Discussion of regenerator for cryogenic energy storage

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Background

Energy storage means a significant push for the "Smart Grid" by serving the grid with peak-load shifting and green power utilization mechanism. As a promising new member of energy storage technologies, liquid air energy storage (LAES) provides higher energy density by transforming electricity into cryogenic energy, i.e., potential energy and thermal energy of liquid air. Such a cryogenic energy storage system calls for a specific, workable regenerator to achieve high efficiency and economy.

Objectives

- ❖ Relationship between the performance of regenerator and the efficiency of LAES.
- ❖ Regenerator with phase-change material sealed in, and method to widen working temperature region.

Conclusion

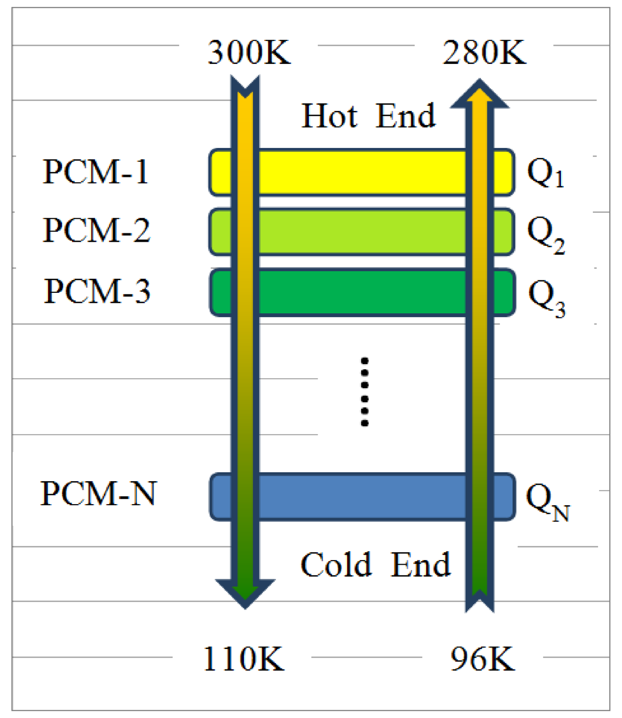
- ❖ A brief comparison of regenerators applied in cryogenic system has been made.
- ❖ A simulation based on one LAES system has been conducted, showing clearly that the system efficiency is influenced deeply by regenerator.
- ❖ Though cryopump consumed little more electricity with the efficiency of regenerator increasing, the system efficiency still rose significantly for the soaring growth of turbine output.
- ❖ Consisting of multiple PCMs ranked in phase change temperature, a new regenerator is expected to overcome the disadvantage of narrow working temperature.

PCMs regenerator

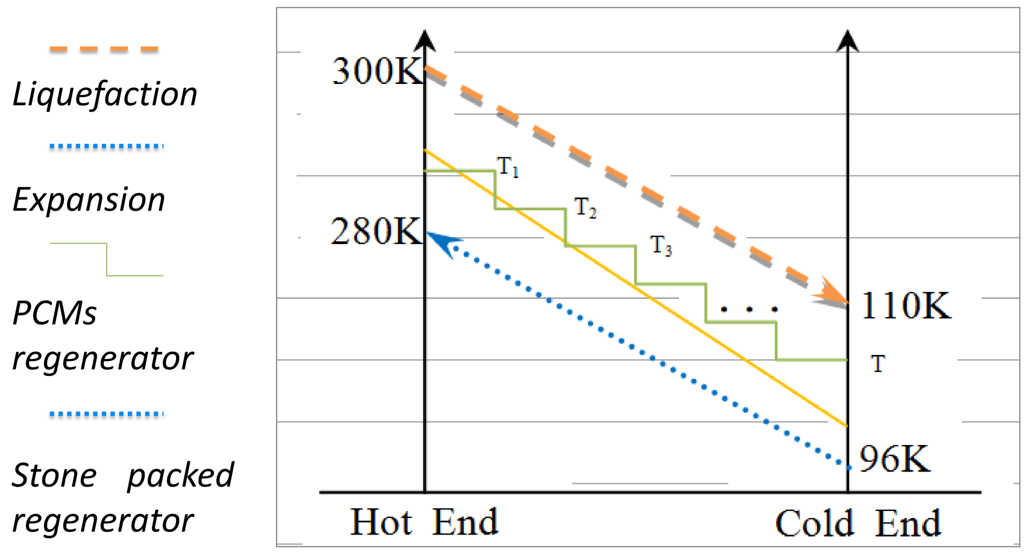
Principle

•Latent heat:
Compared with regenerators storing thermal energy with sensible heat materials, regenerator using phase-change materials as medium provides much larger storage capacity.

