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Simulation and Analysis of Liquefied Air Energy Storage Technology Based on HYSYS Software

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Abstract : *Liquid air energy storage is a new generation of air energy storage system that uses a liquefied air stored in a cryogenic liquid storage tank to form a potential energy reserve. Using Aspen HYSYS software to realize the simulation analysis of the combined process and independent process of liquid air energy storage system, based on the simulation results, it can be seen that the power consumption for liquefied air is much greater than the output work of liquefied air expansion, and its optimization direction is to combine the liquefied process with the Rankine cycle process to increase the overall efficiency of the system.*
Keywords: *Liquid air energy storage; Aspen HYSYS; Process simulation*

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I. Introduction

Liquid air energy storage (LAES) is one of the methods to realize energy storage. Its principle is to make use of liquefied air stored in cryogenic liquid storage tanks to form potential energy reserves. In a system, air is liquefied using off-peak or idle power to store electricity, while the stored liquid air is used as a working fluid to recover energy through the Rankine cycle.[1-4]

Liquefaction air energy storage technology was first proposed by researchers at Newcastle University in 1977. The original research work and achievements were limited to theoretical analysis. Subsequently, the technical cooperation between Mitsubishi heavy Industries of Japan and Hitachi, as well as the technical cooperation between the British Electric Power Company and the University of Leeds in the United Kingdom, greatly promoted the landing and implementation of the technology at different levels[1].Mitsubishi heavy Industry has built the experimental project of 2.6MW. Because the air liquefaction and power recovery in the project are running independently, the efficiency of the system is low. Unlike Mitsubishi heavy Industries, Hitachi of Japan has significantly improved its efficiency by trying to use the cold energy released from the power recovery process for air liquefaction processes. In 2009, the UK Power Company and the University of Leeds began to design and build the world's first 350kW integrated LEAS system model project.

In recent years, energy storage has become more and more important for the power generation industry, especially for some power generation systems using green new energy, the green new energy generation system has intermittent in the operation process, and the adaptability is poor. Energy storage system can store energy at the low point of power demand and release energy during peak period of power demand. Therefore, the large-scale energy storage system will be gradually integrated into the operation of the large power grid, making the large power grid more complete in a certain sense.

II. Principle And Basic Structure Of Liquefied Air Energy Storage Technology

As one of the energy storage technologies, pumping energy storage technology has been considered as a mature technology through more than 100 years of practice. Compressed air energy storage technology has been developed and can be commercialized, but practical applications are not universal. Compared with the traditional compressed air energy storage, the new cryogenic liquefied air energy storage technology realizes the liquid storage of compressed air, and on the basis of covering the many advantages of the traditional compressed air energy storage technology, it gets rid of the geographical position. The limitation of environmental factors such as geomorphological conditions has important advantages such as high energy storage density and removable storage. Therefore, liquefied air energy storage belongs to a new generation of air energy storage system. Compared with pumping energy storage technology and compressed air energy storage technology, LAES technology is still under development in terms of technology maturity.

LAES technology, similar to other types of energy storage systems, still includes three stages: charging, storing and releasing. The first stage is to use peak and valley electric energy or idle power to realize the liquefaction of air (the mode of liquefaction can be chosen as Linde refrigeration cycle or Claude cycle), and then stored in the liquefied air storage tank is the second stage. The third stage is the process of using air as the working fluid for the re-output of electricity through Rankine's cycle. The basic structure of the LAES technology is shown in figure 1[1].

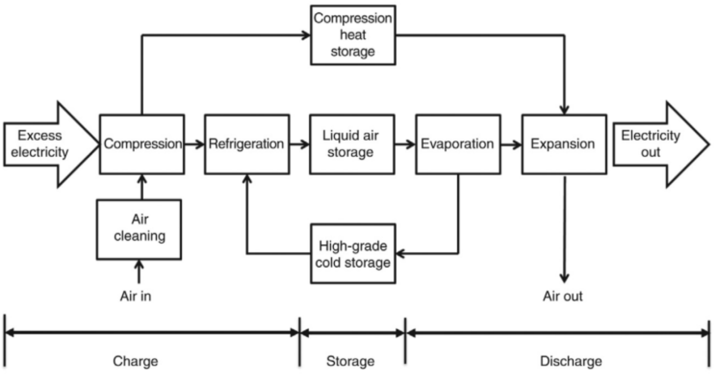

Fig. 1 The basic structure of LAES technology

III. Analysis And Discussion Of Liquefied Air Energy Storage Technology Based On HYSYS Software

3.1 Application of HYSYS in chemical process simulation

The introduction of simulation calculation and simulation techniques into the design of chemical process is a supplement to the understanding of relevant theories and a new attempt. Chemical process simulation is based on the mechanism model of chemical process engineering and describes the chemical process by mathematical method. It can realize the material and heat balance of the process, and can also complete the equipment size estimation and energy analysis.

Aspen HYSYS is a process simulation for oil and gas production, gas processing and oil refining industry, which can simulate steady state and dynamic simulation. It can solve the problems such as the evaluation, design and optimization of various gathering and transportation processes; The design of pipe networks, long-distance pipelines and pumping stations; The design and optimization of gas treatment devices. Non-sequential simulation technology is the most important characteristic of Aspen HYSYS, which is different from other software. In particular, the calculation of unit operation in process simulation is not limited to the calculation of export by import, and the export logistics can also reverse calculate import logistics[5-6].

