Analysis of optimal allocation of nuclear power based on newsboy model

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Abstract. With the increasing role of nuclear power in energy allocation, the problem of energy waste is very serious. This paper first considers the economic compensation between the government and the nuclear power generation enterprises, the repurchase of redundant power and other policy support methods, and constructs the newsboy model, which provides a reference for the rational generation of nuclear power enterprises. The research shows that the higher the production cost per unit of nuclear power, the smaller the optimal generation capacity of nuclear power enterprises will be. The greater the probability that the power produced by nuclear power enterprises is not in surplus, the smaller the optimal power generation of nuclear power enterprises will be. The more fines are imposed on nuclear power enterprises under the unit power shortage, the greater the optimal power generation of nuclear power enterprises will be. The higher the government's purchase price for excess power, the greater the optimal power generation of enterprises will be.

1. Introduction

Economic and social development is closely related to energy, which is not only indispensable to human life, but also indispensable to production and management activities. Nuclear energy is a relatively clean energy, which will not produce waste gas pollution and, if properly handled, will produce less nuclear waste pollution [1]. Moreover, nuclear energy can significantly reduce the cost of clean energy, enabling enterprises and residents to make use of clean energy with lower cost [2]. Despite the chernobyl and fukushima nuclear leakage events in history, nuclear energy is a cheap, reliable and clean safe energy compared to clean energy such as wind, solar and hydropower [3].

With the continuous development of nuclear power, nuclear power enterprises provide more and more power. However, nuclear power enterprises are often established in coastal areas, which are often far away from urban centers or industrial parks where electricity consumption is high. In the absence of a powerful power transmission and distribution network, it is easy for nuclear power enterprises to fail to generate electricity in line with electricity consumption.

Newsboy model was first proposed in 1956 and is widely used to solve a variety of economic and social problems. For example, the order problem between retailers and customers, the inventory problem in the supply chain, capacity utilization and other problems. At present, it has not been found that scholars use the newsboy model to study the adequacy of power generation in nuclear power enterprises.

This paper first considers the economic compensation between the government and the nuclear power generation enterprises, the repurchase of redundant power and other policy support methods, and constructs the newsboy model, which provides a reference for the rational generation of nuclear power enterprises.
2. Problem description and variable definition
There is only one power generation enterprise in a region (in this paper, this power generation enterprise is a nuclear power enterprise), and no other enterprises compete with it. Due to the characteristics of power generation, nuclear power enterprises cannot control power generation as flexibly as coal and natural gas. Nuclear power companies tend to generate surpluses or deficits. In this paper, it is assumed that the price of nuclear power is determined by the amount of electricity produced, rather than the demand for electricity by households and businesses.

When the government supports nuclear power enterprises through policies, the government can either subsidize nuclear power enterprises to a certain extent or purchase the redundant power generation capacity of nuclear power enterprises at a lower price. However, in this situation, a government can also impose fines on nuclear power companies, that is, according to the gap between supply and demand of nuclear power.

In this paper, the power generation of nuclear power enterprises is the control variable. The main variables and parameters in this paper are shown in Table 1:

| Main variable and parameter definitions | Specific meaning                                                                 |
|----------------------------------------|----------------------------------------------------------------------------------|
| V                                      | The benefits to nuclear power companies                                          |
| p                                      | The probability of excess power produced by nuclear power enterprises             |
| D                                      | Society's demand for electricity                                                 |
| Q                                      | The generating capacity of nuclear power plants                                  |
| c                                      | Production costs per unit of nuclear power                                       |
| p                                      | Price per unit of water                                                          |
| G                                      | Penalty on nuclear power enterprises for unit power shortage                     |
| α                                      | Fixed compensation for nuclear power enterprises under the condition of excess power |
| β                                      | The government's purchase price for excess power                                 |

3. Newsboy model without electricity policy support
Many countries do not attach importance to the supply of electricity. The state does not subsidize nuclear power enterprises, nor will it purchase the power produced by nuclear power enterprises at a certain price. Accordingly, it will not impose fines on nuclear power enterprises with insufficient power supply. The power generation of nuclear power enterprises shall be operated in a market-oriented mode. Since it is assumed above that the price of electricity is determined by the quantity supplied rather than the quantity demanded, this paper assumes that the price of nuclear power is $a-bq$ according to the demand function.

The benefits accrue to nuclear power companies include the income they earn from providing electricity to households and other power users, and the cost of generating power for nuclear power companies. Without power policy support, the income function of power generation enterprises can be expressed as:

$$ V(Q) = pD(a-bQ) + (1-p)Q(a-bQ) - cQ $$

In equation (1), $pD(a-bQ)$ represents the income obtained under the condition of excess power produced by nuclear power enterprises. $(1-p)Q(a-bQ)$ represents the income obtained under the condition of insufficient power produced by nuclear power enterprises. $cQ$ represents the cost of power produced by nuclear power enterprises.

