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A Sensitivity Study of Isothermal Thermo-Electric Energy Storage System

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Introduction

● Due to concerns in the renewable energy intermittency issue, interests in the application of EES(Electrical Energy Storage) systems are increasing worldwide.

● The growth in EES systems will be the growth of renewable energy for a major energy source.

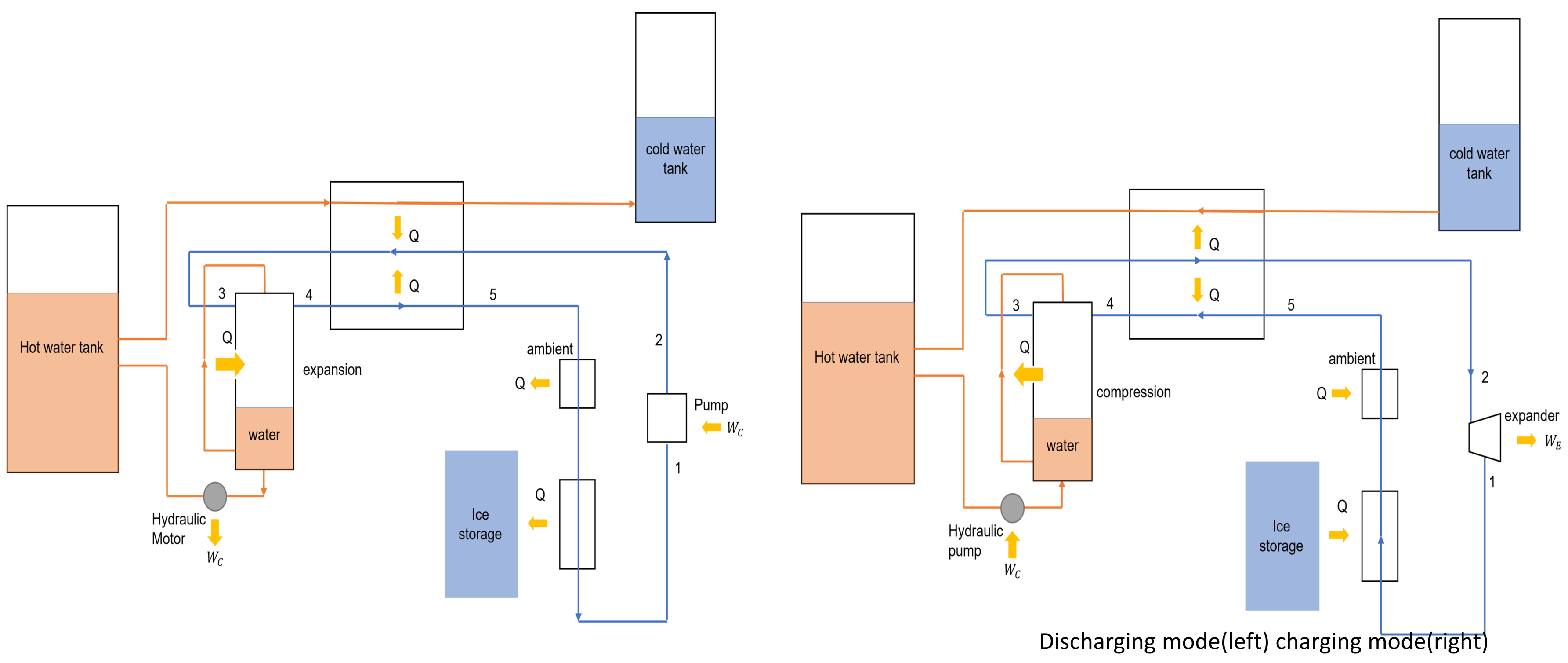
● However, in order to operate EES economically, it is best to store cheap nuclear energy rather than expensive renewable energy, and generate electricity when demand is increasing rapidly.

● An isothermal TEES(thermo-electric energy system) that stores electricity as heat. Moreover, a TEES with high power density is selected, and designed while optimizing the round-trip efficiency.

● The sensitivity of TEES's performance is studied with the assumed component performances to understand and optimize the processes better.

Thermodynamic modeling

● Layout of an isothermal TEES



Discharging mode(left) charging mode(right)

● Assumption

1) There is no pressure drop in the pipelines.

2) There are no changes in potential and kinetic energies.

3) The volume and pressure of the hot tank are determined from the tank temperature at which the water quality is zero, and the temperature and volume of the cold tank are determined with respect to the exchange of heat in the heat exchanger during the discharge cycle and the water quality is zero.

4) The minimum pressure is determined from the isentropic components' inlet temperatures (charging : isentropic expander inlet temperature / discharging : isentropic pump inlet temperature) and quality of working fluid is 0.

