Research on the Cooperation-Competition Mechanism of Microgrid and Active Power Distribution Network Based on Game Theory

Ke GU
Institute of Economic and Technology, State Grid Jilin sheng Electric Power Supply Company, 1427 Pingquan Road, Nanguan District, Changchun, 130062
The corresponding author’s e-mail address: nmglyd@163.com

Abstract. With the increasing of microgrid(MG) construction and grid integration, the importance of cooperation between microgrid and active distribution network is increasingly prominent. Based on the literature review of the power grid cooperation, the article analyzes the reasons and factors of cooperation between them. A general model of interactive game between MG and active distribution network is constructed to study their revenue problem, discuss the conditions for bilateral cooperation-competition between them, and explores the specific mechanism on both sides. The results show that the conditions of cooperation between the two parties need to meet the benefits of the distribution network greater than the MG; The external cost of cooperation between the two parties is positively related to the level of effort for cooperation between the two sides, and is also positively related to the degree of their cooperation; While the assets of the two parties remain in a fixed proportion, and there is a substitution effect between the externality and their own assets.

1. Introduction
A small distribution system is called a microgrid(MG), based on the existence of distributed power supply, combined with energy storage, energy conversion, load, monitoring and protection. The network is an autonomous system capable of self-control, protection and management. The power grid can be used flexibly and efficiently to solve a large number of distributed power supply and network problems. With the emergence of MGs, the main operating targets of the power market have changed a lot. The traditional electricity market includes power generation, transmission, distribution, and users, and it is unidirectional transmission. Each agent in different nodes cooperates with each other; In the case of distributed power sources and MGs, the agent of the power market has increased. As a small distribution network, MG not only makes up for the excessive investment and unreasonable allocation of resources in active distribution network, but also forms a competitive relationship with active distribution network. So it is particularly important to study the competition and cooperation mechanism between them. In 2013, the National Standard for Debugging and Acceptance of MG Access Distribution System, led by the Chinese Academy of Electrical Sciences, was held in Guangzhou, marking the start of the standardization of MG construction at the national level.

At present, breakthroughs have been made in the construction of grid-connected demonstration projects for MGs and active distribution networks that have been widely carried out at home and abroad. The United States has built more than 200 projects for MG demonstration at the University of Wisconsin, Sandia National Laboratory, Lawrence Berkeley National Laboratory, Pearl Harbor-Siken
Joint Basement. Typical European MGs include the Bornholm Island MG Demonstration Project in Denmark, the Zutphen Resort MG Demonstration Project in the Netherlands, and the Mannheim MG Demonstration Project in Germany. These projects mainly verify the switching mechanism between MG access to active distribution network and island operation, and demand side management problem of MG is solved[1]. In addition, Japan, Canada, Australia and other countries are also actively engaged in the construction of MG demonstration projects[2]. Chinese microgrid demonstration projects, such as the Zhangjiaikou National Scenery Storage and Depot Demonstration Project in Hebei, the Turpan New Energy City Microgrid Demonstration Project in Xinjiang, and the Distributed Power Access Wind Storage Microgrid Project in Heerhunde, Inner Mongolia, have effectively solved Power shortages in these areas. These projects reflect the economics of MG and provide a new operation mode for power transmission and distribution.

Based on the analysis of the development trend of MG joining active distribution network and the summary of the relevant research results, this paper clarifies the motivation of competition between MG and active distribution network, constructs the stackelberg game model of MG and active distribution network, and gives the cooperation conditions of MG and active distribution network and puts forward corresponding suggestions. With the gradual completion and functioning of the grid-connected demonstration project such as the microgrid joining the active distribution network, the relevant results of this research will also help to improve the cooperation theory between the microgrid and the active distribution grid and guide the practice, thus this research provides some reference for decision makers.

2. Literature review

At present, a lot of literature has been studied on the microgrid, focusing mainly on the structure of the MG and the optimization of its economic operation. But in recent years, more and more scholars began to pay attention to the operation mechanism of microgrid power market. In addition, the microgrid has several main bodies, and the interaction between different subjects can be studied by multi-agent theory and game theory. This paper only reviews the literature of using these two methods.

