Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 13-14, 2021

Study of Compressed CO_2 Energy System with low-temperature storage tank

Soyoung Lee , Yongju Jeong, Jeong Ik Lee*
Department of Nuclear and Quantum Engineering, KAIST, Daejeon, South Korea
*Corresponding author: jeongiklee@kaist.ac.kr

Introduction

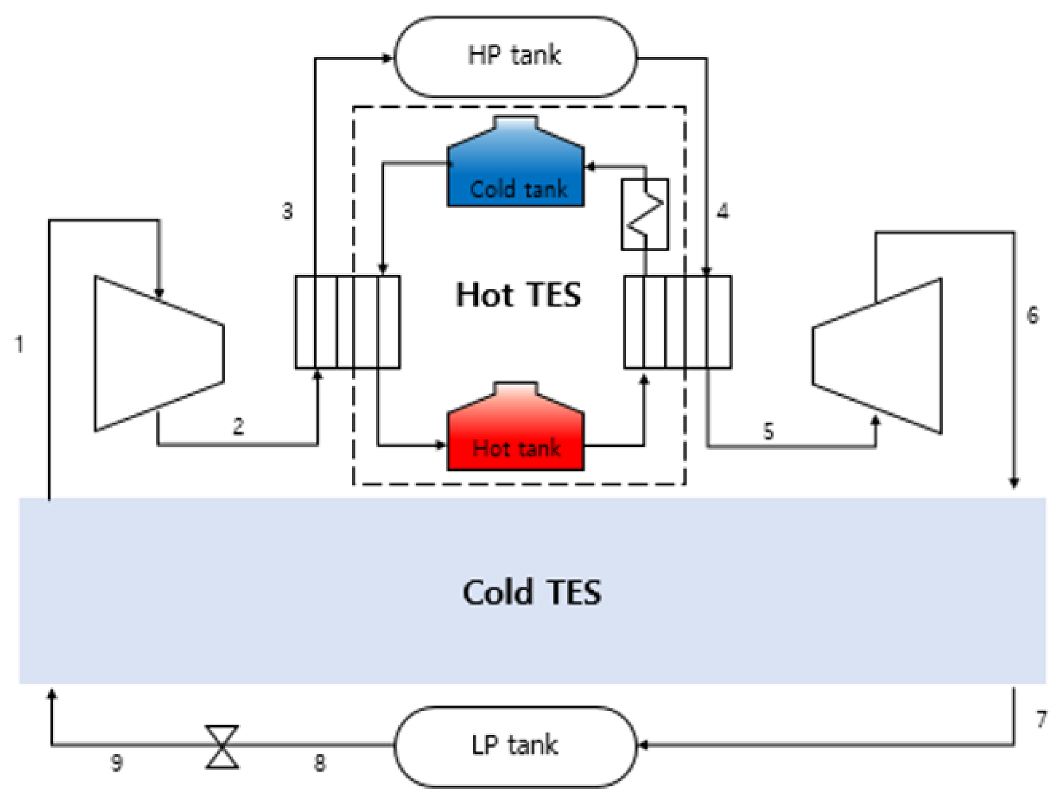
- ✓ As the demand for electricity increases, Energy Storage System (ESS) integrated with thermal and nuclear power plants can alleviate these problems.
- ✓ Since CCES is a closed cycle, there are two or more storage tanks, and the compression ratio is also low. As a result, CCES has low power density .
- ✓ To compensate for low power density of CCES, compressing CO_2 at low pressure near the triple point, and storing saturated liquid CO_2 in storage tank.

System Description

• Assumptions

1) The CO_2 tanks and the TES tanks have the same temperature, pressure, and properties at the inlet and outlet, respectively.
2) There is no pressure drop in the pipes.
3) The turbine and compressors have constant isentropic efficiencies, respectively.
4) The ratio of mass flow rate of charging and discharging is unity.
5) There are no changes in potential and kinetic energies.

