constantly produce steam for constant operation of the steam turbine, even during the Dwell time period of the DEMO.

- All the above mentioned parameters of the proposed TES system are still very preliminary and should be re-confirmed by further detailed simulations.

- In general however, the integration of TES system into DEMO BoP reduces thermal loads to the PCS and allows us to offer power to the grid in predictable and controllable manner.

# Acknowledgement

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Thank you for your attention.

Questions ?