Operation Mode and Value Evaluation System of Integrated Energy System in the Park

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Abstract: The integrated energy system, which covers the coordinated and unified supply of electricity, heat, cold, gas and other forms of energy, is the key technology to promote the clean and low-carbon transformation of energy. By studying the structure of integrated energy system, this paper analyses the three operation modes of integrated energy system project EPC, BT and BOT based on service mechanism, and clarifies the physical form and value transfer relationship between the subjects in the life cycle of integrated energy system. From the two dimensions of exogenous value and endogenous value, this paper analyses the main value evaluation indexes of the integrated energy system on the grid side, the system itself and the user side.

1. Overview
The integrated energy system is a safe, reliable, efficient, clean and intelligent energy integration system that takes natural gas, wind energy, solar energy and other clean energy as energy input, through the optimization construction and operation of multi-energy collaborative energy network, as well as the intelligent interaction between demand and supply, to meet the output of electricity, heat, cold, water, gas and other energy needs [1]. The main reason that restrict the development and construction of the integrated energy system is the diversity of its system form, the flexibility of its change, the influence of its economy, market and policy uncertainty. Combing the effective operation mode, analysing and mining its potential value, and laying the foundation for the reasonable evaluation of the system, has become the key problem to be solved in the promotion of integrated energy system engineering. In literature [2], maturity assessment, environmental impact assessment and overall energy use and conversion efficiency assessment are proposed as macro evaluation criteria. Literature [3] establishes a regional integrated energy system benefit evaluation index system with electricity as the core from energy link, device link, distribution network link and user link, reflecting economic benefit, social benefit and environmental benefit from multiple indexes. Literature [4] established the evaluation index and method of micro energy system in the park from four aspects of economy, reliability, energy consumption and environmental protection. Literature [5] compares the evaluation effect of different types of indicators and different thermal indicators on multi-energy combined supply and energy cascade utilization in regional integrated energy system parks. Literature [6] established integrated energy efficiency indicators to evaluate the energy utilization of multi-energy complementary systems.
In the above research, most of the indicators and value analysis come from the evaluation of independent energy system or equipment. In fact, as a whole form of energy organization, the integrated energy system needs to establish a unified dimension for the upstream and downstream of its industrial chain to deeply tap the value of the multi-energy complementary system. Therefore, in consideration of different investment modes, this paper combs the current domestic and foreign mature business models that can be promoted and copied, and combines the external value and internal value of the integrated energy system to evaluate the overall value of the integrated energy system, so as to provide a theoretical reference for the promotion and expansion of the multi-energy complementary demonstration project.

2. The architecture of integrated energy system
In essence, the integrated energy system architecture can be divided into three parts: "energy input-conversion storage-output module". The energy input module is composed of the natural gas network and the large power grid. The large power grid provides power to the micro grid integrated operator through the transformer. Meanwhile, the system sends the surplus power to the power grid through the transformer, and the natural gas network provides natural gas to the micro grid integrated operator through the compressor. In this process, the micro grid actively responds to the changes of market price and natural gas price, adjusts its own energy consumption habits and energy demand. The external grid and natural gas grid adjust their own transaction price and transaction mode according to the market change trend and market response degree; in the energy conversion and storage module, the wind turbine and photovoltaic unit respectively convert wind energy and solar energy into electric energy. In CCHP, the gas turbine generates electricity, and the waste heat is converted into cold and hot through the waste heat boiler and absorption chiller. Energy storage equipment includes power storage, cold storage, heat storage and cold storage equipment. The cooling and heating power are coupled with each other through the energy conversion equipment as the condition of demand response; the energy output module includes four types of loads of "cold-heat-electricity-gas".

3. Integrated energy system operation mode based on service mechanism
The operation mode with good economic benefit and high environmental protection benefit is the key to the promotion and application of the integrated energy system project. Based on the service mechanism, this chapter analyzes the current commonly used operation mode of the integrated energy system project to lay the foundation for the subsequent value evaluation.

