Transaction Optimization Decision of Integrated Energy Market based on Genetic Algorithm

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Abstract: China is the world's largest energy producer and consumer. In the context of global warming and the transformation of the international energy structure, China's energy development is facing great pressure from the structural reform of the supply and demand side; In the process of China's energy structure transformation, it is urgent to reduce energy consumption while meeting various energy needs and put forward the optimization decision of comprehensive energy market transactions. Therefore, based on genetic algorithm(GA), this paper studies and analyzes the transaction optimization decision of integrated energy market(IEM). This paper briefly introduces the trading system of the energy market and the multi-agent trading mode of the IEM, highlights the GA, and discusses the optimization decision-making of the IEM based on the GA. Finally, the simulation experiment is carried out through the optimization of the IEM. The simulation results show that the proposed operation optimization(OO) decision-making model based on the GA can effectively and improve the social and environmental benefits of the system operation, Improve the economic cost of operation; GA is used to solve the calculation of optimization model, and the feasibility of transaction mechanism and optimization model is verified by the algorithm.

Keywords: Genetic Algorithm, Integrated Energy Market, Market Transaction, Optimization Decision

1 INTRODUCTION

The construction of the comprehensive energy market transaction requires the introduction of a variety of energy. It can be predicted that the characteristics of the comprehensive energy market are unstable demand, many types of energy, many buyers and sellers, and the unstable development of the energy market. The traditional energy trading mode will be due to the differences in the characteristics of different energy commodities and the interest contradictions between energy suppliers. Most of the energy supply and trading are operated independently by the industry, and there are market interests and institutional barriers in cross industry trading. It is difficult to meet the trading needs of the coordinated and optimized operation of multi-agent energy system, and it is difficult to ensure the realization of the coupling of cold, heat, electricity and other multi-energy in trading. Therefore, a set of reasonable and scientific optimization and trading theory is needed to break through the isolated traditional energy trading pattern and build a reasonable and complete integrated

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energy multi-agent service OO trading mode. Therefore, this paper proposes an optimization decision of comprehensive energy market transaction based on GA.

Energy trading is bound to produce interest correlation and decision optimization among multiple decision-making subjects. Fair market mechanism and energy management methods are the premise to ensure energy sharing and improve energy efficiency. Gautam P applies game theory to the power market and studies the interaction mechanism between the interested parties by using master-slave game. The development of integrated energy system(IES) and the rise of energy Internet have expedited the diversification and refinement of integrated energy business, making integrated energy service providers become new market players of energy supply in the future. Integrated energy service providers have flexible functions, extensive businesses and strong interaction with users. They can not only clear energy transactions with energy suppliers, but also aggregate certain user loads, dispatch their own equipment and energy supply through energy conversion and storage, and establish an energy interaction mechanism with users in the way of comprehensive demand response[1].

This paper studies the coordinated and optimized operation of energy resources, and establishes a coordinated, green, economic and shared comprehensive energy system. The IES integrates the production and supply of cold, heat, electricity, gas and other energy forms, makes full use of the coupling and complementary relationship between various energy forms, and optimizes the cost of energy supply and improves the efficiency of energy supply by coordinating the production and interest relations between different energy service entities on the basis of meeting the energy needs of users; Establish a complete and effective integrated energy multi-agent system operation and trading mode to realize the coordinated and optimized operation of multiple integrated energy service entities. Based on GA, this paper studies and analyzes the transaction optimization decision-making of the IEM, coordinates the benefit distribution of multiple parties in the integrated market, improves the enthusiasm of participants, gradually promotes the integration and development of different energy forms under the guidance of the market, and realizes the win-win cooperation of multiple parties in the IES[2].

2 IEM TRANSACTIONS

2.1 Energy Market Trading System

Energy products not only have the characteristics of general commodities, but also have their own unique attributes. Their trading methods are also different from general commodities. Therefore, the trading system that conforms to the laws and requirements of the energy market needs to be established and followed in the trading of energy market. This trading system is an institutional arrangement that all parties to the energy market must follow and reflect the characteristics of energy products, so that energy products can complete transactions effectively, orderly, quickly, economically and at low consumption[3]. This trading system is a collection of a series of specific trading rules, including the combination of futures trading system, spot trading system, block trading system, etc., and the combination of oil trading system, coal trading system, power trading system, etc. under the principle of unified energy market trading system[5]. These trading systems should not be divided and isolated, but restrict, correlate and interact with each other;

2.2 Analysis of Multi-Agent Trading Mode in the Comprehensive Energy Market

In the IES, there are various energy resources and market players. The structure of the multi-agent transaction mode of the IES is shown in Figure 1.

