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Multi Energy Flow Optimal Scheduling Model of Compressed Air Energy Storage Based on Matrix Modeling of Energy Hub

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***Abstract*—Advanced adia-batic compressed air energy storage (AA-CAES) is an electric energy storage system that can realize large-capacity and long-term electric energy storage. In the process of energy storage which additional producted variety of energy flows can be used as a micro-integrated energy system(MIES). considering the multi-energy flow co-supply characteristics of AA-CASE, in order to study the multi-energy flow supply scheduling strategy. this paper builds a general energy exchange analysis model based on the energy hub (Enery Hub), and conducts modular matrix modeling for the internal components of AA-CAES, such as compressors, turbines, and heat exchangers, analyze its thermodynamic properties and energy flow generation efficiency. on this basis, in order to maximize the economy, an optimal scheduling model of AA-CAES based on matrix modeling of EH is proposed. Finally, use the common compressed air energy storage system equipment data to simulation verification.**

Keywords—MIES, EH, AA-CAES, Matrix, Multi energy flow

I. INTRODUCTION

With the depletion of fossil fuels and the increasingly serious problems of environmental pollution, it has become the consensus of governments, enterprises and people in various countries to actively develop distributed renewable power sources and improve comprehensive energy utilization efficiency [1]. At present china has begun to vigorously develop clean energy. Due to the volatility and uncertainty of wind power, photovoltaic and other new energy power generation, their large-scale grid connection will have an impact on the safe and stable operation of the power grid. Due to the time migration ability of power and energy, the application of energy storage devices can make the originally rigidly connected power system flexible, thereby providing technical solutions for the problem of large-scale wind power, photovoltaic and other new energy power generation grid-connected [2] Advanced adiabatic compressed air energy storage (AA-CAES), due to its large storage capacity, high conversion efficiency and good application prospects, has received extensive attention from scholars in recent years, and is considered to be one of the most promising technologies for large-scale energy storage AA-CAES power station can not only provide the system with many types of auxiliary services such as peak regulation, backup, reactive power regulation, but AA-CAES also has a feature with significant advantages of combined cooling, heating and power [3] , this feature enables AA-CAES to be used as a Micro-integrated energy system (MIES), through energy cascade utilization and flexible energy utilization mode, it can achieve a primary energy utilization rate of up to 90% of the input energy [4].

There are also more profound researches on matrix modeling research of integrated energy systems at home and abroad. In 2005, the team of Professor Favre-Perrod P of ETH Zurich put forward the concept of Energy Hub (EH). EH is a multi-port device used to represent the input, output, conversion, and storage of different energy carriers [5]. In 2007, it was first proposed to describe the energy distribution and conversion relationship within the EH through a coupling matrix. EH can couple and integrate various energy sources such as electricity, heat, and cold into a MIES. Through matrix modeling of EH, the operation mechanism of micro-energy system can be studied in detail [6].

At present, scholars at home and abroad have carried out a lot of research on AA-CAES multi-energy flow co-supply and optimal scheduling. Reference [7] combined AA-CAES with wind farms to study the operating characteristics of AA-CAES in the switching state, and gave a mixed integer linear programming model to describe the AA-CAES in the switching state. Reference [8] combined AA-CAES with an external solar thermal storage system, and used the solar thermal collector module as the external expansion heat source of the AA-CAES system to construct a new type of combined heat and power system, and studied the solar thermal collector module. Reference [9] proposes a MIES optimization operation strategy considering AA-CAES unit participation in combined heat and power storage/supply based on the analysis of references [7-8], and obtains the optimal scheduling model through economic analysis. This model can decrease cost of MIES, but this reference only analyzes the combined heat and power supply of MIES, does not consider the external supply of AA-CAES intercooling energy, and does not establish a complete compressed air energy storage multi-energy flow system model.

