Case study suggestion 2024-25

TITLE		
Long-term operation of OTSG in a steam bottoming cycle		
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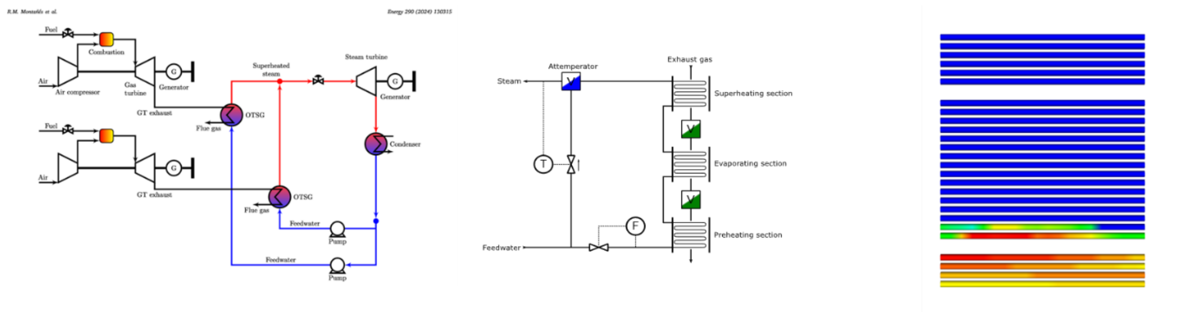

Fig 1. Left: Dynamic GTCC cycle process model. Right) Detailed OTSG model with stress/fatigue analysis

Case description: In the case study, operation and load of the OTSG in a combined cycle power unit offshore will be investigated in terms of planned and un-planned load changes for the gas- and steam turbines and connected to remaining life-time analysis of OTSG components. at the nominal point the combined cycle power plant will provide a total power output of ca. 92 MW_{el}, i.e., ca. 36 MW_{el} from each gas turbine and 20 MW_{el} from the steam turbine. Designs are based on the SGT750 turbines from SIEMENS Energy. Un-planned load changes could for instance be a gas turbine trip. Two classes of OTSG will be designed for a specified heat recovery duty that corresponds to a net power output from the steam turbine given a gas turbine (GT) load. One design will represent a compact OTSG with low internal volume and material mass, while the other will represent a less compact OTSG. Dynamic models with a suitable decentralized control structure of the entire combined cycle will be developed to capture the system dynamics and its effect on the OTSG during transients.

During normal operation, heat is accumulated in the OTSG tube material and during load changes the tube wall temperature will change depending on both of gas turbine exhaust and feed water flow rates. These temperature gradients can induce thermal stress and potentially lead to thermal fatigue and tube ruptures. The temperature swings occurs both as a direct consequence of inlet fluid temperature and indirectly as a result of a 'moving' boiling front inside the OTSG. With dynamic models the temperature changes (gradients) over time can be investigated for a selection of typical scenarios and linked to thermal stress and fatigue estimations.

In the case study, detailed results from the dynamic analysis will be analysed following recommendations from standards like the "ASME Boiler and Pressure Vessel Code" for converting this into a remaining life-time analysis.

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Relevant SPs: SP1 "Efficiency enhancement of gas turbines". Builds on thermal stress and OTSG dynamic models developed in the LowEmission KSP: Digital Twin.

Relevance to the call: NOU 2023: 25 (regjeringen.no) recommends energy efficiency and emission-reducing technologies other than electrification to be evaluated continuously to reach the 2050 goals (Sec. 12.6.3 and 12.7). It also highlights that with the introduction of wind power it will be necessary to keep gas turbines to assure power supply. This will bring continuous variations in net power demand and understanding its effect on the CCGT will be crucial for implementation.

Data: Transient data for power requirements. This can be based from industry sponsors or from the Yme / Inspirer case from Repsol.