With the development of distributed generation and Microgrid technology, MG has gradually integrated into the distribution network and formed a situation of coexistence of MG and distribution network[3]. So the MG and active power distribution lines together to form a MG-active power distribution network system in the area of the active power distribution network [4]. In this system, the existence of electricity transactions between mgs will affect the mode of operation management in the region. If electricity is traded between mgs, direct transactions between mgs and active distribution networks will be reduced, and the content of distribution network scheduling management may be changed. If there is no electricity transaction between the power grids, the mgs can be considered as relatively independent subjects, and they need to seek active distribution to complete power dispatch and operation management. Lu studied the related concept and basic structure of microgrid early [5].Some problems related to the power system of mg and active distribution network were studied systematically[6]. Huang et al. established a two-stage game model including active distribution network and virtual micro network, by which the mechanism of active distribution network’s decision-making operation of each main body had been given, and the option of different stage was obtained through bidding transaction[7].Liu et al. studied the distribution side market trading and bidding mechanism under the participation of a number of MG operators and used the double-layer optimization method and dynamic game mechanism design to determine the distribution of the interests of the main market.[8]. Pan analyzed the reasons for cooperation between the MG and the large power grid, and the policy proposal of the MG was put forward in the aspects of the active distribution network[9].Wang et al. analyzed the influence of distributed power generation and MG technology on active distribution grid from the perspective of distributed power supply.

Nash's cooperative game tool is a very effective way to study multi-subject cooperative games [10].Lu summed up the application of game theory in power system, and points out the equilibrium solution of game theory in renewable energy power generation, MG, demand response and grid
evolution[11]. Kasbekar et al. set up a price competition model between multiple mgs and examine the Nash equilibrium of competition among three mgs. More surplus mgs can gain a more favorable position in the competition, and their selling price will be higher while their profitability will be stronger[12]. Saad et al. considered the electricity trade between mgs and divide mgs into two alliances: the seller (supplier) and the buyer (demand). They obtained both sides the minimum network loss as the goal of electricity exchange optimization solution by using cooperative game model, furthermore, the reasonable profit sharing mechanism of the two sides was analyzed by computer simulation[13].

The above research mainly focused on MG and distribution network from the perspective of technology and cooperation. From a technical perspective, the corresponding solutions are put forward mainly around the technical feasibility of MG, energy system management strategy, cost composition and optimization scheme. From the point of cooperation, these authors mainly focused on the bidding game between multi-agent theory of mgs, dynamic cooperation between MG and active distribution grid and profit allocation mechanism.

It can be seen that the combination of mgs and large power grids is a trend in the development of power systems, and the related practice of various types of connected projects is also increasing. However, few studies have addressed the competition and cooperation of electric power system composed of MG and active distribution network. In particular, the implementation of MG’s construction will help us to break the monopoly of the traditional active distribution network in price and market access, and improve the reliability and flexibility of electricity use in the region. In view of these, the focus of this paper is going to analyze the drivers of cooperation between MG and active distribution network, and explore the key preconditions for cooperation between them. This paper analyzes the impact of the competition between construction of MG and distribution grid on the income of relevant participants, and analyzes its externalities and its unique economic significance.

3. Cooperation model of between MG and active distribution network

In this paper, based on the research of microgrid and active distribution network, we consider how competition and cooperation between MG and active distribution network influence the profits of two parties. That is, MG and active distribution network are the participants in the cooperation, and active distribution network (such as State Grid) has a typical strong position because it is developing the power standards, market access for electricity, trading rules and other aspects; The MG plays the role of power solution provider, which mainly provides various kinds of technology or power services to the active distribution network, and plays a subordinate role in cooperation. Its decision-making depends on the decision-making of the active distribution network. We study the interaction of two players (a private investor in a MG and an active distribution network) in the framework of cooperative game theory. They make decisions to pursue an objective that in our analysis is quantified in monetary terms(e.g., profit maximization). Two parties determine their decision variables respectively(active distribution network’s decision cooperation participation $d$ and asset investment $I_1$, MG’s decision variables for the degree of effort $s$ and asset investment $I_2$). This paper adopts the cooperative income equation commonly used in the economic cooperation game[14]. It is defined as follows:

$$V(s, I_1, I_2) = a - s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2}$$

(1)

While $\rho_1(a - s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2})$ and $\rho_2(a - s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2})$ are their profits in cooperation. Where $\rho_1$ and $\rho_2$ are their respective marginal revenue.

