Research on Energy Storage Optimization Configuration in Integrated Energy System

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Abstract—Integrated Energy System (IES) is an important part of the ISTEM, which is an important part of IES, which solves a variety of energy storage, gas, electricity, heat, cold, etc., as an important part of IES. This paper proposes a wide range of integrated energy storage optimization configuration models for multiple IES architectures, and analyzes the versatility of the model. First, the establishment of a general model of IES can cover various specific structures of IES; secondly, the integrated energy storage optimization configuration model is established on the basis of the IES universal model, so that the configuration model can be applied to a variety of IES architectures. The model is the smallest annual value of the annual value of the system life cycle, decision-making various energy storage configuration capacity and power; finally, in a commercial building IES, an altruistic analysis is carried out, and the optimized configuration model is in other scenes. The versatility is analyzed, and the results show that the model can be applied to the IES of the various architectures, solve the optimized configuration problem of integrated energy storage in different scenarios, and has versatility.

1. Introduction
Since the 21st century, the energy sector is facing challenges in environmental pollution, low energy efficiency, safety, etc\textsuperscript{[1]}. Integrated energy system can effectively improve the utilization efficiency of traditional disposable energy, improve the security and self-healing ability of social supply system, and is an important direction of future energy system development\textsuperscript{[2-3]}

The storage capacity can realize the combination scheduling of various energy in the IES, reducing the operating cost of the system can decouple energy production and consumption, improve the renewable energy of the renewable energy\textsuperscript{[4-8]}; Research on the optimal configuration of energy storage can also restrain the fluctuations of renewable energy and user load and keep the system running safely and reliably.\textsuperscript{[9]} Therefore, it is important to study the optimization of integrated energy storage in IES, which is of great significance for playing the role of integrated energy storage. IES is coordinated with a variety of energy production, conversion, transmission, storage, and consumption of energy integrated systems. How to explore the role of integrated energy storage from integrated energy concepts for more complementary and multi-live coordination scheduling, The general-purpose IES integrated energy storage optimization configuration model is also worth further study.

In response to the above problems, this paper proposes an IES integrated energy storage optimization configuration general model for a wide range of IES architectures. First, establish an universal model of
IES from the concept of integrated energy; secondly, the IES integrated energy storage optimization configuration model is established on the basis of the IES universal model, considering energy storage capacity and power constraints, energy supply and demand balance constraints, energy storage unit constraints, Energy conversion unit constraints, interacting with energy suppliers, with the minimum cost of the annual value of the system life cycle, the capacity and power of the optimal configuration of various energy storage devices in IES; again, commercial buildings Application scenarios, the generalization of the general model is embodied, and the electrothermal cold storage energy in commercial buildings is configured, and the applicability of the model in the scene; finally, analyze the applicability of the optimized configuration model in other scenarios, explain the model Universality.[10-13]

2. General model of integrated energy system
The typical physical architecture of IES is shown in Figure 1. [14] According to energy production, conversion, transmission, storage, consumption, IES, various types of equipment in the system can be divided into different units. [15] The energy production unit mainly includes distributed power generation of photovoltaic power generation, geothermal heating, and heat-generating equipment, can supply energy to users independently of large energy suppliers; energy conversion units mainly include hot and electric three-link, air conditioning, heat pump, electricity Refrigerator, absorbent refrigerator, etc., can achieve a variety of energy conversions, electricity, heat, cold and other energy; energy transmission unit refers to various energy transmission pipes; the energy storage unit mainly includes gas storage tanks, batteries, heat storage A variety of energy storage devices such as a can refers to a terminal user that has a demand for energy.

![Fig.1 Typical physical architecture of IES](image)

The user side IES shown in Fig. 1 contains a particular energy form and a system device, and establishing a more general IES model requires abstract processing. According to the above analysis, the device in the user side IES can be divided into different units according to the function, and therefore the energy production unit, the energy conversion unit, the energy storage unit, and the abstract module such as energy production unit, the energy unit, and the like are used instead of various specific system devices in the IES. IES contains energy forms should also have generality.
3. IES integrated energy storage optimization configuration model

The optimal configuration of the IES integrated energy storage can be described as a given price curve and user's use of users, and the optimization of system economics is optimally economically, optimal, system economy. The capacity and power configuration of the energy storage and the operating scheduling scheme of each device.

3.1. Target function

Assuming that the life cycle of the integrated energy storage system is T year, the reference discount rate is I0, and the optimized configuration is the minimum cost of the annual value in the system life cycle, including the annual value cost and user of the energy storage full life cycle. The cost of purchasing energy within the year.

\[ \min \text{Cost} = C_{LCC} + C_{int} \]  

In: \( C_{LCC} \) is the annual value cost of the energy storage full life cycle; \( C_{int} \) is the cost of purchasing energy from energy suppliers within one year.