•Multiple PCM:
By adjusting the amount and the kinds of PCMs sealed in, the working temperature region and the storage capacity of PCMs regenerator will be exactly feasible to demand.



Comparison



Temperature gap between two ends in stone packed regenerator is lager than that in PCMs regenerator. Therefore , regenerator with PCMs is expected to have more stable performance.

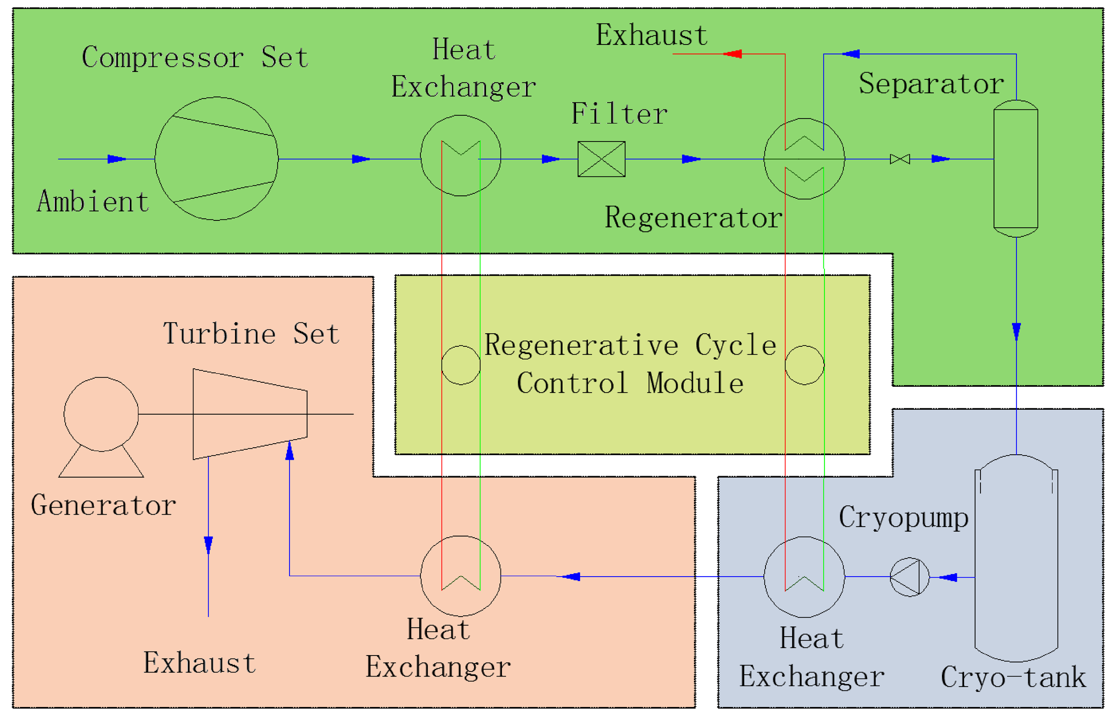
Simulation

Liquid Air Energy Storage

A theoretical LAES system consists of air liquefaction process and liquid air storage process. Also, regenerative cycles are essential to improving the global efficiency.

Liquid air needs to be heated before expansion in turbine. Regenerator will absorb and store most of cold energy through the regenerative cycle.

Air and liquid mixer produced in air liquefaction process will absorb the energy stored in as flowing across the regenerator, and the liquefaction ratio will rise consequently.



