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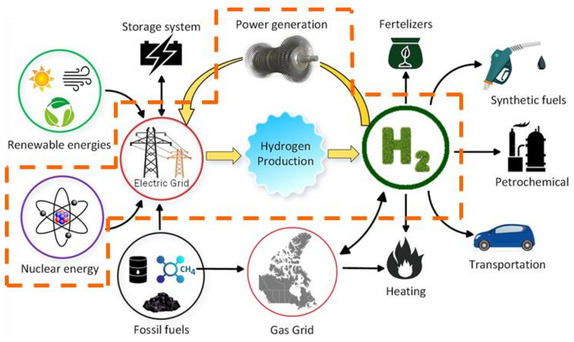
Thermodynamic Analysis of Hydrogen Power Generation Integrated Pressurized Water Reactor

Seunghwan Oh, Jeong Ik Lee*
Department of Nuclear & Quantum Engineering, KAIST
**Corresponding author: jeongiklee@kaist.ac.kr*

Introduction

- Hydrogen is recognized as the most suitable next-generation energy source for the new climate system.
- IAEA, KEEI, and INL presented the potential for hydrogen production in conventional PWR.
- Since hydrogen production results in PWR work loss, there can be a power generation technology that can compensate for PWR work loss by utilizing the produced hydrogen.



- In this study, the layout of hydrogen power generation integrated PWR is suggested and thermodynamically analyzed.

Fig. 1. Importance of hydrogen in integrating different energy sectors

Hydrogen power generation integrated PWR

- Most of the existing hydrogen combustion turbines are mixed with fuel and air, so there is a problem such as NOx emission, which is one of the main causes of fine dust.
- This study suggests a system that operates turbine after combustion with hydrogen and oxygen under steam condition.
- This technology is called hydrogen oxy-combustion (HOC).

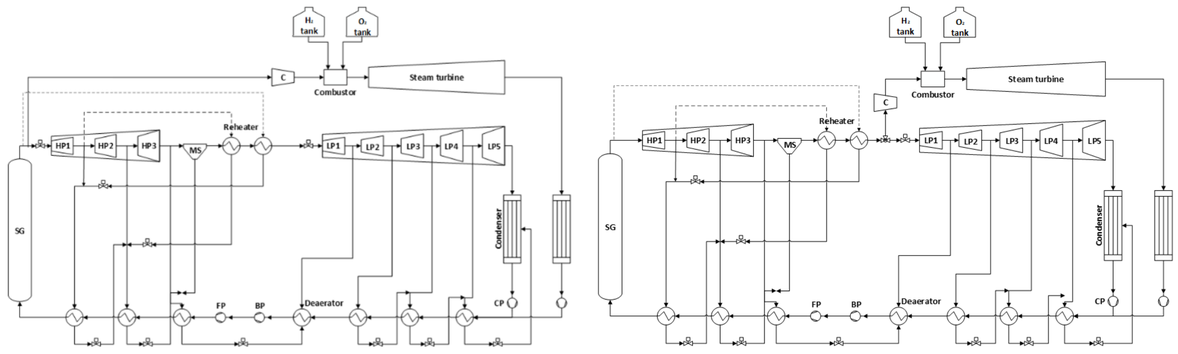


Fig. 2. Hydrogen power generation integrated steam system layout (L) HPT inlet (R) LPT inlet

Table I. HPT and LPT inlet conditions of typical PWR

	HPT	LPT
Temperature [°C]	282.21	263.36
Pressure [MPa]	6.63	1.44

Fig. 3. (T) Electricity according to extraction steam mass flow rate from PWR secondary side (B) Combustion heat (red bar) and turbine work (purple bar) according to extraction points

- The extraction point can be the HPT inlet or the LPT inlet.
- Considering the work loss and ratio of combustion heat and turbine work, LPT inlet extraction is recommended.