• Layout of CCES



Schematic of CCES

• Heat Exchanger

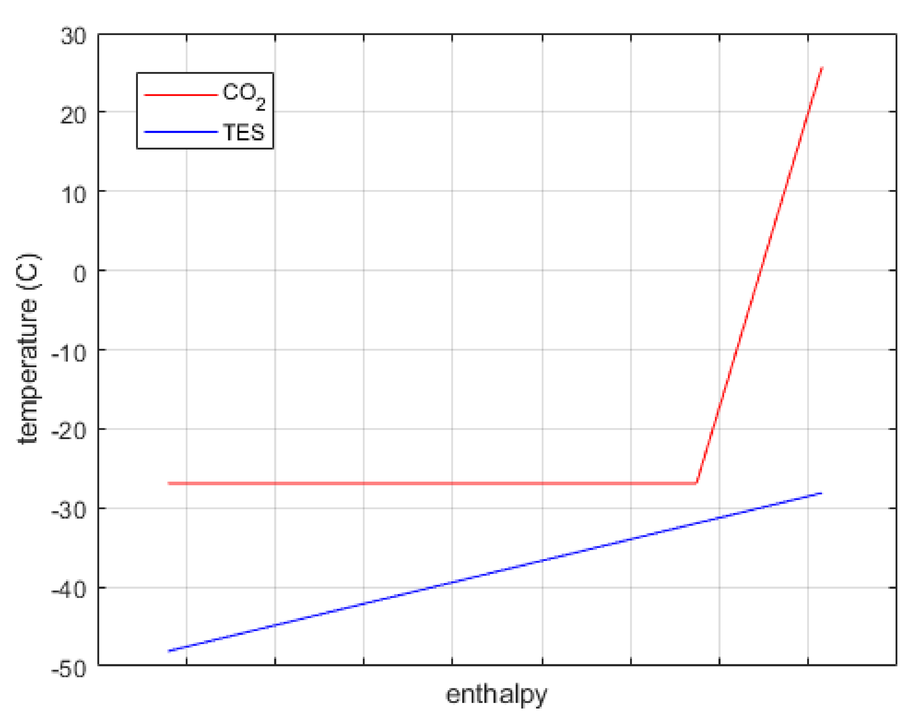
The effectiveness ε is defined, $\varepsilon = \frac{q}{q_{max}}$

q_{max} of counterflow heat exchanger

$$q_{max} = C_{min}(T_{hot,inlet} - T_{cold,inlet})$$

• TES

- ✓ In cold TES, it is assumed that the temperature difference between each tank of cold TES is 20K so that CO_2 can sufficiently exchange heat inside the cold TES, and pinch in heat exchangers is larger than 5K.