Simulation Procedures

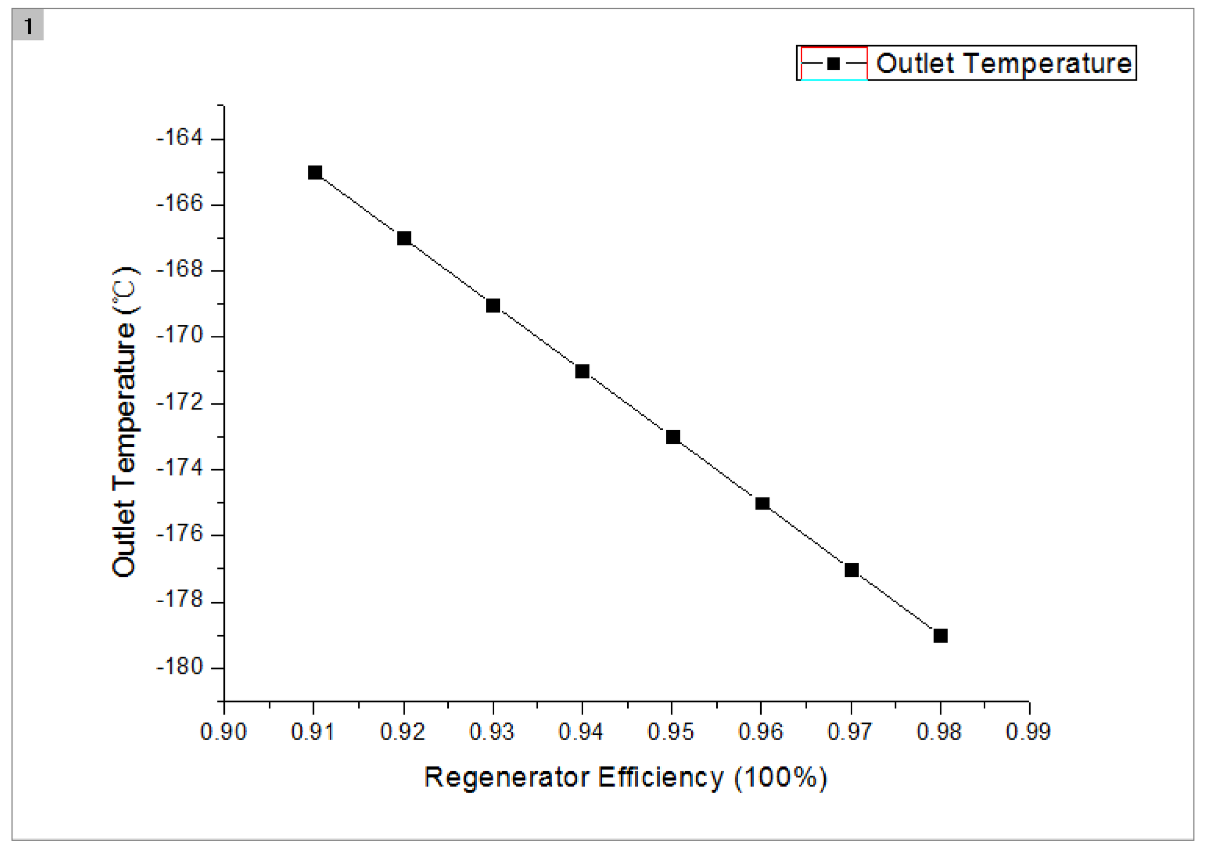
Except for the regenerator, all the devices adopted in the LAES system operated at constant efficiency. Four values were focused on as the efficiency of regenerator changing by each one percentage from 91% to 98%.

Four key values:
• Outlet temperature of regenerator during expansion;
• Cryopump consumption;
• Turbine output;
•System efficiency;

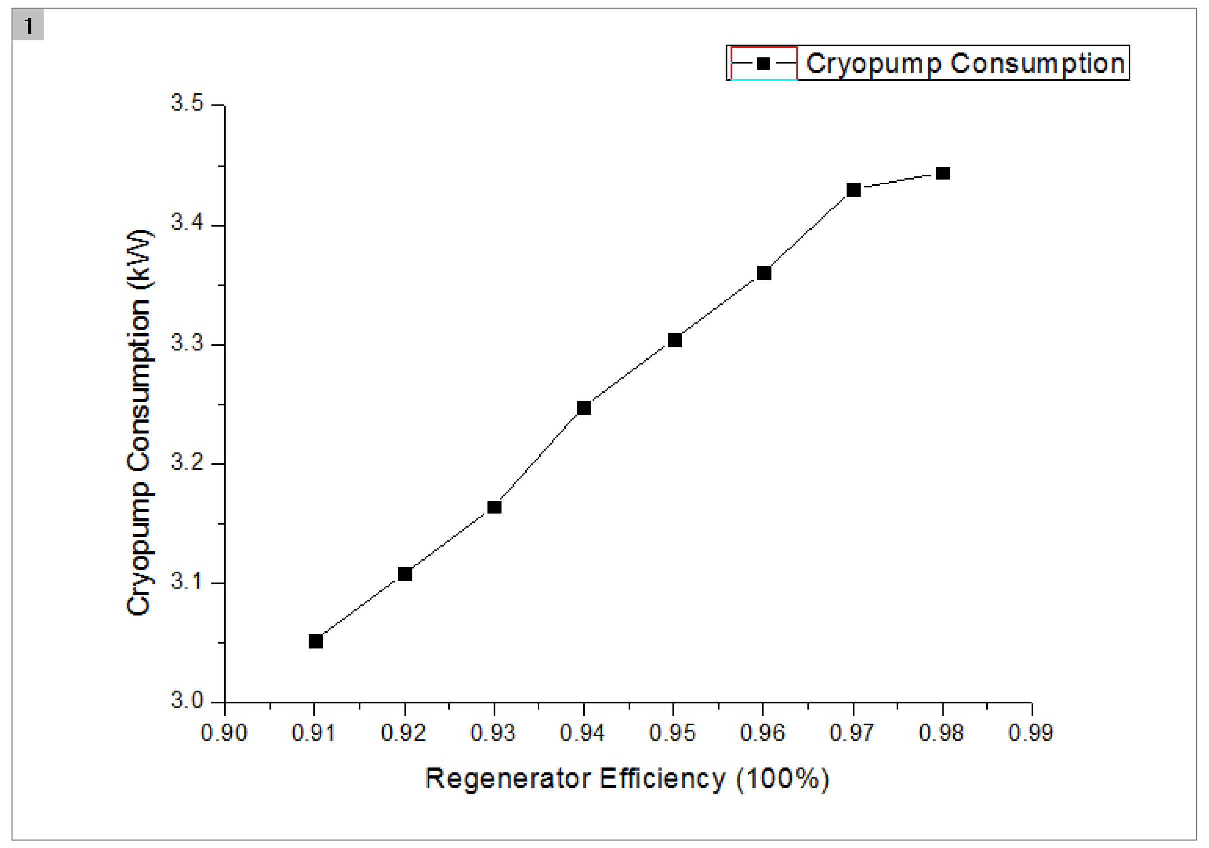
System efficiency was defined as turbine output over global consumption by compressor set and cryopump.

