Thermodynamic characteristics of a novel wind-solar-liquid air energy storage system

W Ji[1,2], Y Zhou[1], C Z Pan[1], Y Sun[1], W Zhang[1] and J J Wang[1, 2,*]

1. CAS Key Laboratory of Cryogenics, Technical Institute of Physics and Chemistry, Beijing 100190, China
2. University of Chinese Academy of Sciences, Beijing 100049, China

C2PoE-06

Introduction

Due to the nature of fluctuation and intermittency, the utilization of wind and solar power will bring a huge impact to the power grid management. Thus the energy storage system is developed to solve the problem. However, for grid-scale electric energy storage, only pumped hydro energy storage and compressed air energy storage can be considered as proper methods. Although both of them have mature application cases, they share fatal shortcoming of geographic constraint. Therefore many liquid air energy storage concepts with high energy storage density were proposed. Nevertheless, most concepts rely on high temperature thermal energy stored during compression, which is constrained by present technology of compressors. Also, fossil fuels are not preferable for renewable energy conversion.

Objectives

- ❖ Develop a novel hybrid wind-solar-liquid air energy storage (WS-LAES) system for grid-scale utilization to avoid the disadvantages of present technology.
- ❖ Store unstable wind and solar power simultaneously for a stable output of electric energy and hot water.

Conclusions

- ❖ A novel grid-scale WS-LAES system without geographic constraints was proposed.
- ❖ The ESE, η_{ex} and EPV can reach 45.7 %, 44.2 % and 74.4 kWh/m³ under the design conditions, respectively.
- ❖ 3900 kWh electric power and 205 tons/day of hot water with a temperature of 60℃ can be produced within a cycle.
- ❖ The increases of compressor adiabatic efficiency, turbine inlet pressure and inlet temperature all have a beneficial effect.

Thermodynamic model

☐ The WS-LAES system is mainly composed of three units:

- ➢ Wind power storage unit
- ➢ Solar heat storage unit
- ➢ Turbo-generation unit

☐ Energy storage process:

- ✓ Produce high pressure air and transfer compression heat into domestic hot water.
- ✓ High pressure air is precooled and throttled to produce liquid air.
- ✓ Stored cryogenic refrigerants and gaseous air supplement the cold energy in HX1 and HX2.
- ✓ Low temperature thermal oil is heated by the solar thermal collector.

☐ Energy release process:

- ✓ Liquid air is pumped to a high pressure and regenerated by the stored refrigerants.
- ✓ Gaseous air is preheated by high temperature thermal oil and then expands to generate power.