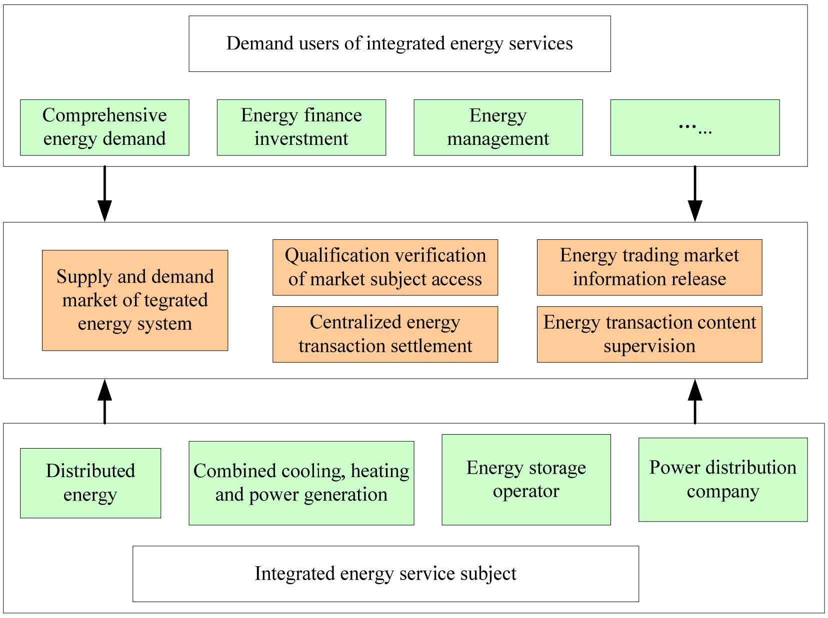

Figure 1. Multi agent transaction mode diagram of IES

In the multi-agent trading mode of the IES, there are mainly three parties: users of integrated energy service demand, IES supply and demand market, and integrated energy supply and demand market. Integrated energy services can be divided into integrated energy demand, energy financial investment, and energy management. This part can be directly linked to the supply and demand market of the energy system, while integrated energy services can be roughly divided into distributed energy, a combination of cooling, heating and power generation, energy storage operators, and power distribution companies. It is also related to the supply and demand market of the energy system. The roles and trading behavior patterns of different market players will be introduced below:

2.2.1 main role of IEM

Users of integrated energy services are users in multi-agent transactions. Due to the consumption needs of integrated energy such as cold and hot electricity, the needs of investment in energy projects and financial services, the needs of users' own energy system management and other energy services, users enter the supply and demand market of IES, and their needs are in line with their needs, beautiful and cheap service objects[4].

The supply and demand market of the IES is the maker and maintainer of the rules of the multi-agent trading market, and undertakes a variety of tasks, including the qualification verification of users, service providers and other different entities entering the market to carry out transactions, the real-time release of energy trading information of market entities through the trading platform center, and the review and supervision of transactions reached between users and integrated energy service providers, And be responsible for the centralized trading of the market and publishing the results of the trading stage[6].

Integrated energy service providers are service providers with different energy service capabilities, including distributed energy suppliers, cold and thermal power suppliers, energy storage operators, power distribution companies, etc. The services of integrated energy service entities are in various forms, including basic energy sales services and energy value-added services such as energy consulting, transformation and leasing[7]. In order to obtain as many benefits as possible in the market, the main bodies of integrated energy services will strive for as much market share as possible through market competition.

Based on the business needs of integrated energy service entities and the service needs of integrated energy users, the trading objects, trading methods and the formation mechanism of trading prices of the multi-agent trading mode of the IES can be preliminarily designed[8].

2.2.2 trading behavior mode of IEM

The main objects of the multi-agent transaction of the IES are the comprehensive energy demand users and the comprehensive energy service subjects. On the one hand, users and service subjects use their own energy supply and demand to conduct various energy service transactions in the market to meet their respective needs; On the other hand, in order to ensure the survival and development of enterprises and expand their own service potential, there are also cooperative transactions of different categories of energy commodities between the subjects of integrated energy services, so as to form a diversified combination of energy operations and services, and improve the market competitiveness of the subjects of integrated energy services.

The trading mode of the IES should adopt a variety of market-oriented trading modes. For a long time, China's power, oil, coal, natural gas and other energy products are mainly planned transactions. In the IES, in order to maximize the role of IES coupling and coordinate heterogeneous energy coupling, we should use market conditions such as price and incentive mechanism, through multi-dimensional market-oriented trading methods such as day trading, day ahead trading, real-time trading, etc, While ensuring the stability of energy supply and demand, we should flexibly adjust the space-time scale of integrated energy trading, so as to provide trading method support for the OO of IES and the improvement of regional energy utilization[11].