This paper proposes a multi-energy flow optimization scheduling model for AA-CAES based on matrix modeling of energy hubs. The model simplifies the AA-CAES system internal energy flow mutual conversion relationship through matrix modeling which give full play to its superior performance in multi-energy combined flow supply, strengthen the system peak shaving and valley filling and the ability to absorb renewable energy, making system run with flexibly and reliably.

II. A General Energy Exchange Analysis Model Based on the Concept of Energy Hub

The concept of EH is a multi-port device that describes the input, output and conversion of different energy carriers, proposed by the team of Professor Favre-Perrod P of ETH Zurich in 2005. Based on the concept of energy hub, a general energy exchange analysis model can be proposed. This model simplifies the multi-energy flow co-supply characteristics of the AA-CAES model and weakens the complex changes within AA-CAES, through allocation matrix and efficiency matrix.

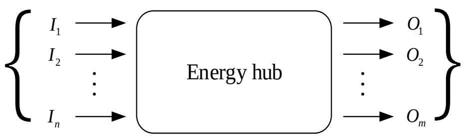

Fig. 1. General energy exchange analysis model

In the above figure, the left end of the general energy exchange analysis model is composed of a variety of original energy inputs. After the energy is converted inside the energy hub, it becomes a variety of energy outputs. Mathematically, the general energy exchange analysis model can be represented by a mapping function.

$$O = f(I) \tag{1}$$

In the formula $O = f(I)$, the function $f(\cdot)$ can take into account the transmission, conversion and storage of various forms of energy. Therefore, a coupling matrix can be used to describe the relationship between input and output:

$$\begin{bmatrix} O_1 \\ O_2 \\ \vdots \\ O_m \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix} \tag{2}$$

In the above formula, c_{mn} is the coupling factor, which represents the ratio of the *m* form of energy output to the *n* form of energy input. The input to output of various forms of energy can be divided into two steps: energy distribution and energy transmission or conversion. Energy distribution refers to the distribution of various energy sources to different energy transmission or transformation equipment in a certain proportion. Energy transmission or conversion refers to the conversion of energy into the equipment through mechanical, chemical and other means, with a certain conversion efficiency. Therefore, the coupling matrix in equation (2) can be further decomposed:

$$\begin{gathered} \begin{bmatrix} I'_1 \\ I'_2 \\ \vdots \\ I'_k \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mn} \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix} \\ \begin{bmatrix} O_1 \\ O_2 \\ \vdots \\ O_m \end{bmatrix} = \begin{bmatrix} \eta_{11} & \eta_{12} & \cdots & \eta_{1k} \\ \eta_{21} & \eta_{22} & \cdots & \eta_{2k} \\ \vdots & \vdots & \ddots & \eta_{3k} \\ \eta_{m1} & \eta_{m2} & \cdots & \eta_{mk} \end{bmatrix} = \begin{bmatrix} I'_1 \\ I'_2 \\ \vdots \\ I'_k \end{bmatrix} \end{gathered} \tag{3}$$

Can be abbreviated as:

$$O = \eta NI = CI \tag{4}$$

d_{mn} is the allocation factor, indicating the proportion of the *m* form of energy input to be converted into the *n* form of energy which corresponding to the distribution matrix with the symbol of *N*. η_{mk} is the efficiency factor, which represents the efficiency of converting *m* forms of energy into the *k* form of energy which corresponding to the efficiency matrix with the symbol η .