● Definition of RTE and power density

‣ $\eta_C = \frac{W_{C,i}}{W_C}$ ‣ $\eta_T = \frac{W_{T,i}}{W_T}$ ‣ $r_{bw} = \frac{W_{T,i}}{W_{C,i}}$

$$RTE = \frac{W_{discharging}}{W_{charging}} = \frac{W_{T2} - W_{C2}}{W_{C1} - W_{T1}} = \frac{\eta_{C1}}{\eta_{C2}} \frac{\eta_{C2}\,\eta_{E2} - r_{bw2}}{1 - \eta_{C1}\,\eta_{T1}\,r_{bw1}} \frac{W_{E2,i}}{W_{C1,i}}$$

$$RTE_{max} = \frac{\eta_{C1}}{\eta_{C2}} \frac{\eta_{C2}\,\eta_{E2} - r_{bw2}}{1 - \eta_{C1}\,\eta_{T1} - r_{bw1}}$$

$$Power\ density = \frac{W_{discharging} \times discharging\ period}{V_{hot\ tank} + V_{cold\ tank}}$$

Result

● System parameters

parameters	value	Unit
Isentropic efficiency of turbine	85	%
Isentropic efficiency of compressor	85	%
Isothermal efficiency of turbine	88	%
Isothermal efficiency of compressor	86	%
Mass flow rate ratio (co_2:water)	1:0.3	

Variable	value	unit
Temperature of hot tank	122	℃
Maximum pressure	16	MPa
Isentropic components inlet temperature	-50	℃

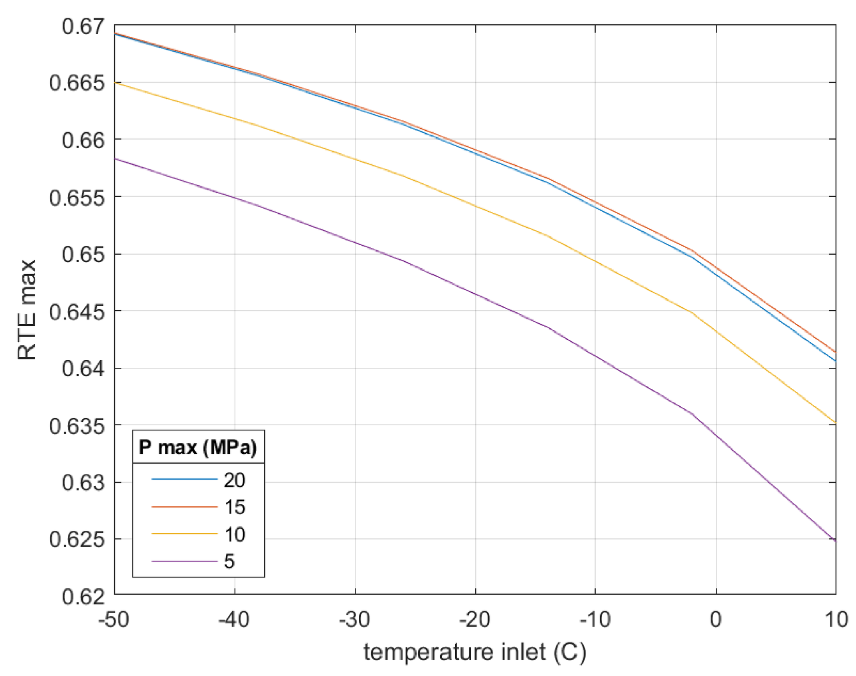


Fig 1. Sensitivity of inlet temperature of isentropic components and maximum pressure-RTE max