The transaction price mechanism of the IES should ensure that it can meet the security, stability, economy and cleaning needs of energy supply and demand. At present, the price mechanism of energy trading in China can be divided into two types, namely, real-time price and planned price[12]. Among them, the formation of real-time prices can be formed in real time according to the trading conditions before and during the market day; The planned price is calculated by the energy enterprise according to the marginal cost and profit of its own energy production. The role of the two different price mechanisms should be to reflect the promotion of the reliability and efficiency of energy supply through prices.

3 OPTIMIZATION DECISION OF COMPREHENSIVE ENERGY MARKET TRANSACTION BASED ON GA

This paper uses the improved GA based on circular chain structure to improve the convergence effect of the optimization algorithm and improve the optimization accuracy of multi-agent operation of the IES. The specific operation steps of GA based on chain loop structure are as follows:

Calculating the fitness value can be regarded as the interface between GA and optimization problem, that is, through the setting of optimization objective function, evaluate the adaptability of different individuals to the optimized environment, so as to determine the direction of individual evolution; choice. The process of directional self replication of population individuals based on their fitness value is called the selection process of GA. In the process of individual self replication, individuals with high adaptability to optimize the environment are easier to survive and inherit their excellent characteristics to the next generation of individuals.

If the fitness of the current individual is less than the maximum fitness value of the neighborhood, the individual stops copying and exits the survival competition of the individual. Assuming that the current individual is located at the grid point (1, I) and there are n competitive individuals in the field, the competitive selection formula between these individuals is shown in formula (1):

$$E_{i+1} = \begin{cases} M_{\max,j} + \gamma(-1)^{\beta}(M_{\max,j} - E_i), if, U(0,1) < p_0 \\ M_{\max,j}, else \end{cases} \tag{1}$$

Crossover. Crossover is the process of exchanging the genetic characteristics of individuals with good fitness and further optimizing to generate better crossover progenies. Compared with the general random crossover operator, the typical individuals evenly distributed in the search space can be identified by using orthogonal crossover. The process of orthogonal crossover operator is as follows: first, determine two parent individuals who need offspring; Secondly, a multifactor orthogonal test was carried out on two individuals; Finally, the individuals with the highest adaptability among the three individuals obtained from the orthogonal results are selected as the optimization offspring.

Variation. Mutation is the process of changing the crossover optimization individual within a limited range to solve the improved state of the individual. It is the process of adding Gaussian disturbance to the individual in the relative definition domain to realize the mutation in a small range. The process of compiling the new variant is shown in formula (2):

$$ns_{h+1} = \begin{cases} r_{i,h+1}, if, U(0,1) < p_0 \\ r_{i,h+1} + G_{gz}, else \end{cases} \tag{2}$$

Where p1/n is the probability of variation (its value is equal to 1/n); GGZ represents the random number generated by Gaussian distribution (its value is between 0 and 1/t); T - the current cycle iteration number of mutation.

Finally, termination conditions. When the fitness function value of the optimal individual in the population meets the set limit, or the fitness function value of the optimal individual and the whole population does not change, or the number of iterations has reached the set upper limit, the operation is terminated and the final optimization result is output. The entire optimization process of the genetic algorithm is shown in Figure 2：

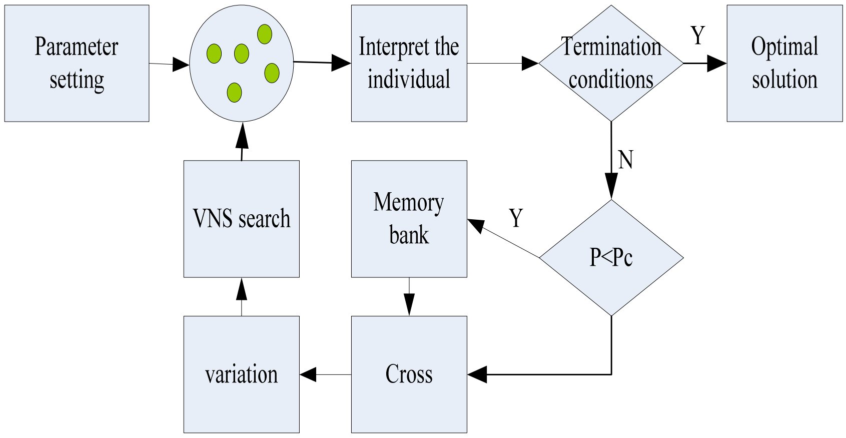

Figure 2. Genetic algorithm structure

4 SIMULATION ANALYSIS OF TRANSACTION OPTIMIZATION IN IEM

In order to verify the effectiveness of the comprehensive energy market transaction optimization decision-making based on GA proposed in this paper, this part combines the actual data to simulate the OO model. This part refers to the historical data of time of use electricity price, natural gas price and energy supply and demand in the region, and carries out the simulation calculation of OO. The simulated IES includes not only renewable energy, but also energy conversion equipment, heating network and power grid. See Table 1 for the capacity of each dispatching unit.