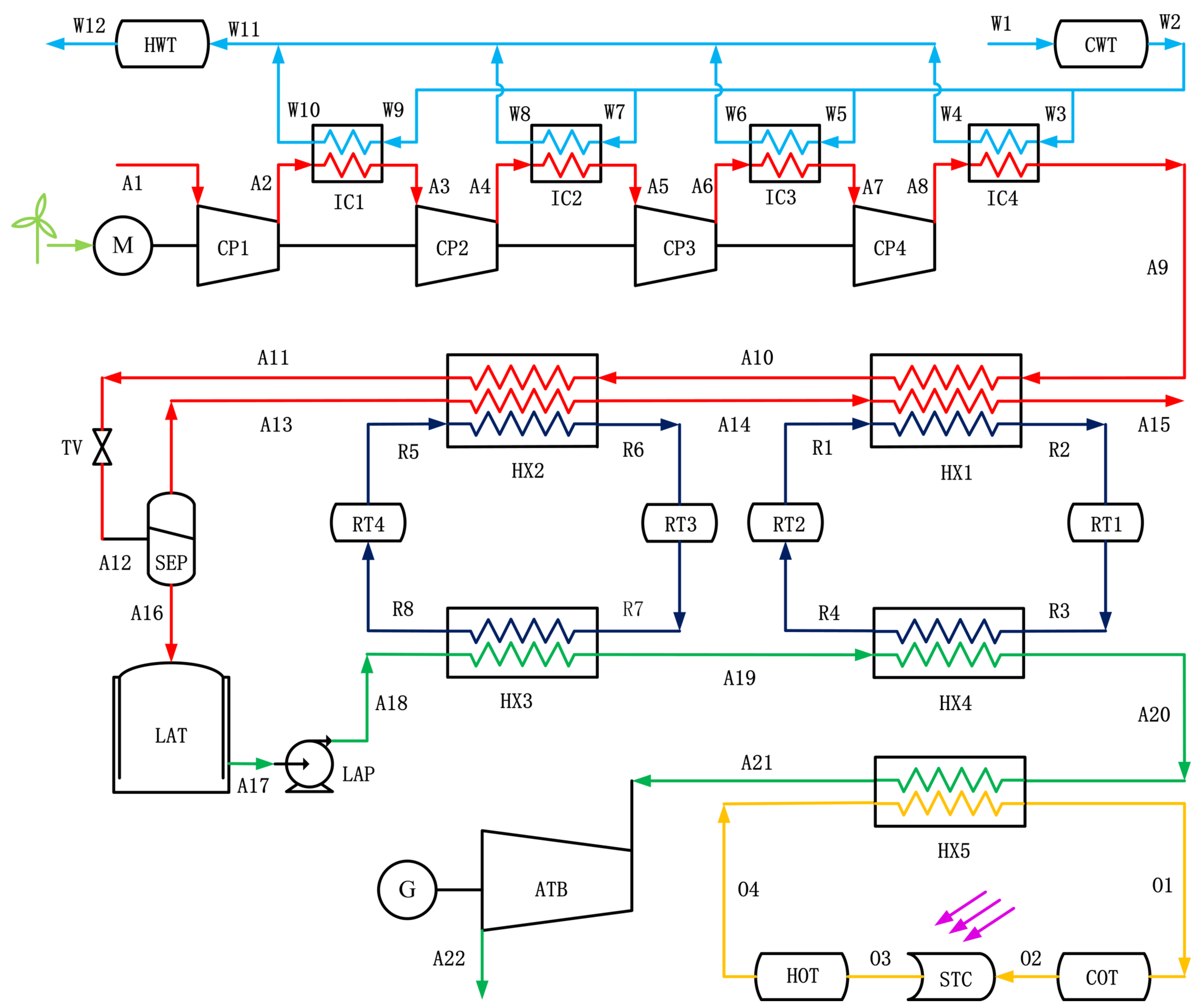

Figure 1. Schematic diagram of the proposed WS-LAES system

Simulation Results

Performance comparison between WS-LAES and the WS-CAES

	WS-LAES	WS-CAES
Power of compressor (kWh)	8538	9178
Power of air turbine (kWh)	3900	7231
Heat absorption of solar thermal collector (kWh)	3827	10500
Temperature of hot water (℃)	60	60.5
Mass of hot water (ton/day)	205	94
ESE (%)	45.7	87.7
η_{ex} (%)	44.2	65.4
EPV (kWh/m³)	74.5	4.19

- ◆ Therminol 66 was chosen for solar energy storage medium.
- ◆ R123 and propane were selected as the cold energy storage medium.
- ◆ 60 ℃ is the recommended temperature for hot water supply in China.
- ◆ The ESE and η_{ex} of WS-LAES is less than that of WS-CAES.
- ◆ The mass of hot water and EPV in WS-LAES are 2.2 and 17.7 times of that in WS-CAES.