III. Multi-Energy Flow Architecture Of AA-CAES Based On Energy Hub

A. *Internal Matrix Modeling Of AA-CAES System*

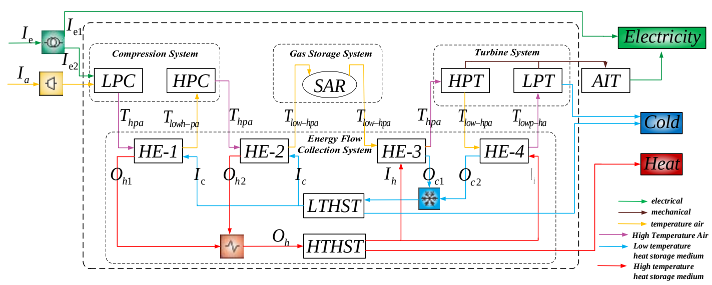

Fig. 2. AA-CAES system and its internal components base on EH

Figure 2 shows the EH-based AA-CAES system and its internal structure. The system consists of four parts: compression system, gas storage system, turbine system and energy flow collection system. The compression system and turbine system are composed of segmented compressors and turbines, and adopt the structure of multi-stage compression, inter-stage cooling and multi-stage expansion, inter-stage reheating.The input end of the system is composed of abandoned electricity generated by new energy power generation and normal temperature air, denoted as I_e 、 I_a . The output end of the system is composed of four energy flows: mechanical energy O_m , electrical load O_e , heat load O_h , and cooling load O_c . After the mechanical energy is output from the system, it will immediately enter the generator to generate electricity. The electricity generated by the generator will be combined with the output energy flow of the AA-CAES system, Acting on external electrical loads, cooling loads and heating loads.

The electrical energy input I_e by the system is composed of abandoned wind power by new energy power generation, and the air I_a is composed of ambient air at normal temperature and pressure. After the two enter the system together as the input terminal, part of the electric energy is directly used for the external electric load, and the loss of the electric energy in the transmission process is negligible, and the other part is used for the air compression of the multi-stage air compressor, which is described in the matrix as follows:

$$I_e \cdot N_e = I_e \cdot \begin{bmatrix} d_{e1} \\ d_{e2} \end{bmatrix} = \begin{bmatrix} I_{e1} \\ I_{e2} \end{bmatrix} \tag{5}$$

In the formula(5), the input electric energy I_e is divided into and two parts I_{e1} and I_{e2} after the action of the distribution matrix N_e , where d_{e1} and d_{e2} respectively represent the distribution ratio, and $d_{e1} + d_{e2} = 1$.

For multi-stage compressors, the "multi-stage compression, inter-stage cooling" mode is used to process the incoming air. The normal temperature and normal pressure air is first compressed at the low pressure compressor, and then the generated high temperature and high pressure air is guided to the heat exchanger, where the heat carried by the high temperature and high pressure air is combined with the low temperature heat exchange medium in the heat exchanger. After the exchange, the cooled air will enter the high-pressure compressor of the next stage, and perform secondary compression, and then enter the primary heat exchanger for heat exchange after the compression.

Electric energy I_{e2} and air I_a enter the low compressor for air compression. In the low-pressure compressor, part of the electrical energy will be converted into high-pressure air internal energy, and the other part will be converted into heat energy, and finally flow out from the output end of the low-pressure compressor as high-temperature and high-pressure gas T_{hpa} . The internal conversion process is shown in formula (6).

$$\begin{cases} I_{in}^{LPC} = \begin{bmatrix} I_{e2} \\ I_a \end{bmatrix} \\ I_{out}^{LPC} = I_{in}^{LPC} \cdot \eta^{LPC} = \begin{bmatrix} O_h \\ O_{pa} \end{bmatrix} = \begin{bmatrix} T_{hpa} \end{bmatrix} \end{cases} \tag{6}$$

In the formula, the normal temperature and normal pressure air I_a and electric energy I_{e2} entering the low-pressure compressor are converted into heat energy O_h and high-pressure air O_{pa} after the action of the efficiency matrix η^{LPC}, both of which can be represented by high-temperature and high-pressure gas T_{hpa} .

