Research on the Coordinated and Sustainable Development of Jiangsu Power Grid under the "Double Carbon" Goal

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Abstract: Under the "double carbon" goal, renewable energy power generation will become the mainstream power generation in the future. The offshore Jiangsu Province has relatively abundant renewable resources, and it also creates favorable conditions for Jiangsu Power Grid Corporation to invest in renewable energy power generation business in the future. The new round of power system reform has had a profound impact on the determination of the investment scale of power grid companies and the optimization of the investment structure. This article first sets the future power supervision scenarios, and then measures the investment capacity and investment needs of power grid companies under different scenarios, determines the investment scale, conducts a coordinated analysis of investment capabilities and investment needs, matches investment capabilities and investment needs, and satisfies investment. Under the premise of demand, improve investment efficiency, and finally realize the coordinated and sustainable development of Jiangsu Power Grid investment.

1. Introduction

As energy consumption continues to increase, renewable energy power generation has become a major way to solve energy problems. In September 2020, the Party Central Committee proposed that China will achieve "double carbon" goal which includes "carbon peak" in 2030 and achieve "carbon neutrality" in 2060. Jiangsu Power Grid Company has relatively abundant renewable resources. Under the "double carbon" goal, the grid company will definitely increase investment in renewable energy power generation, and how to ensure the coordination and sustainable development of various grid investments in the investment process Sex has become an urgent problem to be solved. The new round power system reform brings challenges in many aspects to investment management and control of power grid enterprises, for instance, control over investment scale and implementation of investment regulation [1, 2]. The power grid enterprises are necessary to clarify investment orientation, accurately predict investment demands, master own investment ability, and gradually optimize investment structure so as to improve investment efficiency and benefits [3]. Therefore, this paper will carry out coordinated analysis on investment ability and demands of power grid enterprises under power regulation environment to clarify investment ability and investment demands of power grid enterprises, and ceaselessly optimize investment allocation and improve investment return.
2. Power regulation scenario planning

Analysis on power regulation environment shows the regulation on power grid investment is mainly reflected in electricity price regulation, which is mainly the cost control over power grid investment with high binding force; while due to the profit demands, power grid enterprises are also in the regulation environment of operating performance assessment, showing management and control of power grid enterprises for business benefits. Under different regulation scenarios, the power grid enterprises shall adopt different investment strategies. Thus, this section will analyze influence factors of power regulation environment and set different scenarios for power regulation.

2.1 Analysis on influence factors of power regulation environment

The decision making on power grid investment is driven by regulation constraints and inner demands, in which, constraints contain various regulatory restrictions such as electricity transmission and distribution price and cost supervision; the inner demands are power supply demands and operating objective assessment demands that power grid enterprises shall meet. Therefore, the external key driving factors for formulation of power grid investment strategies can be summarized as two dimensions of electricity transmission and distribution price supervision and experience performance.

In accordance with documents such as Calculation Method of Electricity Transmission and Distribution Price and Business Performance Assessment Methods for Persons in Charge of Central Enterprises, the key external driving factors affecting power regulation environment are shown in the table below.

| Key drying factor                                         | Specific index                                                                 |
|-----------------------------------------------------------|-------------------------------------------------------------------------------|
| Electricity transmission and distribution supervision      | Newly added investment in fixed assets, depreciation rate, operation and maintenance fee, line loss per unit, electric quantity growth rate, and return on equity capital, etc. |
| Business performance requirements                          | Annual net profits, and economic value added                                   |

The first driving factor is electricity transmission and distribution price supervision. The nature of electricity transmission and distribution price supervision is cost supervision. Compared to operation and maintenance fee, line loss per unit and labor costs, the annual investment in fixed assets is the main source of costs. Therefore, the electricity transmission and distribution price supervision can be specified to fixed assets investment under the electricity price objective. When the electricity transmission and distribution price for next period is given, the annual investment in fixed assets may be back-deducted according to electricity price and calculation method of the price.

The second driving factor is business performance requirements, and the main assessment indexes are net profits and economic value added, in which, profits are linked with electricity price and electric quantity. In order to maximize profits, the electricity price is expected to be in a higher level, and meanwhile the electricity transmission and distribution costs are reduced; the economic value added refers to the balance of verified after-tax business profits of enterprises less capital cost, and the calculation formula is economic value added = after-tax net business profits - capital cost = after-tax net business profits - capital adjusted * weighted average cost of capital (WACC). It is obvious that the economic value added is related to WACC. According to the calculation formula, the smaller the WACC is, the larger the economic value added will be.

