Digital Transformation Mode and Investment Path of Power Grid Enterprises Under the Background of New Power System

Weijie Cao[1], Wei Yuan[1], Jian Dai[1], Li Jia[2], Na Li[2], and Wei Wang[2](✉)

[1] State Grid Wuxi Power Supply Company, Wuxi 214100, China
[2] NARI School of Electrical and Automation Engineering Nanjing Normal University, Nanjing 210046, China
wangw_seu@163.com

Abstract. To achieve the goal of dual-carbon target and support the development of new power systems, power grid companies must gradually realize the digital transformation of decision-making business. Based on the analysis of the new power system architecture, this paper determines the digital transformation mode of power grid enterprises. Relying on the typical characteristics of digital transformation, the transformation business of power grid enterprises is divided into internal and external parts, and the influence weight of each business on economic benefit index and low-carbon benefit index is evaluated by subjective and objective method. According to the evaluation results, a digital transformation low-carbon investment allocation model is established to provide a reasonable investment strategy for the digital transformation investment of power grid enterprises. Finally, a power supply company is taken as an example to verify the feasibility of the model and effectiveness.

Keywords: New power system · Digital transformation · Low-carbon benefits · Investment allocation model

1 Introduction

Under the new energy pattern, the country attaches great importance to the development of clean energy. In 2021, the state put forward the goal of "carbon peaking in 2030 and carbon neutrality in 2060" to vigorously promote the coordinated development of generation network load storage. In the same year, the ninth meeting of the Central Financial and Economic Commission also pointed out that a new power system with new energy as the main body should be built. The general layout of "one body, four wings" has been clearly defined in the "TWO Sessions" of State Grid Corporation, pointing out the direction for the digital transformation of power grid enterprises.

In recent years, there have been many domestic and foreign studies on digital transformation and investment allocation models. On the one hand, it is about the research on the path of digital transformation [1–3]. Based on the analysis of the digital transformation of British municipal governments and the problems faced by my country's digital

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transformation, [4] put forward suggestions on my country's digital transformation from the top-level structure and policy and system levels. [5] based on the exploration and practice of digital transformation on the enterprise operation management and control platform, put forward the concept that data is the "asset" of the enterprise. [6] explored and researched the implementation strategies and paths of the digital transformation of power grid enterprises from three aspects: data perception, data application, and mechanism construction. On the other hand, there is research on investment allocation model. [7] established a quantitative model of investment-assisted decision-making based on regional development and expected business performance by studying the allocation of investment scale and structure of power grid companies. [8] used Delphi method and AHP to establish an investment allocation model for distribution network planning based on overall investment capacity. [9] proposed an annual investment decision-making model based on the scale of the power grid and electricity sales and oriented by the evaluation score of the annual investment benefit of a single project. However, the existing research mostly involves the research on the implementation path and investment allocation model of enterprise transformation, and there are few reports on the research on determining the investment model of digital transformation based on the evaluation results of the low-carbon benefit and economic benefit of the implementation path.

To strengthen and lead the high-quality and efficient development of the new power system, and carry out research on the digital transformation structure and investment path of power grid business, this paper determines the digital transformation method of power grid enterprises by analyzing the typical characteristics of the new power system. Based on the evaluation system of low-carbon benefit indicators, and adopting a combination of subjective and objective methods to determine the impact weight of the internal and external business of power grid enterprises on the indicators. According to the evaluation results, a digital transformation low-carbon investment allocation model is established to formulate digital transformation paths for power grid enterprises and investment strategy. In order to promote the digital transformation of power grid companies and the comprehensive development of new power systems through the first trial, from point to point.

2 Requirements for Digital Transformation of New Power Systems

2.1 Overall Architecture

The new power system takes new energy as the main body on the power supply side, realizes digital transformation and development on the grid side, and builds a multi-level source-grid-load-storage integration on the consumption side [10].