3.2. Restrictions

(1) Breakable capacity and power constraint

\[
\begin{aligned}
0 &\leq E_s \leq E_s^{max} \\
0 &\leq P_s \leq P_s^{max}
\end{aligned}
\]  

In: \( s = 1,2,\ldots,N; \) \( E_s \) and \( P_s \) are the capacity and power (decision variables) of the storage device configuration; \( E_s^{max} \) is the maximum capacity limit of the configuration of the first storage device; \( P_s^{max} \) is the maximum power configured for the storage device.

(2) Energy supply and demand balance constraint

\[
W_{buy,s}(t) + W_{pro,s}(t) + \sum_{i=1}^{s-1} K_{i,s}(t) W_{i,s}(t) + W_{dis,s}(t) = \\
W_{sell,s}(t) + \sum_{i=s+1}^{N} W_{s,i}(t) + \sum_{i=s+1}^{N} W_{ch,s}(t) + W_{load,s}(t)
\]  

In: \( s = 1,2,\ldots,N; \) \( W_{dis,s}(t) \) and \( W_{ch,s}(t) \) are the discharge energy and charge of the storage device at the t period, respectively; \( W_{pro,s}(t) \) is the energy produced by the energy production unit of the s energy. Value (known amount); \( W_{load,s}(t) \) is the user load (known amount) of the s energy in the t period. In terms of energy conversion, it is assumed that energy can only be converted from high-grade to low-grade transitions: \( W_{i,s}(t) \) is the amount of energy i consumes energy s, \( K_{i,s}(t) \) is the conversion efficiency of the corresponding energy conversion device. \( W_{s,j}(t) \) is the amount of energy s that is converted into energy j (j> s).

3.3. Solution

The operating characteristics of the energy conversion unit in the integrated energy storage optimization configuration model may be non-linear, so the model is a non-linear plan. Using the segmental linearization method can convert nonlinear planning to a mixed integer linear plan, and the commercial solver CPLEX is called in MATLAB for solving.
4. Example analysis
The example is the application scenario in commercial buildings, and the specific architecture of IES is shown in Figure 2. The universal model of the user side IES integrated energy storage optimization configuration is embodied, and the applicability of model in commercial construction scenarios.

![Figure 2 Business building IES architecture](image)

4.1. Basic data
Construction can be divided into 3 types: hot season, free season, transition season. The price of natural gas in one day remains unchanged, and is 3.15 yuan / m³. The system is shown in Table 1.

| Period        | Time     | Purchase electricity/ (yuan·kWh⁻¹) | Sell electricity/ (yuan·kWh⁻¹) |
|---------------|----------|------------------------------------|-------------------------------|
| Peak hours    | 8:00–12:00, 17:00–21:00 | 1.1234                             | 0.9429                        |
| Flat period   | 12:00–17:00, 21:00–24:00 | 0.7489                             | 0.6414                        |
| Low period    | 0:00–8:00 | 0.3745                             | 0.3015                        |

4.2. Optimization results analysis
The life cycle of the integrated energy storage system is 25 years, and the reference discount rate is 5%, and the electrical energy and hot and cold storage energy of commercial building IES are optimized. If the system only configures to be modified, the electric storage not only requires a conventional electric load of the electricity price peak period, but also needs to transfer air conditioning heating or cooling consumption, which has a higher energy storage program compared to the electric hot and hot energy storage program. Electrical storage capacity and power, due to high cost of energy, etc., the decrease in the total cost of the annual value is not obvious. If the system only configures the cooling energy storage, the annual value is reduced, but due to the lack of electrical storage, the electricity load of the electricity price is not transferred, the economy of the program is slightly poorly high.

5. Conclusion
From the concept of integrated energy, the general model of the user side IES is established, and on this
basis, the user-side IES integrated energy storage optimization configuration model is proposed, and the model has versatility. For different integrated energy storage applications such as commercial buildings, integrated energy micros, the universal models can be constructed in this scene, and the integrated energy storage is optimized according to the optimized configuration of this paper. In the future IES, new devices such as gas storage may be added, or new energy forms can also be configured to consider integrated energy storage according to the IES integrated energy storage optimization in this paper. The integrated energy storage optimization configuration model proposed in this paper considers the source of the peak price difference, how to participate in the auxiliary service market, the income of the demand response is included in the configuration model, will become the next research direction.

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