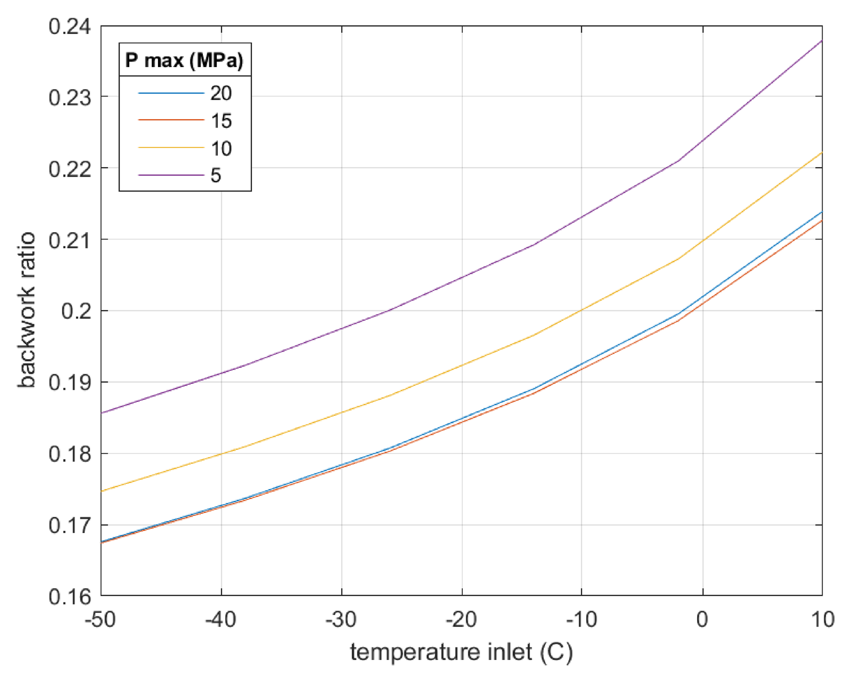


Fig 2. Sensitivity of inlet temperature of isentropic components and maximum pressure-simplified back work ratio

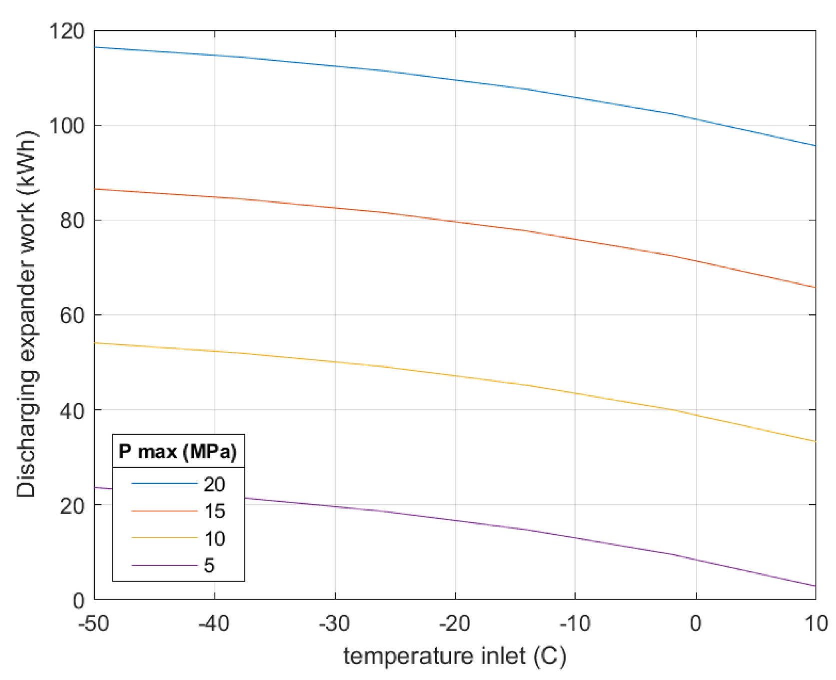


Fig 3. Sensitivity of inlet temperature of isentropic components and maximum pressure-Discharging expander work (discharging period : 5hr)

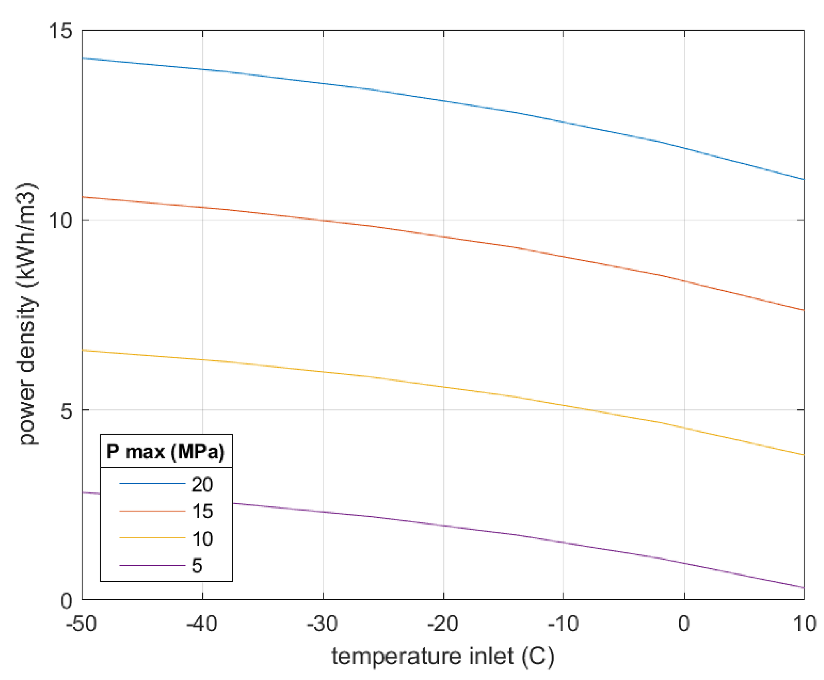


Fig 4. Sensitivity of inlet temperature of isentropic components and maximum power density (discharging period : 5hr)