2.2 Division of power regulation scenarios

Based on analysis on key driving factors and specific indexes affecting power regulation environment, the power regulation scenarios are divided.

(1) Scenario I: easy investment and low profit requirements
In this scenario, due to easy electricity transmission and distribution price supervision, the electricity price is increasing progressively 1% every period, and the investment in fixed assets in the next period is calculated according to calculating methods of electricity transmission and distribution price; since the business performance requirements are low in this scenario, the higher WACC (8%) is set.

(2) Scenario II: easy investment and high profit requirements
In this scenario, due to easy electricity transmission and distribution price supervision, the electricity price is increasing progressively 1% every period, and the investment in fixed assets in the next period is calculated according to calculating methods of electricity transmission and distribution price; since business performance requirements are high in this scenario, the lower WACC (6.5%) is set.

(3) Scenario III: limited investment and low profit requirements
In this scenario, due to tight electricity transmission and distribution price supervision, the electricity price in next period shall be equal to the level in current period, and the investment in fixed assets in the next period is calculated according to calculating methods of electricity transmission and distribution price; since business performance requirements are low in this scenario, the higher WACC (8%) is set.

(4) Scenario IV: limited investment and high profit requirements
In this scenario, due to tight electricity transmission and distribution price supervision, the electricity price in next period shall be equal to the level in current period, and the investment in fixed assets in the next period is calculated according to calculating methods of electricity transmission and distribution price; since business performance requirements are high in this scenario, the lower WACC (6.5%) is set.

3. Measurement model for investment ability of power grid enterprises under power regulation environment
This paper, from source of enterprise investment fund, divides the investment fund sources into three parts, respectively profits, depreciation and financing according to analysis of power grid investment factors. Meanwhile, with the investment fund as one part of current assets, the measurement model for power grid investment ability is developed [4, 5].

For profits, the influence of effective assets and allowed yield of power grid enterprises on profits will be considered; for depreciation, the influence of change in original value of fixed assets and comprehensive depreciation rate on depreciation will be considered; for financing, due to upper limit of debt-to-asset ratio, the structure of closing assets, closing liabilities and amount of net profits of the enterprises shall be taken into account, and the maximum financing amount shall be calculated based on the data; for current assets, the effect assets and withdrawal proportion of current assets of enterprises shall be considered, and current assets added to power grid enterprises every year shall be calculated.

Thus, the entire measurement system can be divided to four subsystems, including profits subsystem, depreciation subsystem, financing subsystem and current assets subsystem. The four subsystems affect, restrict and act on each other through variable input and output among each other, and jointly finish specific function of investment ability measurement system.

The calculation formula of investment ability is as follows:

\[ \text{IC}_i = \text{NPI}_i - \text{TP}_i + \Delta D_i + \Delta F_i - \Delta LA_i \]

In the formula, \( \text{IC}_i \) is the investment ability in the \( i \) year under electricity transmission and distribution price supervision; \( \text{NPI}_i \) is the net profits of power grid enterprises in the \( i \) year under electricity transmission and distribution price supervision; \( \text{TP}_i \) is the profits delivered of power grid enterprises in the \( i \) year; \( \Delta D_i \) is the depreciation amount in the \( i \) year electricity transmission and distribution price supervision; \( \Delta F_i \) is the newly added financing amount in the \( i \) year under electricity transmission and distribution price supervision; \( \Delta LA_i \) is the newly added current assets of enterprises in the \( i \) year under electricity transmission and distribution price supervision.
Firstly, this paper calculated prediction indexes of the four subsystems and predicted investment ability according to the model.

(1) Net profits

After electricity transmission and distribution price reform in 2017, the allowed yield can be used as net profits of power grid enterprises in current year, in which, net profits = allowed yield = effective assets which can withdraw profits × allowed yield rate; 10% of the amount is the withdrawal rate of statutory surplus reserve, i.e., profits delivered = net profits × 10%. The estimated value of net profits is calculated based on basic operating index data.

(2) Depreciation amount

The depreciation amount will be calculated according to straight line depreciation method, i.e., annual depreciation amount = {Original value of fixed assets withdrawing depreciation (1 - ratio of remaining value)}/depreciation years, in which depreciation rate = (1 - ratio of remaining value). For the convenience of model calculation, the proportion of increased fixed assets every year will be calculated according to newly added investment in various fixed assets. Based on the proportion of increased fixed assets, and in combination with depreciation rate of various fixed assets after electricity transmission and distribution price reform plan is implemented, the comprehensive pricing depreciation rate will be calculated. Through simplification, the calculation formula of depreciation amount is: depreciation amount = opening fixed assets withdrawing depreciation × comprehensive pricing depreciation rate.