After the high-temperature and high-pressure gas flows out from the output port of the low-pressure compressor, it will immediately enter the 1-th heat exchanger. In the 1-th heat exchanger, it will work together with the cold energy I_c distributed from the low-temperature heat storage tank. The heat energy carried by is exchanged from the gas through the efficiency matrix , and two energy flows are generated at the output end, heat energy and lower-temperature and high-pressure gas, and the process is shown in formula (7).

$$\begin{cases} I_{in}^{HE-1} = \begin{bmatrix} T_{hpa} \\ I_c \end{bmatrix} \\ I_{out}^{HE-1} = I_{in}^{HE-1} \cdot \eta^{HE-1} = \begin{bmatrix} O_{h1} \\ T_{lowh-pa} \end{bmatrix} \end{cases} \tag{7}$$

In the formula, I_{in}^{HE-1} represents the input of 1-th heat exchanger, I_{out}^{HE-1} represents the output of 1-th heat exchanger. η^{HE-1} represents the heat exchange efficiency of the heat exchanger, and participates in the conversion of energy flow in the form of an efficiency matrix. specially, $T_{lowh-pa}$ stands for lower-temperature and high-pressure gas, but the temperature of the gas is higher than normal temperature, but lower than the temperature after compression

The lower-temperature and high-pressure gas $T_{lowh-pa}$ flowing out from the output end of the low-pressure heat exchanger will immediately enter the high-pressure compressor for secondary compression, as shown in the process formula (8).

$$\begin{cases} I_{\text{in}}^{HPC} = \begin{bmatrix} I_{\text{e2}} \\ T_{lowh-pa} \end{bmatrix} \\ I_{out}^{HPC} = I_{in}^{HPC} \cdot \eta^{HPC} = \begin{bmatrix} O_h \\ T_{lowh-pa} \end{bmatrix} = \begin{bmatrix} T_{hpa} \end{bmatrix} \end{cases} \tag{8}$$

The input end of the high-pressure compressor is composed of electric energy and low-temperature high-pressure gas. Inside the high-pressure compressor, part of the electric energy is converted into heat energy, and the other part is continuously converted into the internal energy of the high-pressure gas.

At the output end, the high-pressure gas with high temperature flows out of the high-pressure compressor, and then immediately flows into the 2-th heat exchanger.

$$\begin{cases} I_{in}^{HE-2} = \begin{bmatrix} T_{hpa} \\ I_c \end{bmatrix} \\ I_{out}^{HE-2} = I_{in}^{HE-2} \cdot \eta^{HE-2} = \begin{bmatrix} O_{h2} \\ T_{lowh-pa} \end{bmatrix} \end{cases} \tag{9}$$

In the 2-th heat exchanger, the high-temperature and high-pressure gas flowing out of the high-pressure compressor and the cold energy flowing out from the low-temperature heat accumulator work together to exchange energy at the input end, and the heat energy carried by it is exchanged through the efficiency matrix η^{HE-2} .

Then heat energy and lower-temperature high-pressure gas flow out from the output port of the 2-th heat exchanger, and the lower-temperature high-pressure gas will flow into the gas storage system. In the gas storage system, the loss of high-pressure gas during transmission and storage is ignored, and the gas storage system can be obtained. The input and output matrix of the system is:

$$I_{in}^{SAR} = I_{out}^{SAR} = \left[T_{lowh-pa} \right] = T_{lowh-pa} \tag{10}$$

And the heat displaced by the 1-th heat exchanger and the 2-th heat exchanger during operation will be collectively collected into the high-temperature heat storage for storage.

$$I_{in}^{HTHST} = O_{h1} + O_{h2} \tag{11}$$

If the stored high-pressure gas needs to be converted into electricity for external supply, the stored low-temperature high-pressure gas needs to be released and turbined 1-th from the gas storage chamber. In order to obtain better turbine effect, the system adopts the turbine mode of multi-stage expansion, inter-stage heating. Before entering the high-pressure turbine, the lower-temperature and high-pressure gas needs to flow into the heat exchanger for heating. The input end of the third heat exchanger is composed of the high-pressure gas flowing out of the gas storage chamber and the heat energy flowing out of the high-temperature heat storage chamber.

$$\begin{cases} I_{in}^{HE-3} = \begin{bmatrix} T_{lowh-pa} \\ I_c \end{bmatrix} \\ I_{out}^{HE-3} = I_{in}^{HE-3} \cdot \eta^{HE-3} = \begin{bmatrix} O_{c1} \\ T_{hpa} \end{bmatrix} \end{cases} \tag{12}$$