3.1. Contract energy management (EPC) mode
Contract energy management refers to the use of energy service contracts by energy-saving service companies to bring professional services to customers, such as energy-saving diagnosis, transformation and financing. At the same time, investment will be recovered through energy-saving benefit sharing, and more scientific benefits will be obtained. The model includes three types: energy cost custody, energy-saving benefit sharing and energy-saving guarantee. The relationship between the modes is shown in Figure 1.
EPC mode is divided into the following three types:

1. **Energy saving benefit sharing type**
   Energy-saving service companies can provide a complete service system and financial support for electrical energy replacement projects, complete the project with the active cooperation of customers, and share with customers according to a set proportion during the contract period, thereby bringing benefits. After the contract expires, the ownership of the project and the electric energy substitution benefits belong to the customer, so the customer's cash flow will never be negative.

2. **Energy saving type**
   Customers provide funds for power substitution projects by stages, actively participate in project promotion, and the energy-saving service company is responsible for providing services for the whole process, and ensure that the project has a good energy-saving effect. According to the contract, the customer needs to pay the relevant fees to the energy-saving service company. If the project fails to meet the established energy saving requirements, the energy-saving service company shall bear certain responsibilities and economic losses according to the contract content; otherwise, if the project is excessive, the company shall share the excess profits with customers according to the proportion.

3. **Energy cost custody**
   The customer entrusts the energy-saving service company to complete the operation management and energy-saving transformation of the energy system for the electric energy substitution project, and pays the energy custody fee according to the contract content. The company raises funds independently for the transformation of energy system and the management of customers, contracting all energy costs. The energy service quality indicators and specific confirmation methods are clearly indicated in the contract. If they are not up to the standard, the company needs to make compensation according to the contract content.

3.2. **Build-Transfer BT mode**
   BT (Build-Transfer) mode is the abbreviation of "Build-Transfer", which is one of the relatively new modes in all investment and financing construction modes. The government uses the concession agreement to authorize the enterprise, so that the enterprise can provide financing for the project and help the smooth implementation of the project. After the project construction inspection is qualified, the government is responsible for redeeming it and making use of the future financial budget funds to pay for the project and get the corresponding return. Figure 2 shows the BT mode.
3.3. Build-Operate-Transfer (BOT) mode

BOT (Build-Operate-Transfer) mode is the abbreviation of "Build-Operate-Transfer". In essence, it is one of the modes of infrastructure construction, investment and operation. The government is responsible for issuing the concession to the private institutions, so that they can raise funds within the specified time, complete the infrastructure construction and the operation and management of relevant services and products. Figure 3 shows the BOT mode.

Figure 3. BOT mode diagram.

4. Value evaluation of integrated energy system

4.1. Overview of the value of integrated energy system

The value of integrated energy system includes two aspects: exogenous value and endogenous value. Exogenous value is embodied in the value of the system to society, the government and the users. The value to society is embodied in the equivalent environmental value of the integrated energy system, which can promote the consumption and utilization of large-scale renewable energy and reduce carbon emissions through the collaborative optimization of multiple energy sources. The value to the government is reflected in the improvement of energy efficiency of integrated energy system and the potential value brought by optimizing energy structure, such as reducing investment expenditure, reducing transmission loss and investment risk. The value to users is reflected in that the integrated energy system can meet the power, gas and heat/cold demand of end users, and reduce the energy cost of users through the interaction of supply and demand. The research object of the endogenous value of the integrated energy system is the system itself, which is reflected in the comparison and selection of different schemes, including economic price and social environmental value.

4.2. Grid-side value

1. Loss on sale of electricity

The loss of revenue from electricity sales reflects the energy supply of the system. Assuming that the power supply of the integrated energy system is not enough to meet the user's demand, the purchased power is required. If the system is completely self-consumed, the purchased power is not required. At this time, the revenue from grid loss is shown in formula 1.

\[ G = Q \times (P_0 - C_s) \]  

(1)
In the formula, \( G \) is the profit and loss of electricity sales of the grid, the unit is 10,000 yuan; \( Q \) is the annual electricity consumption of the user, the unit is kW / h; \( P_g \) is the average retail price of the grid, he unit is yuan / kwh; \( C_s \) is the average cost of electricity sales of the grid, the unit is yuan.