(3) Maximum increased financing amount

The maximum increased financing amount, under upper limit of debt-to-assets ratio, can be calculated through predicted data of two basic operating indexes including total assets and total liabilities as well as the calculation date of net profits.

(4) Increased current assets

The increased current assets may be calculated based on the historical value of total assets and predicted value of effective assets according to certain withdrawal proportion of retained current assets.

(5) Measurement of investment ability

The investment ability can be measured according to investment ability measurement formula.

4. Measurement model for investment demands of power grid enterprises under power regulation environment

The prediction theory of grey system is to process original data based on historical data, establish grey prediction model, and seek for a method describing certain development rules of the object system. The prediction made based on grey dynamic $GM(n, h)$ model is known as grey prediction. The $GM(n, h)$ model established by grey system is the time continuous function model of differential equation. The model parameters are adjustable, and the structure varies as times goes by so as to break the restriction of common model which needs more data and is difficult to get differential performance. In the model, $n$ means the order of differential equation and $h$ is the number of variables. The grey prediction is featured in: firstly, grey prediction needs little data; secondly, the computation of grey prediction method is simple; thirdly, grey prediction does not need excessive related factors while data is easy to get; fourthly, grey prediction can be applied to near-term, short-term and medium or long term prediction. The estimate of power grid investment demand is the precondition to formulate annual investment plan, and the change of power grid investment demands has obvious rule of time. Therefore, the development trend can be predicted according to historical situations [6, 7]. This paper adopts grey prediction model to estimate power grid investment demands.

$GM(1,1)$ modeling process is as follows:

(1) Record original data sequence $X^{(0)}$ as non-negative sequence:

$$X^{(0)} = \left\{ x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(n) \right\}$$
In the formula, \( x^{(0)}(k) \geq 0, k = 1,2,\ldots,n \)

(2) The corresponding generated data sequence is \( X^{(1)} \):

\[
X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \ldots, x^{(1)}(n)\}
\]

In the formula, \( x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1,2,\ldots,n \)

(3) The proximal mean generated sequence of \( Z^{(1)} \) and \( X^{(1)} \):

\[
Z^{(1)} = \{z^{(1)}(1), z^{(1)}(2), \ldots, z^{(1)}(n)\}
\]

In the formula, \( Z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1), k = 1,2,\ldots,n \)

(4) Name \( x^{(0)}(k) + az^{(1)}(k) = b \) as \( GM(1,1) \) model, and \( a, b \) are parameters which should be solved by modeling; if \( a = (a, b)^T \) is parameter list, and

\[
Y = \begin{bmatrix} x^{(0)}(2) \\
 x^{(0)}(3) \\
 \vdots \\
 x^{(0)}(n) \end{bmatrix},
B = \begin{bmatrix} -z^{(1)}(2) & 1 \\
 -z^{(1)}(3) & 1 \\
 -z^{(1)}(4) & 1 \\
 -z^{(1)}(5) & 1 \end{bmatrix}
\]

Get the least square estimation coefficient list of the differential equation \( x^{(0)}(k) + az^{(1)}(k) = b \), meeting requirements of:

\[
\hat{a} = (B^TB)^{-1}B^TY
\]

Name \( \frac{dx^{(1)}}{dt} + ax^{(1)} = b \) as grey differential equation, and the winterization equation of \( x^{(0)}(k) + az^{(1)}(k) = b \) is known as shadow equation.

As mentioned above,

1. The solution of winterization equation \( \frac{dx^{(1)}}{dt} + ax^{(1)} = b \) or time response function is:

\[
\hat{x}^{(1)}(t) = (x^{(1)}(0) - \frac{b}{a})e^{-at} + \frac{b}{a}
\]

2. The time response function of \( GM(1,1) \) grey differential equation \( x^{(0)}(k) + az^{(1)}(k) = b \) is:

\[
\hat{x}^{(1)}(k + 1) = (x^{(0)}(0) - \frac{b}{a})e^{-ak} + \frac{b}{a}, k = 1,2,\ldots,n
\]