The partial derivative of $Q$ can be obtained from equation (1):

$$ \frac{\partial V}{\partial Q} = pD(-b) + (1-p)[a-bQ-bQ] - c $$

(2)
Let equation (2) equal to zero, it can be concluded that:

\[ Q^* = \frac{1}{2b(1-p)} (-bpD + a - a p - c) \] (3)

Conclusion 1 (no policy support) : The higher the production cost per unit of nuclear power, the smaller the optimal power generation. The greater the probability that there is no excess power produced by nuclear power enterprises, the smaller the optimal power generation of nuclear power enterprises will be.

4. Newspaper boy model under compensation to nuclear power enterprises

In order to ensure the stable power supply of nuclear power enterprises, the government provides certain subsidies to nuclear power enterprises (only when the power generation capacity of nuclear power enterprises exceeds the demand of residents and enterprises, nuclear power enterprises can enjoy this subsidy). However, if the power generation capacity of nuclear power companies is less than the demand of residents and enterprises, then the government will impose fines on the power generation companies according to the gap between supply and demand.

The benefits to nuclear power companies include the income they earn from providing electricity to residents and other power users, the cost of generating power for nuclear power companies, government subsidies for nuclear power companies, and government fines for nuclear power companies that do not generate enough electricity. Under the condition of compensation for nuclear power enterprises, the expression of the return function of nuclear power enterprises is as follows:

\[ V(Q) = pD(a-bQ) + (1-p)Q(a - bQ) - cQ + p\alpha - (1-p)(D-Q)G \] (4)

The partial derivative of Q can be obtained from equation (4):

\[ \frac{\partial V}{\partial Q} = pD(-b) + (1-p)[a-bQ-bQ] - c - (1-p)G(-1) \] (5)

Let equation (5) equal to zero, it can be concluded that:

\[ \bar{Q}^* = \frac{1}{2b(1-p)} (-bpD + a - ap - c + G - Gp) \] (6)

Conclusion 2 (compensation for nuclear power enterprises) : The higher the production cost per unit of nuclear power, the smaller the optimal power generation. The greater the probability that there is no excess power produced by nuclear power enterprises, the smaller the optimal power generation of nuclear power enterprises will be. The more fines are imposed on nuclear power enterprises under the unit power shortage, the greater the optimal generation capacity of nuclear power enterprises will be.

5. The government buys back the newsboy model under the excess power of nuclear power enterprises

To ensure that nuclear-power companies lose more power than they need, the government buys the extra power they produce at a price. However, the purchase price for excess power is generally less than the cost of generating power for nuclear companies.

The benefits to nuclear power companies include the income generated by nuclear power companies from providing electricity to residents and other power users, the cost of generating power for nuclear power companies, the amount of excess power the government buys from nuclear power companies, and the fines the government imposes on nuclear power companies that do not generate enough power. Under the condition that the government buys back the excess power of nuclear power enterprises, the expression of the return function of nuclear power enterprises is as follows:

\[ \hat{V}(Q) = pD(a-bQ) + (1-p)Q(a - bQ) - cQ + p(Q-D)\beta - (1-p)(D-Q)G \] (7)

The partial derivative of Q can be obtained from equation (7):
\[
\frac{\partial \hat{V}}{\partial Q} = pD(-b) + (1-p)[a-bQ-bQ]-c + p\beta - (1-p)G(-1)
\]  \hspace{1cm} (8)

Let equation (8) equal to zero, it can be concluded that:

\[
\hat{Q}^* = \frac{1}{2b(1-p)}(-bpD+a-ap-c+p\beta+G-Gp)
\]  \hspace{1cm} (9)

Conclusion 3 (government repurchase of excess power) : The higher the production cost per unit of nuclear power, the smaller the optimal power generation. The greater the probability that there is no excess power produced by nuclear power enterprises, the smaller the optimal power generation of nuclear power enterprises will be. The higher the government's purchase price for excess power, the greater the optimal power generation of enterprises will be.

6. Conclusion

In recent years, with the rapid economic development, the demand for energy is increasing, but all countries are facing the problem of energy shortage. Most scholars solve the problem of optimizing energy efficiency from the aspects of engineering and technology, but seldom use the methods of management and operational research. This paper establishes the newsboy model, and considers the economic compensation between the government and the nuclear power generation enterprises, the repurchase of redundant power and other policy support methods, thus drawing relevant conclusions.

The research shows that the higher the production cost per unit of nuclear power, the smaller the optimal power generation will be. The greater the probability that the power produced by nuclear power enterprises is not in surplus, the smaller the optimal power generation of nuclear power enterprises is. The more fines are imposed on nuclear power enterprises under the unit power shortage, the greater the optimal power generation of nuclear power enterprises will be. The higher the government's purchase price for excess power, the greater the optimal power generation of enterprises will be.

The research in this paper can also be expanded. For example, this paper only considers that there are only nuclear power generation enterprises in one region, and does not take other power generation enterprises into consideration to study relevant issues. In future studies, other types of power generation enterprises can be taken into account.

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