In formula (12), the heat energy distributed from the high-temperature storage and the lower-temperature and high-pressure gas flowing out of the gas storage are used as input ends to flow into the 3-th heat exchanger together. In the 3-th heat exchanger, heat energy is used to increase the temperature of the lower-temperature and high-pressure gas, producing high-temperature, high-pressure gas and cold energy. The high-temperature and high-pressure gas flows to the high-pressure turbine as the output of the 3-th heat exchanger, and the cold energy flows to the low-temperature heat storage for storage.

$$\begin{cases} I_{in}^{HPT} = \left[T_{hpa} \right] \\ I_{out}^{HPT} = I_{in}^{HPT} \cdot \eta^{HPT} = \begin{bmatrix} O_{m1} \\ T_{low-hpa} \end{bmatrix} \end{cases} \tag{13}$$

In formula (13), the high-temperature and high-pressure gas generated by the 3-th heat exchanger flows into the high-pressure turbine as the input end, and passes through the efficiency matrix inside the high-pressure turbine. The internal energy of the gas will be converted into mechanical energy and lower-temperature lower-pressure gas $T_{low-hpa}$ which is lower than the temperature after compression, but higher than normal temperature, and the pressure is higher than that of normal temperature air, but lower than the air pressure after compression, in which the mechanical energy and the mechanical energy generated by the low-pressure turbine work together to act on the generator to generate electricity. When the lower-temperature and lower-pressure gas flows out from the output end of the high pressure turbine, it needs to flow into the 4-th heat exchanger for the final heating. 4-th heat exchanger and 3-th heat exchanger are the same, the input end is composed of lower-temperature and lower-pressure gas and heat energy. In 4-th heat exchanger, the lower-temperature and lower-pressure gas is exchanged with the heat energy distributed from the high temperature heat storage chamber through the efficiency matrix. Generating cold energy and high-temperature and lower-pressure gas, the process is shown in formula (14). Specially, $T_{lowp-ha}$ has high-temperature, but the pressure is higher than normal pressure but not higher than the pressure after compression

$$\begin{cases} I_{in}^{HE-4} = \begin{bmatrix} T_{low-hpa} \\ I_{h2} \end{bmatrix} \\ I_{out}^{HE-4} = I_{in}^{HE-4} \cdot \eta^{HE-4} = \begin{bmatrix} O_{c2} \\ T_{lowp-ha} \end{bmatrix} \end{cases} \tag{14}$$

Finally, the high-temperature and lower-pressure gas flows into the low-pressure turbine for the last turbine. In the low-pressure turbine, the internal energy of the high-temperature and lower-pressure gas is converted into mechanical energy and normal temperature and normal pressure gas, which is directly discharged into the air, and the mechanical energy will flow into the generator together with , and generate electricity in the generator.

$$\begin{cases} I_{\text{in}}^{ALT} = O_m = O_{m1} + O_{m2} \\ \eta_c^{ALT} = \left[\eta_e^{ALT} \right] \\ I_{out}^{ALT} = I_{\text{in}}^{ALT} \cdot \eta_c^{ALT} = O_{e1} \end{cases} \tag{15}$$

In formula (15), the input end of the generator is composed of the mechanical energy and mechanical energy generated by the high-voltage turbine and the low-voltage turbine, and electric energy is generated after the action of the efficiency matrix.

B. Optimization Objectives and Constraints

Optimization Goal: For a typical AA-CAES system, electric energy and heat energy can be supplied to the outside, and the electric energy can be converted into gas internal energy by compressing the gas when the electricity price is cheap. Turbine power generation is carried out when the electricity price is high, the internal energy of the gas is converted into electric energy, and the unconsumed heat energy in the system is supplied to the outside world, so as to maximize the profit while meeting the energy demand of users.