Table II. Hydrogen oxy-combustion power cycle condition

	Turb	Comp		Turb	Comp
Efficiency [%]	90	80	Inlet temperature [°C]	800.00	263.36
Extraction steam mass flow rate [kg/s]	110.89		Inlet pressure [MPa]	Variable	1.44

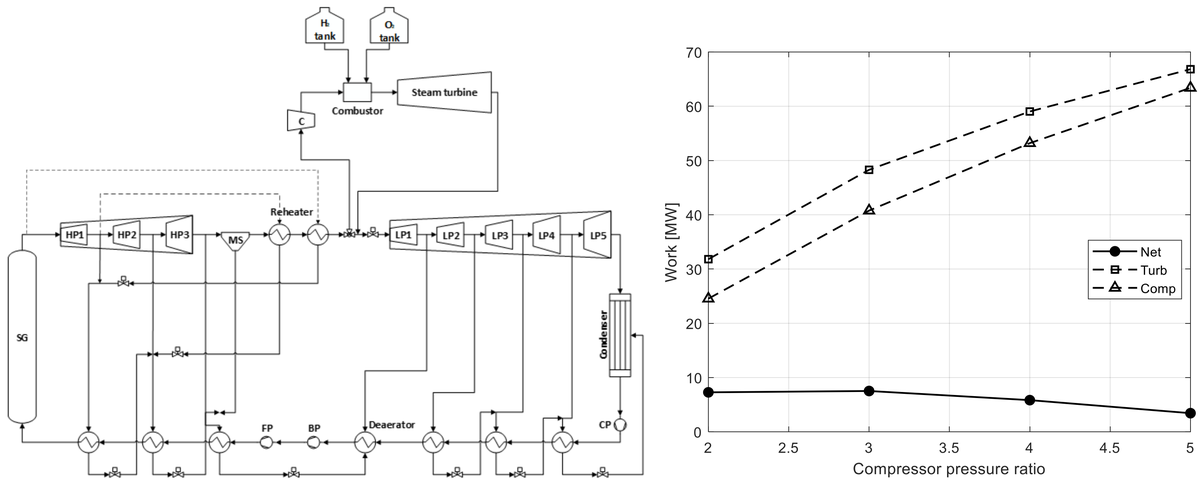


Fig. 4. HOC power cycle: (L) circulation cycle (R) turbomachinery work

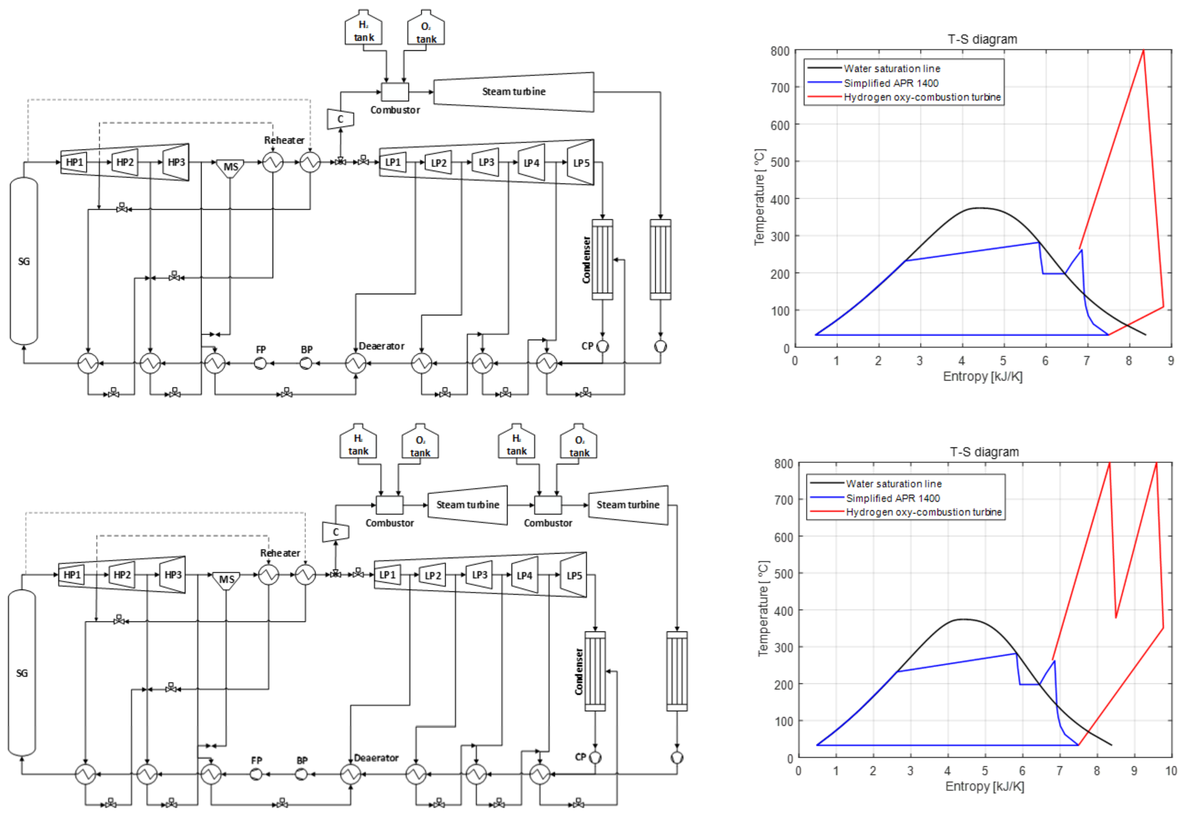


Fig. 5. HOC power cycle and T-s diagram (T) simple cycle (B) reheat cycle

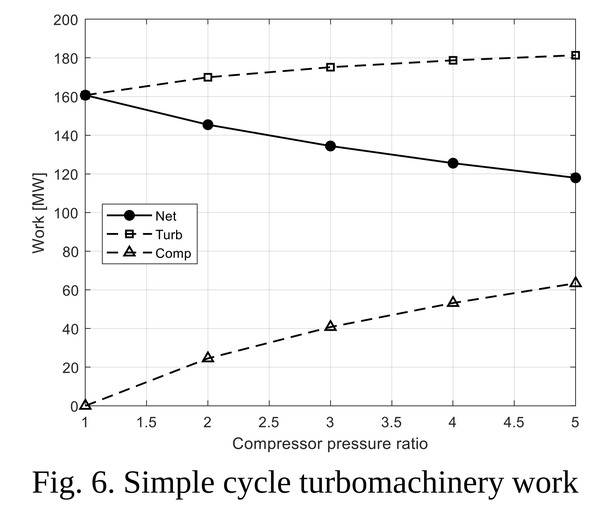


Fig. 6. Simple cycle turbomachinery work

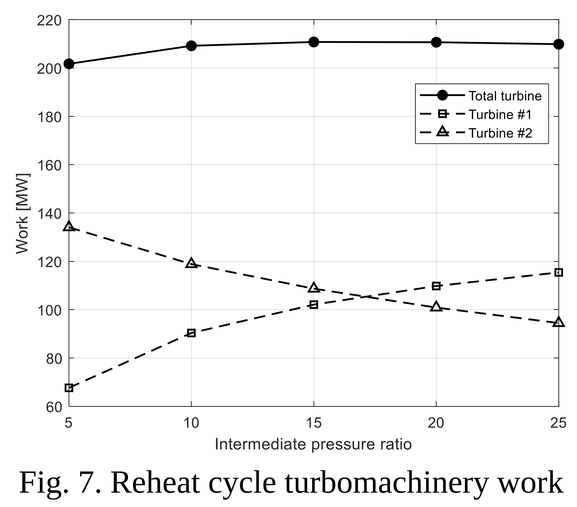