In terms of finishing structure, the new power system covers two parts: energy grid system and information support system. The energy grid system promotes multi-energy coupling, complementarity and multi-aggregation interaction through the coordination of source, network, load and storage, and promotes the upgrade of the strong power grid to a new power system with new energy as the main body, realizes the green development of the power grid, and ensures the safe supply of energy. The information support system through the power grid digital transformation will comprehensively improve the capabilities of information collection, transmission, processing, application, and security, and promote the upgrading of smart grids to smart grids, as shown in Fig. 1.

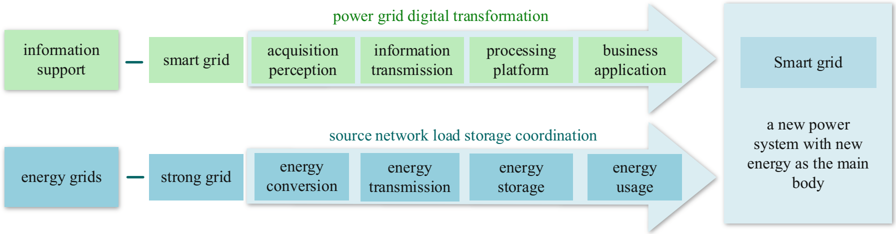

Fig. 1. New power system architecture

2.2 Digital Transformation Methods of Power Grid Enterprises

The object of digital transformation is business. From a business perspective, digital transformation is an in-depth change and Refactor. The digital transformation approach is shown in Fig. 2.

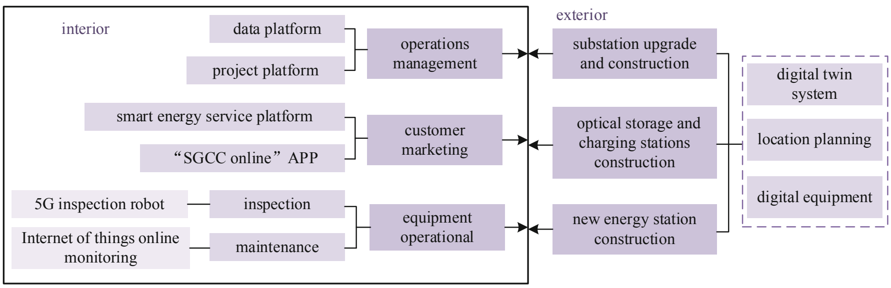

Fig. 2. Digital transformation mode

Divide the business of power grid enterprises into internal and external businesses. Internal business includes operations management, customer marketing, equipment operation and maintenance, operation scheduling, carbon monitoring, etc. External business includes substation upgrade construction, optical storage and charging station construction, new energy station construction, etc.

Power grid enterprises complete digital transformation through the construction of data center, project center, smart energy service center, and carbon monitoring service center. Among them, 5G inspection robots, drones, sensors, Internet of Things online monitoring and other equipment are used to complete data information collection and transmission.External business completes the planning, construction and operation of substations, charging stations and new energy stations through digital twin system, new energy cloud platform and other technologies.

3 Investment Indicators Impact Weight Determination

3.1 Evaluation Metrics

(1) Economic Benefit Index
The internal and external business economic benefit indicators of the digital transformation and upgrading of power grid enterprises are established by the AHP, as shown in Table 1.

Table 1. Economic benefit evaluation index

First-level indicator	Second-level indicators	Three-level indicator
Economic benefits A1	Total investment cash flow B1	Upgrade Benefit C1
		Equipment cost C2
		Land cost C3
		VAT C4
	Input-output	Investment income ratio C5
	ratio B2	Payback period C6

Among them, payback period refers to the time (year) required for the total amount of income obtained after the investment to reach the total investment amount invested in the investment project.

(2) Low Carbon Benefit Indicator
The low-carbon benefit index of internal and external business of the digital transformation and upgrading of power grid enterprises is established by the AHP, as shown in Table 2.