Temperature profile in cold TES

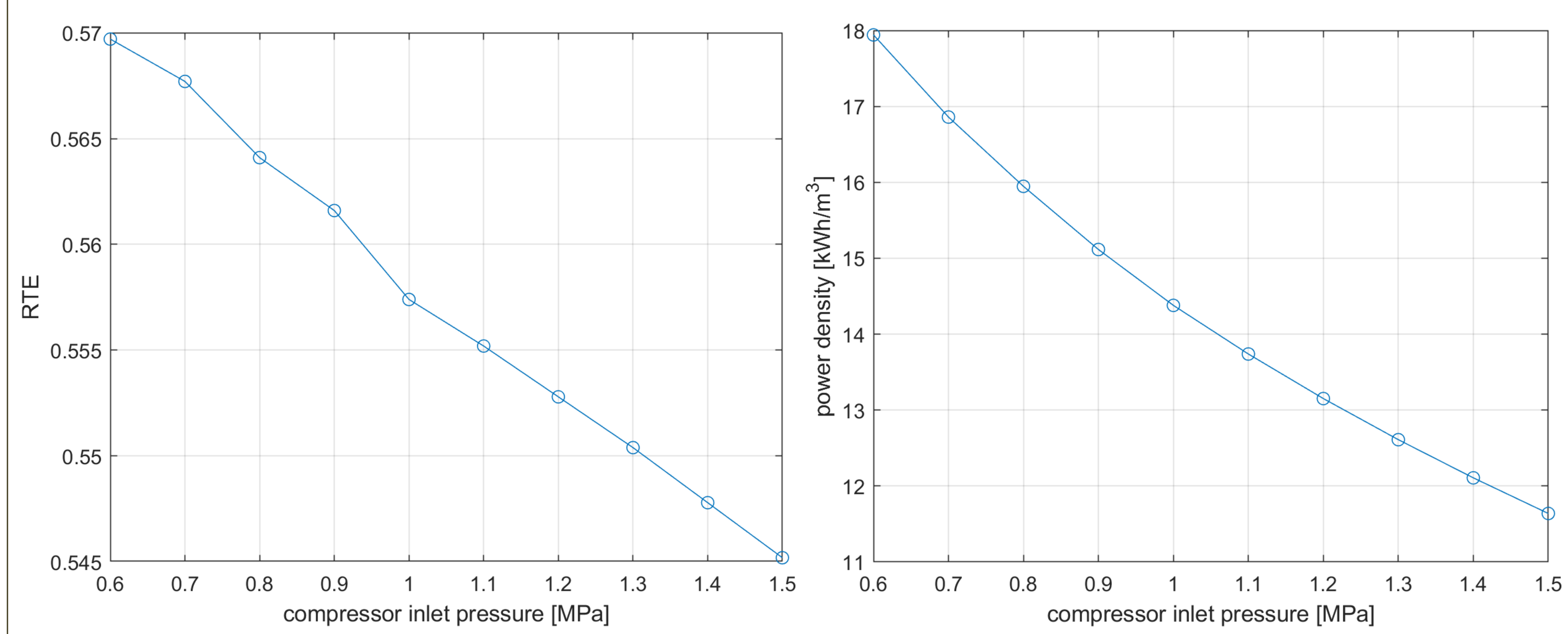
Result and Discussion

• System Parameters

Parameters	Value
Compressor isentropic efficiency (%)	80
Turbine isentropic efficiency (%)	85
Inlet pressure of HPT (MPa)	30
Pinch in heat exchangers (℃)	5
Maximum effectiveness of heat exchanger	0.9
Heat exchanger pressure drop (%)	1
Quality of CO_2 in LPT	0
Quality of CO_2 in compressor inlet	1
Hot TES cold tank temperature (℃)	100
Temperature difference between cold TES (℃)	20

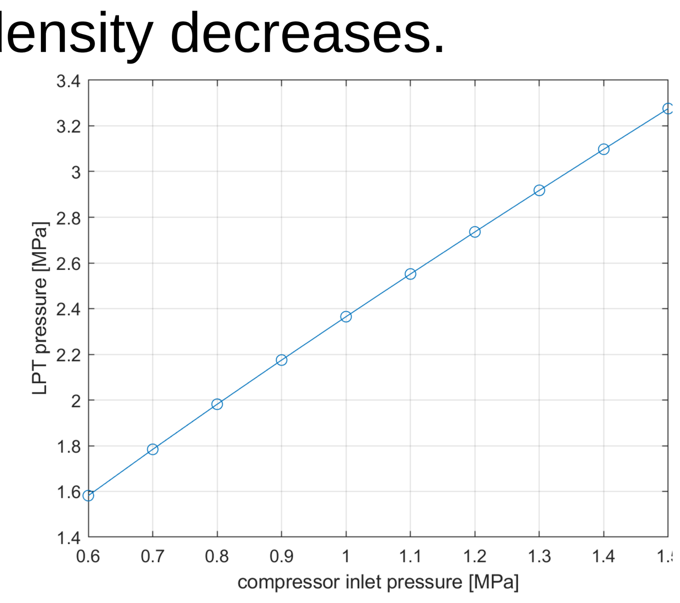
• Result and Discussion

$$RTE = \frac{\dot{W}_{expansion}}{\dot{W}_{compression}}, \quad Power\ density = \frac{\dot{W}_{expansion}}{V_{HPT} + V_{LPT}}$$



Effect of compressor inlet pressure on RTE and power density

- ✓ Both RTE and power density increase as the compressor inlet pressure decreases.
- ✓ Pressure of the LPT determined by the compressor inlet pressure, cold TES temperature difference, and the pinch in the heat exchangers.
- ✓ As the compressor inlet pressure increases, the LPT pressure increases. Accordingly, the temperature of the saturated liquid CO_2 stored in the LPT increases, and decreases the compression ratio. So, power density decreases.



Effect of compressor inlet pressure on LPT pressure

Summary and Future work

- ✓ Compressor inlet pressure decreases, the RTE and power density are improved. The maximum RTE is about 57% and the maximum power density is about 17.94 kWh/m³.
- ✓ In the future, cold TES optimization will be proceeded to further improve the system's performance. More detail modeling will be conducted soon regarding the optimization of CCES RTE and power density by adding off-design model.