Parametric analysis

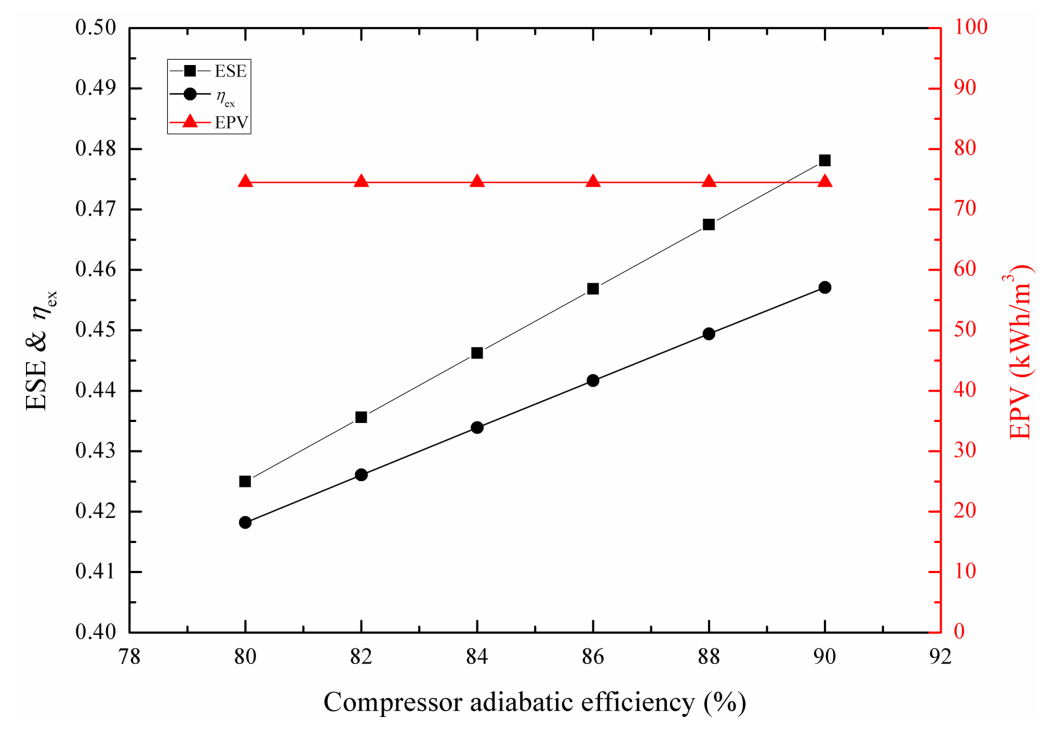

Figure 2. Effect of compressor adiabatic efficiency

- ➢ ESE and η_{ex} both increase with the increasing compressor adiabatic efficiency because the power consumption of compressor chain decreases when the adiabatic efficiency increases.
- ➢ Although a high adiabatic efficiency is beneficial, it bears a limit constrained by available technology.