Fig. 7. Reheat cycle turbomachinery work

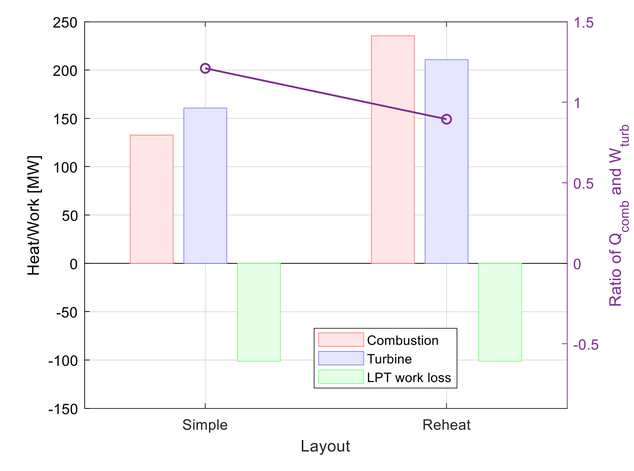


Fig. 8. Comparison of combustion heat and turbine work between simple cycle and reheat cycle

- The simple cycle is more efficient since the turbine work compared to the combustion heat is less than when it is the reheat cycle

Conclusions

- In this study, the layout of hydrogen power generation integrated PWR using HOC is proposed.
- Circulation, simple and reheat cycles can be candidates for HOC cycle layout, and thermodynamic analysis revealed that simple cycle without compression process is most preferred design choice.