Constraints: (1) Each energy distribution ratio is dynamically adjusted within its reasonable operating range within an hour, but the sum of the total distribution ratio is 1. (2) The compressor and turbine only operate within the specified power range. (3) The conversion efficiency and distribution matrix need to vary within a reasonable range. (4) It should also satisfy the equality constraints of the energy flow conversion inside the energy hub, as shown in formula (16).

$$\begin{aligned} \max \quad & \pi = \sum S - c = \sum_{output} L \cdot \alpha - \sum_{input} P \cdot \beta \\ \text{s.t.} \quad & \sum v_m = 1, \quad \forall m \in \mathcal{M}, \\ & P_{\min} \le P_i \le P_{\max}, \quad \forall i, \\ & \eta_{\min} \le \eta_i \le \eta_{\max}, \quad \forall i, \end{aligned} \tag{16}$$

IV. Matrix Modeling Of Multi-energy Flow In AA-CAES Power Station

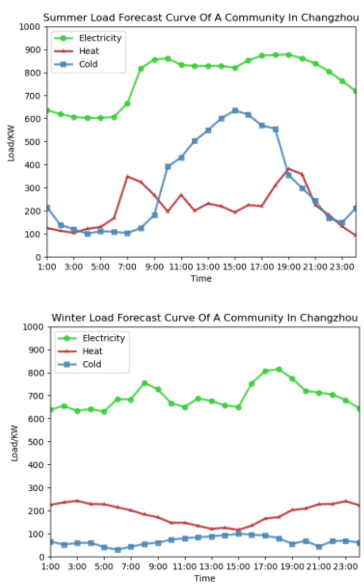

Fig. 3. Heating load forecasting curve of a residential area in Changzhou in summer and winter

In this paper, an example analysis is carried out based on the typical electric heating load data of a district in Changzhou in summer and winter. Because the collection of cold energy is related to the overall parameters of the AA-CAES power station, the external supply of cold energy is not considered in the analysis of the example in this paper. A few days ago, the forecast curve of electric heating load in a residential area in Changzhou in summer and winter is shown in Figure 3.

The scheduling parameters of a typical compressed air energy storage power station system are shown in Table 1.

TABLE I. Scheduling Parameters of AA-CAES Plant

Device parameters	**Min**	**Max**
Compression(Generating) power/kW	800	2000
Generating power/kW	480	1200
Heat storage(release) power/kW	0	500(300)
Compressor(Turbine) stages	2	2
Compressor(Turbine) efficiency	0	85%
Heat Exchanger Energy Efficiency	0	0.7
System electricity to electricity efficiency	0	53%
Compressor inlet rated temperature/K	312	312
Rated inlet temperature of turbine at all levels/K	363	363
Environment temperature/K	298	298
Gas chamber volume/m3	0	7200

The compressors and turbines of the AA-CAES power station in this example all adopt a two-stage compression turbine structure. The electricity price adopts the time-of-use electricity price, and the purchase price and sale price in summer and winter are shown in Table 2. In the current international context of energy shortage, the purchase price and the sale price may fluctuate due to various factors. Therefore, in the example analysis, the price of each energy source fluctuates randomly within ±5% per hour.

TABLE II. Unit Price of Energy Purchased and Sold

Season	α_e **(RMB/kWh)**	α_h **(RMB/kWh)**	β_e **valley (RMB/kWh)**	β_e **peek (RMB/kWh)**
Summer	0.60	1.04	0.27	0.29
Winter	0.60	0.98	0.20	0.22

A. Result Analysis

This paper sets up three scenarios to compare and analyze the economic benefits of compressed air energy storage multi-energy flow systems.

Scenario 1, AA-CAES uses valley electricity to charge from 23:00 to 7:00 at night, and from 8:00 to 16:00 during the day, external turbine power supply is performed according to the user's actual electrical load. Scenario 2, AA-CAES power station uses valley electricity to charge from 23:00 to 7:00 at night, and from 10:00 to 14:00 during the day, external power supply and heating are provided according to the actual needs of users Scenario 3, the power station works 24 hours a day and is only charged from 23:00 to 7:00 in the evening. During the daytime, the turbine is used for external power supply and heating from 9:00 to 16:00. During the rest of the time, the power from other power stations is directly purchased, and the external power is supplied according to the actual load of the user.