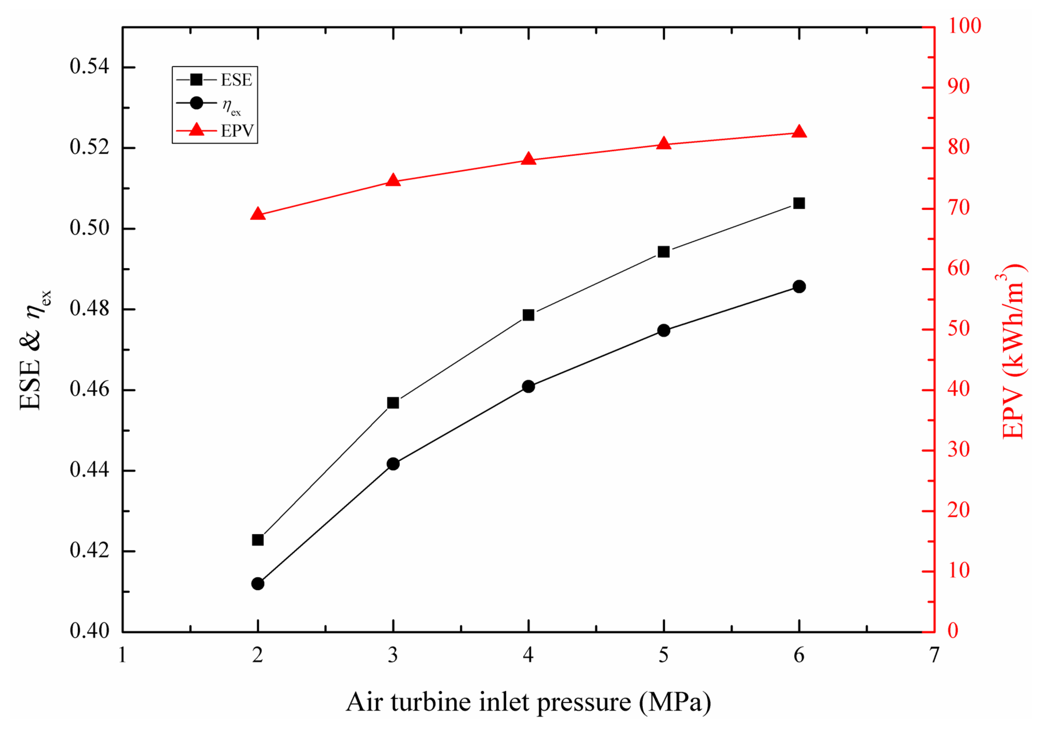

Figure 3. Effect of air turbine inlet pressure

- ➢ All indexes increase with the increasing air turbine inlet pressure attributed to a larger power of air turbine under a higher inlet pressure.
- ➢ The growth rate gradually slows down while the equipment cost increases. An optimum inlet pressure is a tradeoff between the system performance and economic cost.

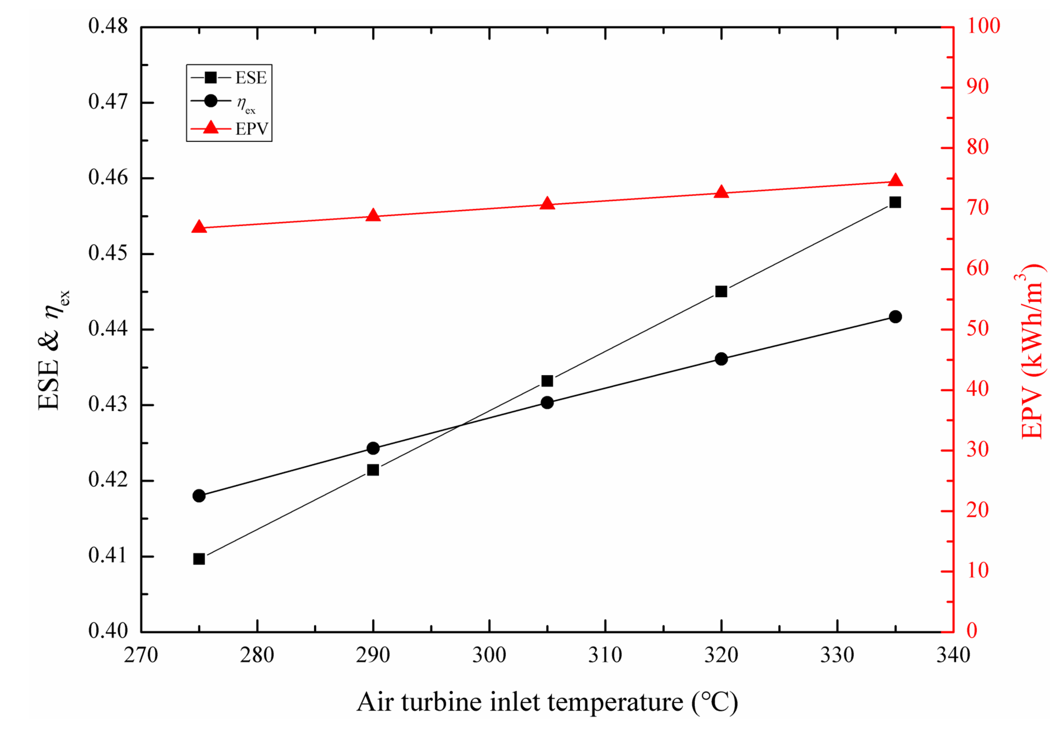

Figure 4. Effect of air turbine inlet temperature

- ➢ All indexes increase with the increasing air turbine inlet temperature as a result of a greater heat absorption of STC .
- ➢ A higher air turbine inlet temperature is preferable but it is constrained by the properties of thermal oil.

If any questions, please contact me: 13810112937@163.com

Presented at the CEC/ICMC 2017, July 9 – 13, Monona Terrace in Madison Wisconsin; Session: C2PoE - Industrial Applications; I.D. number: C2PoE-06