Table 1. Operating parameters of comprehensive energy equipment

Equipment type	name	Equipment capacity	Unit marginal cost
Energy supply equipment	Distributed photovoltaic	200KW	0.9 yuan / kWh
	CCHP	150KW	2.6 yuan / kWh
Energy storage equipment	Energy storage battery	225KW	0.75 yuan / kWh

This paper considers the interest demands of different stakeholders, takes the relative proximity of the investment proportion of the operating entities participating in the coordination in the system as a reference, and determines the final OO scheme in the Pareto optimal solution set. According to the operation results, the daily operation cost of the GA optimization decision scenario (hereinafter referred to as scenario 1) is reduced by 47.87 yuan compared with the traditional decision scenario (hereinafter referred to as scenario 2), 3.05% of the total operating cost of scenario 2; In terms of clean energy utilization, scenario 1 increased by 0.3 percentage points compared with scenario 2, with a growth rate of 1.02%. The 22 hour objective function data change of the coordinated operation scheme is shown in Figure 3.

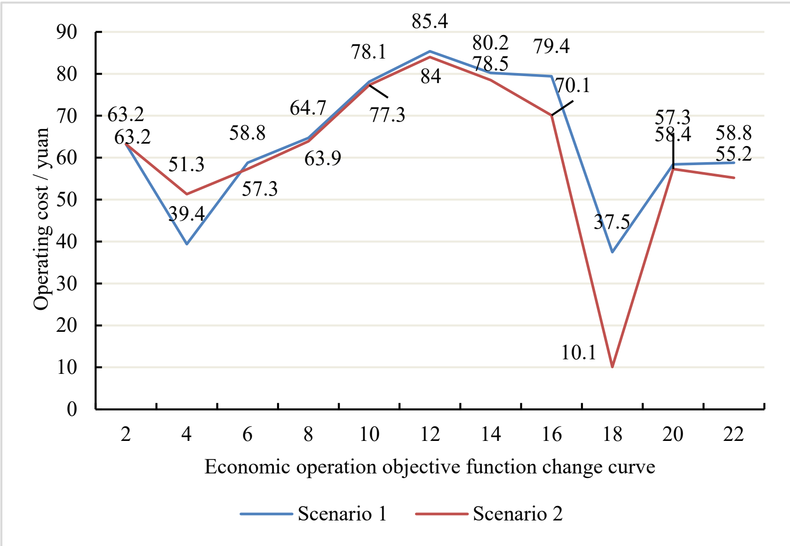

Figure 3. Economic operation objective function change curve

As can be seen from the above figure, scenario 1 based on GA is superior to scenario 2 based on traditional coordinated operation in terms of economy and clean energy utilization. In the IES, the coordinated and optimized operation of distribution network, distributed photovoltaic and CCHP has improved the comprehensive benefits of system operation. Among them, distributed photovoltaic has good environmental benefits and plays an important role in improving the utilization rate of regional clean energy. Supported by the coordinated operation of multi energy grid connection, distributed photovoltaic as a random power source, its power output has been used to the greatest extent. The distribution network uses the market mechanism of energy storage batteries to respond to the time-of-use electricity price to stabilize the random output fluctuation of distributed generation while ensuring the economy of system operation. As the supplier of cooling, heating and electricity in the system, CCHP measures and compares the fluctuation of gas price and time of use electricity price. At the same time, it changes the output ratio of electric heating load by adjusting the electric heating ratio, optimizes the operation cost of the system, and reduces the use of coal power.

5 CONCLUSIONS

From the perspective of the interests and social benefits of the operating subjects in the operation of the IES, this paper establishes the OO model of the integrated energy trading market with the optimal economy and social environmental benefits based on GA, and carries out the simulation, and achieves good results. With the increasing openness of the electricity market, especially the rise of business-oriented integrated energy users, the electrothermal transaction between multiple entities is no longer one-way. Each subject has a variety of role relationships, and carries out two-way communication of energy and information in the process of different transactions. In view of this flexible market relationship in the future, in order to improve the economy of all parties, improve the utilization rate of renewable energy and reduce environmental pollution. The market participation of wind power needs to be considered in the future comprehensive energy market transaction optimization decision-making model, and the comprehensive energy market transaction optimization decision-making based on GA needs to be further studied.

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