Figure 4 shows the profit and income of the three scenarios in summer and winter. It can be seen that with the increase of external energy supply and the increase of supply time, the profit is constantly rising. Scenario 1 has the lowest profit in winter, because the valley-peak price of electricity in winter is lower than that in summer, and the power load in winter is smaller than that in summer. As a result, the profit of scenario 1 is the lowest among the three scenarios. The summer income of scenario 2 increased by 22% compared with winter, and the summer profit of scenario 1 increased by 428% compared with the same period of the same period. The growth point of profit and income mainly comes from the external supply of heat energy. scenario 3, the profit increase in summer is 17% higher than that in winter, which is smaller than the increase in income of scenario 2, but the profit of scenario 3 is increased by 162% compared with scenario 2. The main profit growth point comes from the increase in the duration of power supply and heating.

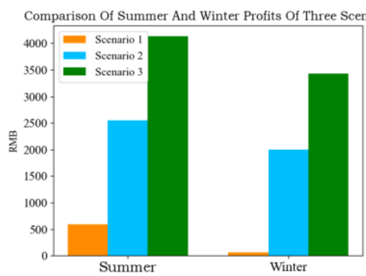

Fig. 4. Comparison of profits of three scenarios in summer and winter

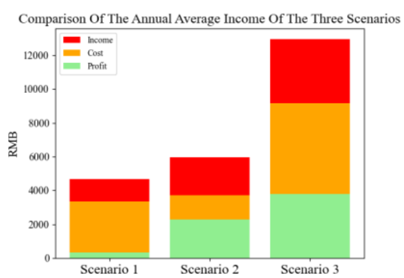

Fig. 5. Comparison of annual average income of three scenarios

The average annual income of the three scenario is shown in the figure above. scenario 1 has the lowest average annual profit because it only sells electric energy, and the cost of electricity purchase accounts for most of the average income. It does not have great economical aspects, and the daily profit cannot cover its construction cost. scenario 2 sells additional heat energy on the basis of scenario 1, and the profit ratio increases significantly in the proportion of revenue. The profit from heat energy offsets a large amount of electricity purchase costs, making the overall revenue increase. In scenario 3, due to the 24-hour operation of the AA-CAES power station, its overall operating cost has increased significantly compared with the first two scenario, and the profit has increased, but the increase ratio is not high compared with scenario 2. The reason is that in China electricity price has a policy of benefiting the people. However, the valley-to-peak electricity price does not have a large difference, and the electricity price cannot reflect its commodity attributes, as result high profits cannot be obtained only by the output and sales price difference of electricity. In the three scenario designed in this paper, the sale of cold energy is not considered, and the price of cold energy is different due to different temperatures. But in practice, the external supply of cold energy is mainly generated by the outlet air temperature of the turbine. Therefore, if there is a system that requires a large amount of cooling energy next to the AA-CAES system, the economic benefits of the AA-CAES system will be further improved.

V. Conclusion

AA-CAES power station is a new type of large-scale energy storage device. It can not only be used for electric energy storage, but also can be used for peak regulation and phase regulation of the power grid. If the additional energy flow generated by the CAES during the operation process is collected, it can not only meet its own energy consumption, but also provide stable supply to the outside world and improve energy utilization. This paper proposes a multi-energy flow system model for compressed air energy storage based on the EH concept. The simulation example shows that:

1) The simple *electricity-to-electricity* efficiency of AA-CAES power station is low. In order to make full use of energy and improve energy utilization efficiency, it is necessary to collect and supply the extra energy flow generated during the operation of the system to improve the energy utilization of the system. In order to improve system energy utilization and overall economic benefits

2) AA-CAES has the specific characteristics of the micro integrated energy system of combined cooling, heating and power. By adjusting the operation mode, reduce the energy consumption of other cooling and heating systems and improve the energy efficiency of the area.

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