2. Postpone the upgrading and expansion of power grid
Energy storage is an important part of integrated energy system, and it is also the link of multi-energy subsystem. When the load peak valley difference in a region is large and the upgrading and reconstruction speed is slow, the application of energy storage by users in the region can delay the upgrading and expansion of the power grid to a certain extent, and the delay period can be expressed as follows:

\[
\Delta N = \frac{\log \left( \frac{1}{1 - \alpha} \right)}{\log (1 + \tau)}
\]

(2)

And the annual benefits of the energy storage system due to the delay of grid expansion are as follows:

\[
E_{\text{def}} = \frac{C_{\text{inv}} \left( 1 - \left( \frac{1 + i r e f}{1 + dr} \right)^{N \Delta N} \right)}{N}
\]

(3)

Where \( 1 - \alpha \) refers to the peak clipping coefficient of the energy storage device, \( \alpha \) refers to the ratio of the rated power of the battery to the peak power of the load, and \( \tau \) refers to the annual load growth rate.

4.3. Intrinsic value of integrated energy system

1. System energy efficiency

\[
\eta_{gss} = \frac{E_i + Q_s + Q_c}{\sum_{j=1}^{N} E_j + \eta_f g_f + \sum_{j=1}^{n} \eta_f g_f}
\]

(4)

Where \( E_i \) refers to the electric load, the unit is kW / h; \( Q_s \) refers to the heat load, the unit is kW / h; \( Q_c \) refers to the cooling load, the unit is kW / h; \( \sum_{j=1}^{N} E_j \) refers to the energy generated by all renewable energy, the unit is kW / h; \( N \) is the total number of renewable distributed energy types; \( E_{\text{pul}} \) refers to the annual purchased power of integrated energy system; \( \eta_f g_f \) refers to the flat power supply efficiency of power plant; \( \sum_{j=1}^{n} F_j \) refers to the annual natural gas heat of each gas equipment, \( n \) is the total number of gas equipment types.

2. Benefits of environmental emission reduction

Compared with the traditional energy system, the integrated energy system increases the utilization of renewable energy, reduces the emission of harmful gases, and produces equal environmental benefits, which can be reflected by economic value indicators. The environmental emission reduction benefit of the system is defined as \( B_{\text{env}} \), compared with conventional coal-fired power generation, the environmental value of pollutant emission reduction of the system under the condition of generating the same amount of electricity is as follows:
\[ B_{\text{inv}} = \sum_{i=1}^{n} V_i \left[ Q_{\text{gas}} \left( q_{i}^{\text{in}} - q_{i}^{\text{out}} \right) + Q_{\text{dg}} \left( q_{i}^{\text{in}} - q_{i}^{\text{out}} \right) \right] \] (5)

3. The cost of the entire system life cycle

For integrated energy operators, in the process of system construction and operation, the total cost mainly consists of the following three parts: construction cost \( C_{\text{con}} \), i.e. initial investment of equipment and grid structure; maintenance cost \( C_{\text{om}} \), i.e. line protection, equipment and equipment maintenance, etc.; equipment and operation cost \( C_{\text{op}} \), mainly refers to the fuel cost incurred in the process of equipment operation. All expenses are of equal annual value, in hundred million yuan.

\[ C = C_{\text{con}} + C_{\text{om}} + C_{\text{op}} \] (6)

4.4. User side value assessment

User side value is evaluated by \( PMV \). \( PMV \) value reflects the evaluation index of human body's cold and heat sensation, and represents the average cold and heat sensation of most people to the same environment. When the heat output of the human body is equal to the heat dissipation, the human body is in a state of heat balance, which is expressed by the following formula:

\[ PDD = 100 - 95 \times \exp \left[ -\left(0.03353 PMV^4 + 0.2179 PMV^2 \right) \right] \] (7)

\( PDD \) index indicates the percentage of people dissatisfied with the thermal environment. Using probability analysis method, the quantitative relationship between \( PMV \) and \( PDD \) is obtained.

5. Conclusion

This paper summarizes the development process of the integrated energy system project operation mode, and analyses the current domestic and foreign commonly used integrated energy project operation mode and the operation characteristics of different operation modes from the perspective of service mechanism. Scientific multi-energy system benefit evaluation is one of the key issues in mining integrated energy utilization value and building intelligent energy Internet. This paper proposes a value evaluation system considering the exogenous and endogenous value of the integrated energy system, which will provide a reference for the scientific evaluation of the integrated energy system project operation.

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