Electricity consumed by compressors in air liquefaction was constant.

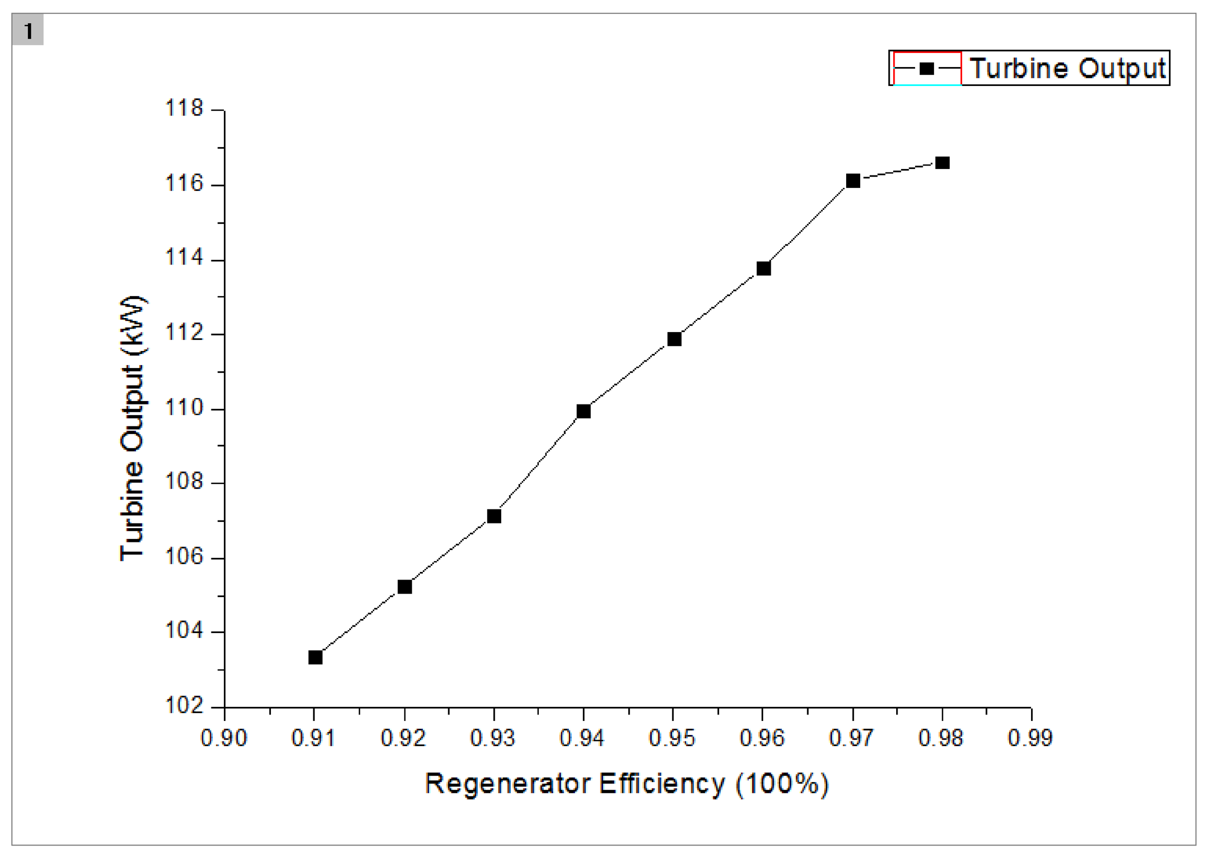
Results



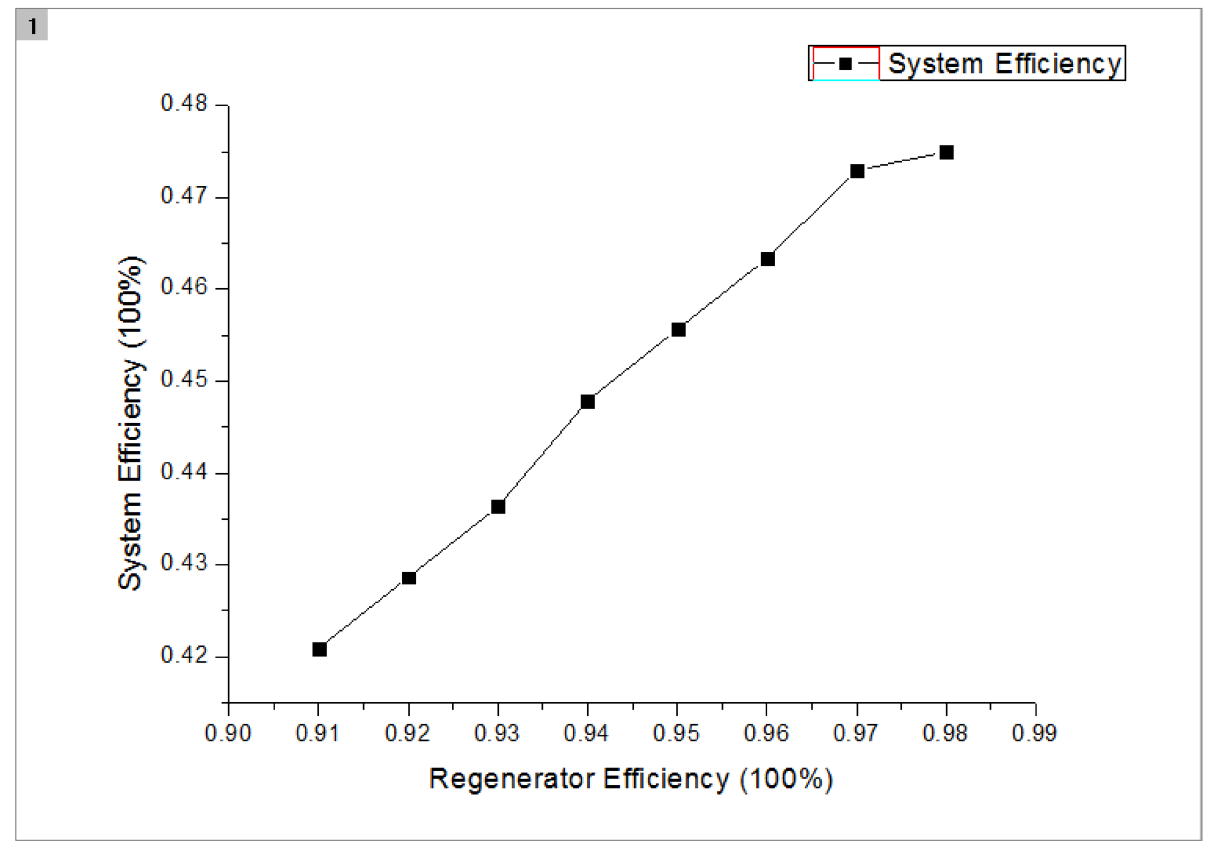
With the increase of regenerator efficiency, the outlet temperature dropped linearly. This temperature drop means higher regenerator efficiency will contribute to storing more cold energy.



Cryopump tended to consume more electricity as regenerator efficiency increasing. This tendency means the flux in cryopump was increasing. Further, it implies the amount of liquid air stored in cryo-tank was increasing.



As a result of the increasing of cryopump flux, turbine output rose subsequently. The increase of turbine output was more obvious than that of cryopump consumption for the bigger enthalpy difference during expansion.



The compressor set consumption was constant in this simulation, therefore, system efficiency defined as output over consumption increased obviously with the increase of regenerator efficiency.

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