3. Make \( x^{(1)}(0) = x^{(0)}(1) \), then:

\[
\hat{x}^{(1)}(k + 1) = (x^{(0)}(1) - \frac{b}{a})e^{-ak} + \frac{b}{a}, k = 1,2,\ldots,n
\]

4. Reducing value

\[
\hat{x}^{(1)}(k + 1) = \hat{x}^{(1)}(k + 1) - \hat{x}^{(1)}(k), k = 1,2,\ldots,n
\]

5. Coordinated analysis on investment ability and investment demands of power grid enterprises under different regulation strengths

In accordance with measurement model of power grid investment ability and investment demands, this paper calculated investment demands and ability under four scenarios, and carried out comparative and coordinated analysis.
5.1 Investment scale under power regulation environment

Take actual data of Jiangsu Power Grid as example. Based on measurement model of investment ability and investment demands mentioned above, the investment scale is calculated. The investment demand from 2020 to 2025 is predicted according to the power grid investment data from 2010 to 2019, which is the lower limit of investment scale; as upper limit of investment scale, the investment ability is calculated in combination with indexes of power grid investment ability measurement and index value set in regulation scenarios; the upper and lower limit of investment scale comprise investment scale of the power grid. The investment ability and investment demand of power grid in each scenario are measured as follows.

Table 2 Measurement of power grid investment scale under different regulation strengths (Unit: CNY 0.1 billion)

| Year       | 2019   | 2020   | 2021   | 2022   | 2023   | 2024   | 2025   |
|------------|--------|--------|--------|--------|--------|--------|--------|
| Investment ability in scenario I | 455.51 | 489.56 | 530.78 | 581.09 | 636.66 | 695.63 | 757.72 |
| Investment ability in scenario II | 403.79 | 433.52 | 488.13 | 548.75 | 603.93 | 659.92 | 718.66 |
| Investment ability in scenario III | 455.51 | 489.56 | 527.50 | 571.85 | 620.41 | 671.57 | 725.33 |
| Investment ability in scenario IV | 403.79 | 433.52 | 465.47 | 520.95 | 589.20 | 637.45 | 687.47 |
| Investment demands | 421.94 | 447.53 | 474.67 | 503.45 | 533.98 | 566.36 | 600.70 |

5.2 Coordinated analysis on investment ability and investment demands

The coordination and matching between investment demands and investment ability is an important factor affecting development of an enterprise. Fundamentally, the investment demand for power grid development is the investment incurred to meet electricity consumption demands of customers. During power grid development, it is necessary to arrange investment ability and investment demands as a whole. In specific, power grid investment ability is measured accurately, as the restriction of investment arrangement, to control indexes such as profits and liabilities within healthy and reasonable range.

When investment ability is larger than investment demand (i.e., 2021-2025 in Scenario I and Scenario II, 2022-2025 in Scenario III and Scenario IV), specific items in item group will be evaluated and selected, and investment will be inputted to optimized project portfolio; on this basis, moreover, this paper considers adding strategic investment proportion, suitably expanding investment scale and reducing future investment cost.

When investment ability is smaller than investment demands (2019-2020 in Scenario II, 2019-2021 in Scenario IV), enterprises may dynamically adjust investment ability and demands to make them match. Firstly, enterprises shall adjust current investment ability, and properly improve profitability by digging efficiency of inventory assets and suitably improving liability level or actively applying for electricity price policies to the government. Next, if aforesaid methods still fail to guarantee matching investment ability and investment demands, enterprises shall make further adjustment of investment demands. For instance, they can establish investment benefit assessment system for power grid investment projects to evaluate targeted investment project, select optimal development strategy plan, and further study how to arrange power grid investment for various voltage grades based on confirmed overall investment scale to optimize investment structure of power grid enterprises; or shift backward investment demands by reducing standby coefficient requirements in some years to optimize investment time sequence of power grid enterprises and make investment demands and investment ability match.

6. Summary

Under the background of the national “dual carbon” goal, renewable energy power generation will become the mainstream power generation mode in the future. In order to ensure the coordinated and sustainable development of future Jiangsu power grid investment, this article first sets the future power supervision scenarios; then proposes The investment demand and investment capacity calculation model of power grid enterprises is developed; secondly, in different scenarios, the investment capacity and investment demand of power grid enterprises are measured, the investment
scale is determined, and the investment capacity and investment demand are coordinated and analyzed. This article can help grid companies determine a reasonable investment scale to meet investment needs and improve investment returns.

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