3.2 Simulation of liquefied Air Energy Storage Process with HYSYS Software

In the simulation process, it is considered that air is a binary mixture of oxygen and nitrogen, so the impurity and water in the air are not considered, and the influence of CO_2 on the thermodynamic process of the system is not considered. Air liquefaction (LA) is directly used as a circulating fluid for open Rankine cycle in the process, as shown in figure 2. In the process shown in figure 2, the air liquefaction process is run in conjunction with the Rankine cycle power output process. During the combined cycle, the liquefied air in the storage tank is pumped at low temperature, and the outlet pressure reaches a higher pressure. After twice evaporating and rising the heat transfer between the outlet air and the normal temperature air with Rankine's circulation, the air is placed in the air. In the overheating state, by entering the expander expansion to do work, output the net work, realize the power release and recovery.

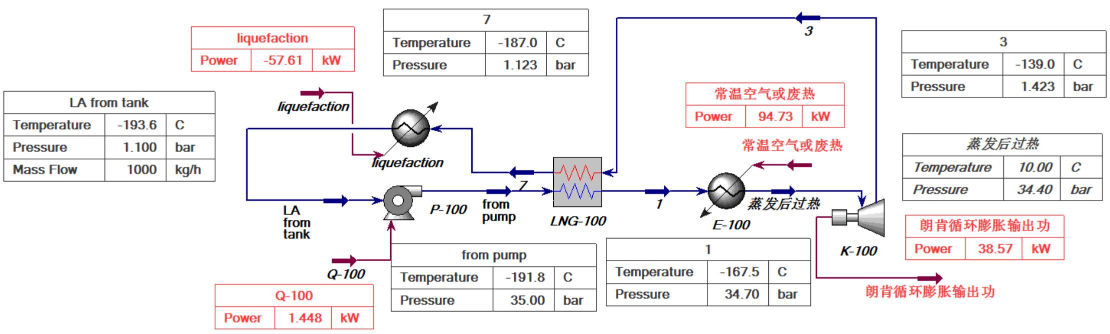

Fig. 2 Combination process of air liquefaction and Rankine cycle

At present, the air liquefaction seen in the market comes from large air separation plants. The simplest way to realize air liquefaction is the well-known Linde cycle. The compressed air is throttled and cooled to obtain liquefied air. At present, there are some complex process forms. The energy required for air liquefaction of 1kg is about 1080 kJ,. Therefore, 1080 kJ/kg can be used as the reference power for air liquefaction. In the simulation process shown in figure 2, the air liquefaction flow rate of 1000 kg/h is taken as the basic flow rate of the process simulation. The heat transfer of engine exhaust reaches the state point 1, and then gasifies with room temperature air (or low temperature waste heat) and enters the expander expansion to do work. The output work is 38.57 kW, expanders exhaust and liquefied air after pump heat transfer precooling, The total power consumption of liquefaction is 57.61 kW.

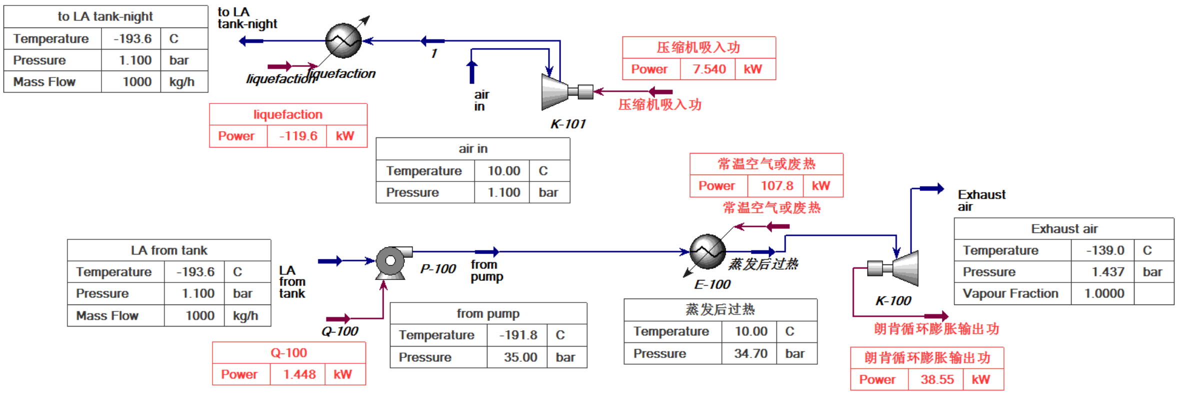

Fig. 3 Independent flow chart

Unlike the simulation process shown in figure 2, the flow shown in figure 3 is that of air liquefaction and open Rankine cycle working independently. For the sake of comparison and analysis, the air liquefaction flow rate of 1000 kg/h is also used as the basic flow rate of the process simulation, and the air liquefaction is realized by using idle power in the evening, and stored in the storage tank. During the day, the energy stored in the liquefied air is used to achieve the output of work, that is, the power release. During the daytime working period, the liquefied air after pump boost, after gasification superheated with normal temperature air (or low temperature waste heat) into the expander expansion work, its output work is 38.55 kW; in the evening operation of the air. In the liquefaction process, obtaining the same flow of liquefied air requires energy consumption of 119.6 kW.

IV. Conclusion

It can be seen that the power consumption for air liquefaction is much larger than the output work for air liquefaction expansion based on the simulation process parameters of joint and independent processes. The optimization direction is to combine liquefaction process with Rankine cycle process. To improve the overall efficiency of the system.

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