According to the cooperation theory, the two sides can benefit from externalities in the process of cooperation, such as MG and enterprises of power supply chain where active distribution network is located. The addition of MG reduces the monopoly level of active distribution network to a certain extent, which is caused by the competition between MG and active distribution network. Compared
with the past, when the agent of MG joins the power competition, it will force active distribution network to make certain concessions in the power market competition, such as relaxing the price control of the power market, reducing the market access standards, improving the service level and so on. Through introducing the competition mechanism into the power market, MG enterprises can gain more benefits through market competition mechanism than before, and improve their bargaining ability to a certain extent. With the increasing of market competition, the price of electricity purchasing by the end-users will inevitably decrease. At the same time, the use of clean energy in the MG is more frequent, which partly replaces the traditional high energy consumption. The high pollution of electricity by fire has raised the carbon emission reduction level of the whole society, increased social welfare, and brought about an increase in the external benefits of both sides. Therefore, both MG and active distribution network can obtain external benefits from the competition and cooperation of both sides, while there will be external costs. The total profits of active distribution enterprise and MG enterprise is:

\[ R_i = \rho_i (1 + \nu_i) (a - s^{-\beta} I_1^{-\alpha_i} I_2^{-\alpha_i}) \]  \hspace{1cm} (2)

\[ R_2 = \rho_2 (1 + \nu_2) (a - s^{-\beta} I_1^{-\alpha_i} I_2^{-\alpha_i}) \]  \hspace{1cm} (3)

The total cost of active distribution network enterprise and MG enterprise in cooperation is:

\[ C_i = ds + \lambda_i I_i \]  \hspace{1cm} (4)

\[ C_2 = s(1 - d) + \lambda_2 I_2 \]  \hspace{1cm} (5)

The related symbols and their meanings covered in this paper are shown in Table 1.

| Variable | Meaning |
|----------|---------|
| \( i \)  | \( i=1,2 \)represent active distribution network enterprise and MG enterprise respectively |
| \( d \)  | The level of cooperative participation in active distribution network \( 0 \leq d \leq 1 \) |
| \( \rho_i \) | Marginal benefit of unit cooperation results transferred from enterprise \( i \) to its own revenue |
| \( \lambda_i \) | Private assets caused by the externality of enterprise \( i \) |
| \( C_i \)  | The total cost of enterprise \( i \) |
| \( \alpha_i \) | The investment elasticity of enterprise \( i \) cooperative income to assets |
| \( a \)  | Potential maximum benefit from cooperation between two parties |
| \( s \)  | Cooperation effort of MG |
| \( I_i \)  | Asset input of enterprise \( i \) |
| \( \nu_i \)  | The proportion of corporate external revenue relative to total revenue |
| \( R_i \)  | Total revenue of enterprise \( i \) |
| \( \beta \)  | Investment elasticity of income to cooperative effort |
| \( \pi_i \)  | The total profits of the enterprise \( i \) |
| \( \pi_{co} \)  | Total profits of the two parties |
4. Model establishment and solution analysis

4.1. Profit in the cooperation between the active distribution network and the MG

According to the profit of (2)-(3) and cost of (4)-(5), the profits of distribution network and MG enterprise is respectively

\[ \pi_1 = \rho_1 (1 + v_1)(a - s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2}) - (ds + \hat{\lambda}_1I_1) \]

\[ \pi_2 = \rho_2 (1 + v_2)(a - s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2}) - [s(1-d) + \hat{\lambda}_2I_2] \]

The total profits after cooperation between the two parties is

\[ \pi_{co} = \rho_1 (1 + v_1)(a - s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2}) - (s + \hat{\lambda}_1I_1 + \hat{\lambda}_2I_2) \]

In order to simplify expressions, we replace variables with complex expressions.

\[ \phi = \rho_1 (1 + v_1), \quad \varphi = \rho_2 (1 + v_2), \quad \theta = 1 + \beta + \alpha_2. \]

4.2. Distribution network and MG enterprise leading-follow game relationship analysis

In the dominant relationship of active distribution network, the game structure of two sides is stackelberg game dominated by the active distribution network. As a follower, MG should make its own decision on the basis of the decision of the active distribution network. In the case of decentralized decision-making, the goal of each member maximize its own profit regardless of the decisions of other members. Therefore, MG company determines the overall level of effort \( s \) and asset input \( I_2 \), while active distribution network determines the degree of cooperation participation \( d \) and the amount of assets investment \( I_1 \).

In the decentralized decision-making, active distribution network active distribution network plays as leader in the respective supply chains, and decides \( d \) and \( I_1 \), then MG decides its own variables based on active distribution network decision and obtains the biggest profit. Therefore, proposition 1 can be obtained.