Case potential and impact:

- Increased confidence for design and deployment of compact offshore steam bottoming cycles
- Estimate effects of varying and disruptive operation on compact OTSGs
- Potential for CO_2 reduction will be in the order of 25% compared to simple cycle gas turbines

Project plan:

Case study leader: Rubén M. Montañés (SINTEF Energy Research)

Activity 1 - System design and scenarios definition: This activity will focus on defining the design (number of tubes, diameter, etc.) of the heavier OTSG system. While weight minimization and compactness is paramount offshore, some technology suppliers and operators are reluctant to implement very compact designs as they might be perceived as less robust. This work will design a heavy waste heat recovery unit in order to compare its transient performance with the existing LE Task 1.1 baseline power only combined cycle. Key differences are tube diameter, design with new diameter given allowed pressure loss. The work will also organize workshops with partners to define industry relevant operational scenarios. Therefore, in this work, two combined cycle power only cycles will be evaluated. Part of the work will include the definition of the likelihood of instances of short-term operations and how often short-term events happen.

- Power only cycle with compact OTSG – single core – model that is currently used in SP1
- Power only cycle with heavier OTSG – new design to be provided in this case study

Activity 2 - Dynamic model development and control structure implementation: For the heavier OTSG based system, a dynamic system model of the combined cycle will be modeled in Modelica/Dymola to be able to capture system transients. A similar control structure as already implemented in the power only cycle with compact OTSG will be implemented to allow for systematic comparisons with dynamic simulations.

Activity 3 - Short- and long-term scenario analysis: Load change and trip scenarios that are relevant for short-term operation and long-term fatigue analysis.:

- Short-term analysis: to evaluate differences in process dynamic responses for both designs.
- Long-term analysis: to evaluate thermal fatigue of selected components according to available standards for both compact and less compact designs considering likelihood of short-term events. Builds on thermal stress models developed in the LowEmission KSP: Digital Twin.

Activity 4 – Simplified dynamic model development and analysis (Master student): Linked to Activity 2 and 3. Development of simplified and open-source models of combined cycles with compact and heavier OTSGs that capture relevant outputs. Model parameters will be provided by SINTEF. This model will be used for short-term scenario analysis.
Student: 5th year master student at the department of Chemical Engineering, PSE group, at NTNU.
Supervisor: Prof. Sigurd Skogestad
Co-supervisors at SINTEF: Lucas Ferreira Bernardino and Rubén M. Montañés

	Q3 24'			Q4 24'			Q1 25'			Q2 25'			Q3 25'			Q4 25'	
Tasks		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Task 1.1 Definition of OTSG and process design			M1		M2	M3											
Task 1.2 Heavy single core OTSG and process design							M5										
Task 2.1 Dynamic modeling implementation Dymola/Modelica									M6								
Task 2.2 Dynamic simulation from Dymola/Modelica										M8		M9					
Task 3.1 Establish methotology for thermal fatigue/lifetime analysis										M7							
Task 3.2 Fatigue - remaining lifefime analysis FlexCS																M11	
Task 3.3 Synthesis Report and Dissemination in LE Webinar																M11	
Task 4. Project/Master student supervision						M4						M10					

Figure 2. Gantt diagram with key tasks for each activity and milestones (M).

<u>Milestones:</u>

M1 – September 2024: Preliminary definition of OTSG and process designs ready

M2 – November 2024: Workshop with partners to define OTSG and process designs

M3 – December 2024: Short status report describing work in 2024

M4 – December 2024: Specialization project from master student delivered

M5- January. 2025: System design ready for both OTSG alternatives

M6 - March 2025: Dynamic models and control structures ready for both OTSG alternatives

M7- April 2025: Methodology for thermal fatigue lifetime analysis established

M8 - April 2025: Workshop with partners for scenario definition and frequency of events

M9 - June 2025: Dynamic simulations for scenario analysis finished

M10 - June 2025: Master thesis delivered

M11 - October 2025: Results ready. *<u>Final memo submitted in November 2025.</u>*

<u>Plans for dissemination:</u>

- Within the LowEmission Center: Status report end of 2024, Memo end of project, LE webinar
- With the industrial partners: workshops to define scenarios and discuss results
- There is the aim to write a scientific publication

Industry sponsors: TotalEnergies, ConocoPhillips

Possibilities for technology transfer:

Industry sponsors have a very high interest in deploying combined cycles. This case study may set the base, e.g., for maintenance recommendations based on measurements from system, increasing confidence and accelerating deployment.

Duration:
August 2024-November 2025