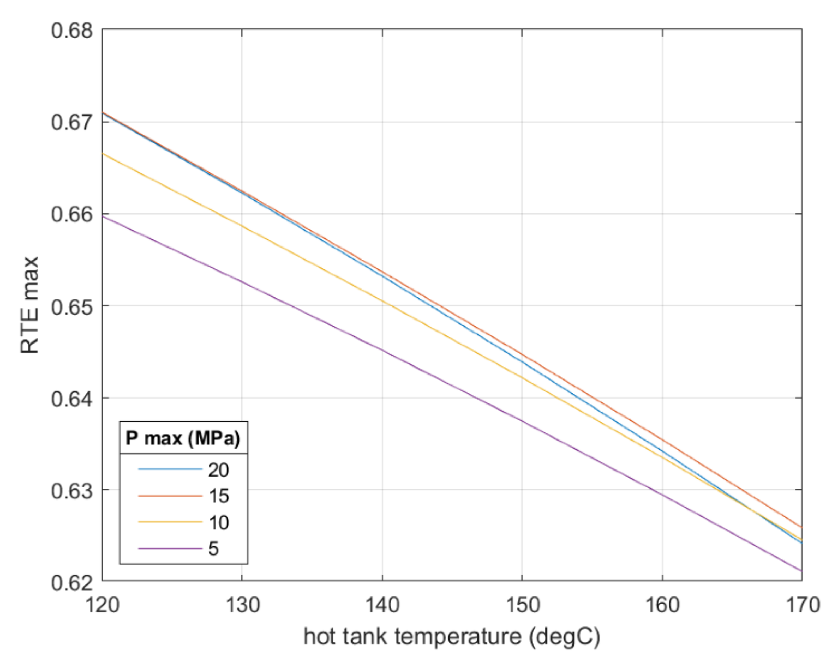


Fig 5. Sensitivity of hot tank temperature and maximum pressure-RTE max

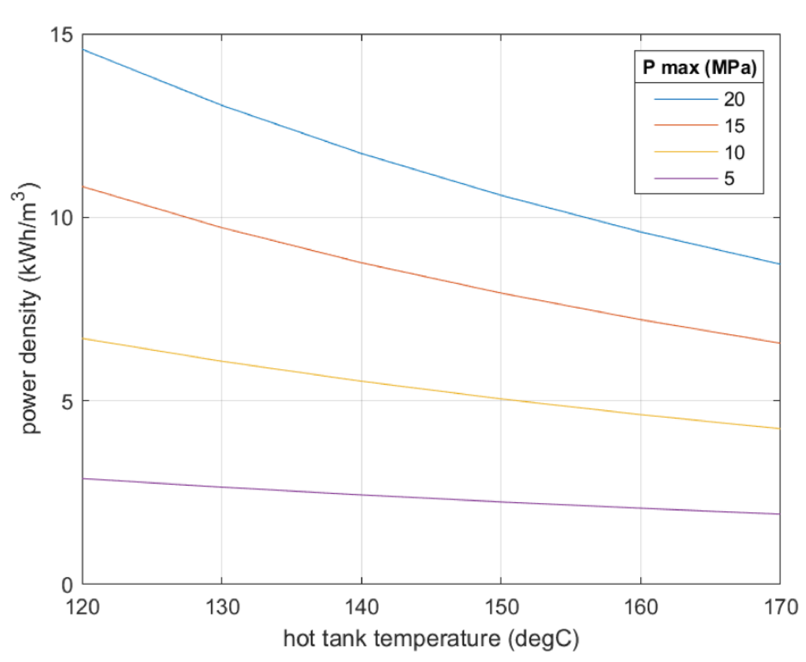


Fig 5. Sensitivity of hot tank temperature and maximum pressure-power density

• The higher the temperature of the hot water tank has, the lower RTE and the lower power density because the hot tank temperature increases, the temperature at which isothermal expansion occurs increases and the work of isothermal expansion becomes smaller.

• The reversal of pressure is due to the reversal of the work ratio of the isothermal expansion and isentropic compression.

• The maximum round-trip efficiency and power density are more sensitive to pressure than to the isentropic components' inlet temperature.