Performance Analysis of Thermal Energy Storage System
For Nuclear Power Plant Application

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Introduction

A low-carbon power generation technology is important to mitigate climate crisis.

- Energy storage system (ESS) can stabilize grid system and make it more efficient.
- Recently, thermal energy storage system (TES) has been studied for nuclear power plant (NPP) application.
- The TES temperature is determined by the operating temperature of the NPP.
- It is important to select a suitable heat transfer fluid (HTF).
- Therefore, TES performance is analyzed for NPP application using round-trip efficiency (RTE) and energy density.

TES integrated NPP

- During charging mode, thermal energy of NPP transfer to TES.
- HTF is heated through heat exchanger and stored in the hot tank.
- When additional power is required (discharging mode), thermal energy is converted to electric energy using TES dedicated power cycle.

Heat transfer fluid (HTF)

- The main HTF used in power plant industry are HITEC salt and solar salt.
- However, both of these salt mixtures become thermally and chemically unstable at temperatures above 600 °C.
- Thus, liquid sodium was recommended as HTF at higher temperature.

SI-CO2: power cycle

- The SI-CO2 power cycle has higher efficiency than that of the steam Rankine cycle for the same turbine inlet temperature.
- Since it operates above the critical point, the pressure ratio is small and the turbine outlet temperature is high.
- The SI-CO2 power cycle requires a large amount of recuperation process to increase the efficiency.
- The SI-CO2 recompression cycle has high cycle efficiency and is mainly used to avoid the pinch point problem in recuperators.

Table II. SI-CO2 recompression cycle conditions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine efficiency [%]</td>
<td>90</td>
</tr>
<tr>
<td>Compressor efficiency [%]</td>
<td>80</td>
</tr>
<tr>
<td>Heat exchanger effectiveness [%]</td>
<td>90</td>
</tr>
<tr>
<td>Heat exchanger pressure drop [%]</td>
<td>1</td>
</tr>
<tr>
<td>Main compressor outlet pressure [MPa]</td>
<td>25</td>
</tr>
<tr>
<td>Main compressor inlet temperature [°C]</td>
<td>35</td>
</tr>
<tr>
<td>Net work [MW]</td>
<td>10</td>
</tr>
<tr>
<td>Turbine inlet temperature [°C]</td>
<td>Variable</td>
</tr>
<tr>
<td>Main Compressor inlet pressure [MPa]</td>
<td>Variable</td>
</tr>
<tr>
<td>Split ratio</td>
<td>Variable</td>
</tr>
</tbody>
</table>

\[ \eta_{RTE} = \frac{W_{w/TES}}{W_{w/o TES}} \]

Eq. 1. RTE general definition

- Since the power cycle of NPP is not known, only the performance of the TES dedicated power cycle is analyzed.

- Energy density is defined as the amount of energy that can be produced per volume.

\[ \omega = \frac{W_{out/\text{t}} \cdot \text{disch}}{m_{\text{disch}} \cdot \rho_{\text{hot}} + m_{\text{ch}} \cdot \rho_{\text{cold}}} \]

Eq. 2. Energy density definition with two tank TES

Conclusions

- One of the solutions to the intermittency problem of renewable energy is flexible operation of conventional power plants.
- Overall, the energy density of TES is quite comparable to the other mechanical energy storage system (CAES, LAES).
- It is found that using TES is better for Gen-IV type reactors rather than coupling with conventional NPP (PWR).