**Proposition 1.** In cooperation pattern which is dominated by the active power distribution network, participation in active distribution networks, asset-to-investment ratios of both parties and the optimal level of MG cooperation effort are respectively:

\[ d = \frac{\phi - \theta \varphi}{\phi - \beta \varphi}, \quad I_1^* = \frac{\lambda_2 \alpha_1 (\phi - \beta \varphi)}{\lambda_1}, \quad I_2^* = \frac{\lambda_2 \alpha_2 (1 + \alpha_2) \varphi}{\lambda_1} \]

and

\[ s = \left[ \frac{1 + \alpha_2}{\beta (\phi - \beta \varphi)} \right]^{\alpha_2} \cdot \left( \frac{\lambda_2}{\alpha_2 \varphi} \right)^{\alpha_2} \cdot \left( \frac{\beta \lambda_2}{\alpha_2} \right)^{-\alpha_2} \cdot \left[ \frac{1}{(\theta + \alpha_1)} \right]. \]

Proof. In the decision-making process, active distribution network and MG determine the amount of cooperative effort and asset investment in the current period. The active distribution network first determines the amount of self-owned assets and the degree of participation, and then the MG determines the amount of assets invested and the total degree of cooperation effort.

Under the stackelberg game with active distribution network leadership, we use the inverse solution method to solve the decision variables of the MG through the optimization method.

Using MG company's profit which is given by formula (7) for partial guidance of the level of cooperative efforts and the amount of assets invested by MG, the optimal total cooperative effort level and the amount of assets invested can be obtained from the following equations:

\[ \frac{\partial \pi_2}{\partial s} = \beta \varphi s^{-\beta - 1}I_1^{-\alpha_1}I_2^{-\alpha_2} - (1-d) = 0 \]

\[ \frac{\partial \pi_2}{\partial I_2} = \alpha_2 \varphi s^{-\beta}I_1^{-\alpha_1}I_2^{-\alpha_2} - \hat{\lambda}_2 = 0 \]

By solving this equation group, it is straightforward to find that the optimal solutions for \( s \) and \( I_2 \) are


\[ s^* = \left[ \frac{1-d}{\beta \phi} \right] I_1^{\alpha_1}, \left( \frac{\alpha_2 - \alpha_3 d}{\alpha_2} \right)^{\alpha_2} \right]^{1/\theta} \tag{9} \]

\[ I_2^* = \left[ \frac{\lambda_2}{\alpha_2 \phi} \right] I_1^{\alpha_1}, \left( \frac{\beta \lambda_2}{\alpha_2 - \alpha_3 d} \right)^{\alpha_2} \right]^{1/\theta} \tag{10} \]

And the ratio of the total cooperative effort and asset input of MG is shown in the following

\[ \frac{s^*}{I_2^*} = \frac{\beta \lambda_2}{\alpha_2 (1-d)} \tag{11} \]

Substituting into (6), we have \( \max \pi_i = \phi(a - s^* \beta I_1^{\alpha_1} I_2^{\alpha_2}) - (s^* d + \lambda_1 I_1) \). Simplifying it leads to

\[
\begin{align*}
\pi_i &= \phi \left[ a - \left( \frac{1-d}{\beta \phi} \right) I_1^{\alpha_1} \left( \frac{\alpha_2 - \alpha_3 d}{\alpha_2} \right)^{\alpha_2} \right]^{\beta/\theta} \cdot I_1^{\alpha_1} \cdot \left[ \frac{\lambda_2}{\alpha_2 \phi} \right] I_1^{\alpha_1} \left( \frac{\beta \lambda_2}{\alpha_2 - \alpha_3 d} \right)^{\alpha_2} \right]^{\alpha_2/\theta} \\
&\quad - d \cdot \left[ \frac{1-d}{\beta \phi} \right] I_1^{\alpha_1} \left( \frac{\alpha_2 - \alpha_3 d}{\alpha_2} \right)^{\alpha_2} \right]^{1/\theta} - \lambda_1 I_1
\end{align*}
\]  

Using the optimization method, the optimal participation level and the asset input amount of the active distribution network are shown in the following respectively

\[
\begin{align*}
d^* &= \begin{cases} 
\frac{\phi - \theta \psi}{\beta \phi}, & \phi > \theta \psi \\
0, & \phi \leq \theta \psi 
\end{cases} \tag{13} \\
I_1^* &= \left[ \frac{\lambda_2 \alpha_1 (\phi - \beta \psi)}{\lambda_1 \alpha_2 (1 + \alpha_2) \phi} \right] \cdot \left[ \frac{\beta \lambda_2 (\phi - \beta \psi)}{\alpha_2 (1 + \alpha_2) \phi} \right]^{\alpha_2} \right]^{1/\theta (\theta + \alpha_1)} \tag{14} \\
\end{align*}
\]