Table 2. Low-carbon benefit evaluation indicators

First-level indicator	Second-level indicators	Three-level indicator
Low carbon benefits A2	Low carbon output B3	Carbon emission intensity C7
	Carbon emission rate B4	Carbon emissions per unit investment C8
		Carbon reduction rate C
		Average carbon emission rate C10

Among them, carbon emission intensity refers to the carbon dioxide emissions generated by the growth of the unit of gross domestic product (GDP), which is mainly used to measure the relationship between the economy and carbon emissions.

3.2 Assessment Method

The objective evaluation method-entropy weight method and the subjective evaluation method-AHP [11] are used to solve the objective and subjective weights of the indicators, and then the linear weighted average method is used to solve the combined weights to obtain the evaluation index weights. The algorithm flow chart is as follows: shown in Fig. 3.

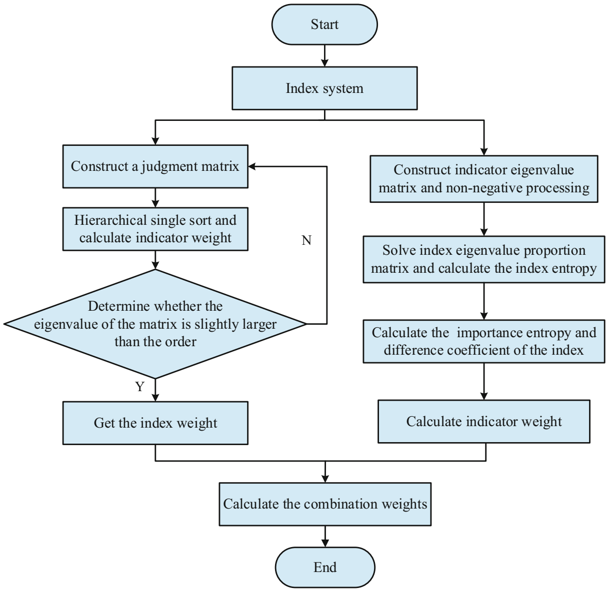

Fig. 3. Flow chart of evaluation method

4 Digital Transformation Low-Carbon Investment Allocation Model

4.1 Building a Decision Model

The low-carbon benefit and economic benefit of power grid business are evaluated through the evaluation system, and the influence weight of each power grid business on the index is obtained. Based on the weight of low-carbon benefit and economic benefit, the investment allocation decision of power grid business is made. An investment allocation model can be established as follows:

$$P_i = \frac{\left(X_i \cdot a_i/\overline{b}_i + X_i\right)}{\sum_{i=1}^{n}\left(X_i \cdot a_i/\overline{b}_i + X_i\right)} \quad (1)$$

where P_i is the largest digital transformation scale of the i-th business in the past three years; $\overline{b}_i$ is the average weight of the economic benefit level and low-carbon benefit level of the i-th business; a_i is the investment allocation ratio correction coefficient of the i-th business.

4.2 Model Parameter Solution

(1) Calculate the average value of the economic benefit level weight and completion level weight of the i-th business

$$\overline{b}_i = \left(b_{xi} + b_{yi}\right)/2 \tag{2}$$

where b_{xi}, b_{yi} are the economic benefit level weight and low carbon benefit level weight of the i-th business, respectively.

(2) Calculate the correction coefficient a_i of the investment allocation ratio of the i-th business

The value of a_i is closely related to the economic benefit level weight of the i-th business and the low-carbon benefit level weight. We define a_{1i} as the business economic benefit of the i-th business, and a_{2i} as the low-carbon benefit investment allocation correction coefficient. Considering the American psychologist Hertz Berg proposed the influence of "two-factor theory", when allocating investment to power grid business, it is necessary to fully consider the level of business development and future development potential. The specific solution is made through the following analysis.