Furthermore, the MG’s decision variables are given below

\[
\begin{align*}
I_2^* &= \left[ \frac{\lambda_2 \alpha_1 (\phi - \beta \psi)}{\alpha_2 \phi} \right] \cdot \left[ \frac{\beta \lambda_2 (\phi - \beta \psi)}{\alpha_2 (1 + \alpha_2) \phi} \right]^{\alpha_2} \right]^{1/\theta \alpha_2} \tag{15} \\
\end{align*}
\]

Thus we can have

\[
\begin{align*}
\frac{I_1^*}{I_2^*} &= \frac{\alpha_2 \phi}{\lambda_1 \alpha_2 (1 + \alpha_2) \phi} \tag{17} \\
\end{align*}
\]

Substituting \( d^*, s^*, I_1^*, I_2^* \) into (6)-(8), the profits from MG, active distribution network and the total profit are shown below

\[
\begin{align*}
\pi_i^* &= a \phi - \frac{\lambda_1 (\theta + \alpha_2) (\phi - \beta \psi)}{\alpha_2 (1 + \alpha_2) \phi} - \lambda_2 \cdot \frac{\beta \lambda_2 (\phi - \beta \psi)}{\alpha_2 (1 + \alpha_2) \phi} \right]^{\alpha_2} \right]^{1/\theta (\theta + \alpha_1)} \\
\pi_2^* &= a \phi - \frac{\lambda_2 \theta}{\alpha_2} \cdot \left[ \frac{\lambda_2 \alpha_1 (\phi - \beta \psi)}{\lambda_1 \alpha_2 (1 + \alpha_2) \phi} \right]^{\alpha_2} \right]^{1/\theta \alpha_2} \tag{18} \\
\end{align*}
\]
4.3. Analysis of cooperative game results

By proving the proposition 1 process and combining the definition of the enterprise's marginal revenue, the basic preconditions for cooperation between the active distribution network and the microgrid enterprises can be obtained. With the above results, we can derive proposition 2.

**Proposition 2** Only when the marginal revenue of the active distribution network enterprise in the cooperative process is larger than the marginal benefit of the microgrid enterprise in the inferior position and meets \( \phi \theta > \), their cooperation can be truly realized.

In the competition and cooperation between MG and active distribution network, active distribution network is a channel leader, the MG acts as a follower, and the active distribution network has a dominant position in the market. It has a high voice in terms of standard setting, service level and market access, so it is in a dominant position in cooperation. One of the most important reasons is that the active distribution network has invested a large amount of assets in the early stage, thus it formed a relatively high dominance position in the power system. According to the theory of competition and transaction cost: co-opetition reduces the external transaction costs and internal organization costs of enterprises. Through cooperative contracts, companies establish stable trading relationships and reduce higher transaction costs due to market uncertainty and frequent transactions. At the same time, due to the exchange of information between the cooperative enterprises and the realization of communication, the problem of incomplete information is alleviated and the information costs are reduced. The sharing of information among cooperative companies also helps to reduce internal management costs and improve organizational efficiency. When the asset allocation of an active distribution network enterprise is high, it will pose a threat to related competitors such as microgrid enterprises through its own asset investment advantages, such as withdrawing investment, terminating cooperation, etc. Therefore, in order to promote mutual cooperation, active distribution network company will require more revenue, that is, the ratio of the active distribution network in a dominant position relative to the MG enterprise in a disadvantaged position is large enough. There are enough incentives to invest more of their own assets and to promote cooperation between the two parties so as to achieve a win-win situation.

**Proposition 3** The total cooperative effort \( s^* \) and the respective efforts \( d^* s^* \) of the active distribution grid and \( s^* (1 - d^*) \) of the MG are positively related to the marginal unit losses \( \lambda_1 \) and \( \lambda_2 \) of both parties' own asset inputs, That is to say, no matter how the active distribution network participates in the cooperation between two parties, as the marginal loss of asset investment increases, the cooperation effort of both parties will increase.

Proof: Examining (14), we can conclude that all the parameters are positively related to \( \phi \theta > \),
\[
\frac{\partial s^*}{\partial \lambda_1} > 0 \text{ and } \frac{\partial s^*}{\partial \lambda_2} > 0 .
\] In addition, \( d^* \) is not related to \( \lambda_1 \) and \( \lambda_2 \). Therefore, \( d^* s^* \) and \( s^* (1 - d^*) \) of two parties are positively correlated with \( \lambda_1 \) and \( \lambda_2 \), so that proposition 3 is obtained.

After the MG joins active distribution network, it breaks the traditional active distribution network's price and market access control, and enhanced the degree of marketization of electricity. At the same time, owing to the competition of MG, the monopoly of active distribution network is declining, which makes the allocation of power resources more reasonable and improves the efficiency of power market. When price control and market access are broken, the bargaining power of MG-
related company relatives to active distribution networks is increasing, which is the positive externalities brought about by the addition of MG. As the status of active distribution network in the power market continues to decline, in order to ensure that its own revenue does not deteriorate, active distribution network will naturally participate in cooperation, which will help reduce transaction costs and increase social welfare.

**Proposition 4** Both partners maintain a fixed amount of investment in their own assets. When the externality is greater, the investment of own assets will decrease. However, if the externalities are smaller, the investment in own assets will increase. That is, there is a substitution effect between the externality and the private assets.

Proof: By (16) and (17):

\[
\frac{s^*d^*}{I_1^*} = \frac{\lambda_1 \alpha_2 (1 + \alpha_2) \varphi d^*}{\alpha_1 \lambda_2 (\phi - \beta \varphi)} \cdot \frac{s^*}{I_2^*},
\]

then by (11), we get:

\[
\frac{s^*d^*}{I_1^*} = \frac{\lambda_1 \alpha_2 (1 + \alpha_2) \varphi d^*}{\alpha_1 \lambda_2 (\phi - \beta \varphi)} = \frac{\beta \lambda_1 (1 + \alpha_2) \varphi d^*}{\alpha_1 (\phi - \beta \varphi)(1 - d^*)}.
\]

(18)

By (13), \(\frac{d^*}{1 - d^*}\) is unique and is given by

\[
\frac{d^*}{1 - d^*} = \frac{\phi - \theta \varphi}{(1 + \alpha_2) \varphi}
\]

(19)

We note that by (18) and (19), \(\frac{s^*d^*}{I_1^*}\) is positively related to the externality. For the dominant active distribution network enterprise, \(s^*d^* / I_1^*\) and \(\lambda_1\) are positively related, and \(s^*(1 - d^*) / I_2^*\) and \(\lambda_2\) are positively related to the disadvantaged MG enterprise. Therefore, we get proposition 4.

Most of the traditional active distribution networks use fossil fuels such as coal to generate electricity, which has caused huge energy consumption and pressure on resources. This type of power generation is increasingly inconsistent with China's energy use policy.

In the cooperation between microgrids and active distribution networks, active distribution networks pay more attention to how their own power quality and operational reliability are based on reducing costs and achieving clean energy standards, while MG is precisely the use of clean energy and can achieve the problem of power supply in the active distribution network. Its own power supply is still effective, so two sides can achieve a more reasonable allocation of resources over a wider range. Because of this, the competition between MG and active distribution network can generate positive externalities. By effective integration and rational allocation of clean energy, fossil energy and other power resources, the increase of overall income can be achieved while ensuring the satisfaction of power demand. Through the optimization of energy allocation, it meets the requirements of the current "energy saving and emission reduction" new normal, reduces carbon emissions, reduces the cost of environmental governance, and increases the society welfare. Therefore, whether it is from the perspective of enterprises or governments, it is necessary to continuously strengthen the construction of MG, strive to improve the technology of MG into large power grid, and promote the perfection of the competition mechanism between the parties, which will have a positive impact on the future power and the whole society.

5. Conclusion

The MG is a single controllable unit, which combines micro-power, load, energy storage system and control devices with advanced power electronics technology. At the same time, it supplies electricity and heat to the users. The MG can be connected with an active distribution network, and can also be disconnected from the main network in case of power grid failure or need. The research shows that the MG is an effective way for large-scale access of distributed power to active distribution network. MG
gives full play to the advantages of distributed power, and improves the overall efficiency and flexibility of the system. This paper focuses on the analysis of the competing relationship between MG and an active distribution network. The Stackelberg game is used to study the power system composed of active distribution network-MG. It is found that the active distribution network in the dominant position needs to gain more revenue to encourage the cooperation with MG enterprise. At the same time, it is found that when there are benefits and costs of cooperation externalities, externalities are positively correlated with the degree of enterprise cooperation efforts, and externalities have substitution effects with the enterprise's asset investment, so the cooperation between the two sides can obtain greater benefits.

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