The economic benefit evaluation incentive factor, economic benefit evaluation health care factor, low carbon benefit incentive factor and low carbon benefit health care factor are defined as: A, B, C, D, which can be solved by the following methods:

$$\begin{aligned} A &= b_{xin}/b_{xi\mathrm{m}} \\ B &= b_{xin}/b_{xi\mathrm{m}} \\ C &= b_{yin}/b_{yi\mathrm{m}} \\ D &= b_{yin}/b_{yi\mathrm{m}} \end{aligned} \tag{3}$$

where $b_{xi\mathrm{m}}$, b_{xin} are the highest and lowest weight of the economic benefit level index of the i-th power grid business, respectively; $b_{yi\mathrm{m}}$, b_{yin} are the highest and lowest weight of the low-carbon benefit level index of the i-th power grid business, respectively.

a_{1i}, a_{2i} two correction coefficient calculation criteria: compare the evaluation weight of the secondary index with the comprehensive weight of the index system, compare the weight of the economic efficiency index of the i-th power grid business with the total weight of the comprehensive evaluation of the power grid business, and compare it with the objective weight of the index Make a weighted comparison. If the result is greater than zero, then $a_{1i} \in [B, 1]$, $a_{2i} \in [D, 1]$; if the result is less than zero, then $a_{1i} \in [1, A]$, $a_{2i} \in [1, C]$, the i-th power grid business investment allocation ratio correction coefficient can be calculated and solved by the following formula.

$$a_i = \left(a_{1i}b_{xi} + a_{2i}b_{yi}\right)/2 \tag{4}$$

5 Case Analysis

Taking the digital transformation of a power supply company as an example to analyze, the company's business is divided into internal and external business proposed in Sect. 1.3, including a total of six types. The three types of internal businesses and three external businesses are respectively evaluated to the degree of influence of the evaluation indicators, and the internal business evaluation weights are shown in Fig. 4, and the external business evaluation weights are shown in Fig. 5.

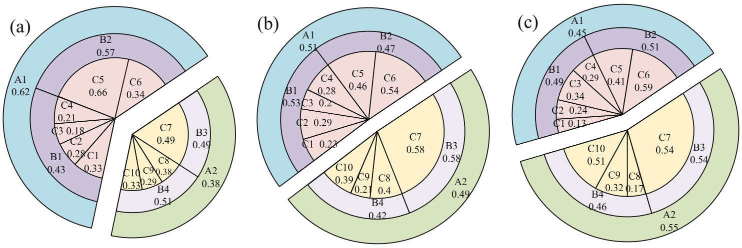

Fig. 4. Weight of internal service indicators

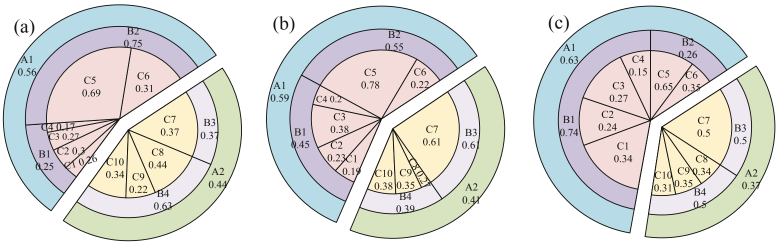

Fig. 5. Weight of external business indicators

As can be seen from Fig. 4 and Fig. 5, the impact of internal and external businesses on economic indicators and low-carbon indicators is different. The investment allocation proportion of each business inside and outside each power grid is calculated through the investment allocation proportion model as shown in Fig. 6.

Based on the actual investment amount of power grid enterprises, the total investment amount is planned as the actual total investment amount, and the investment allocation decision model considered in this paper is used for investment allocation. The results are shown in Table 3.

It can be seen from Table 3 that when the traditional planning and investment method is used for investment allocation, the maximum relative error is 12.99%, and the average relative error is 8.03%. The relative error is 2.82%, and the internal and external relative error of the model calculation of investment allocation is only one-tenth of the original planned investment allocation, and the model investment allocation ratio as a whole is closer to the actual investment completion.

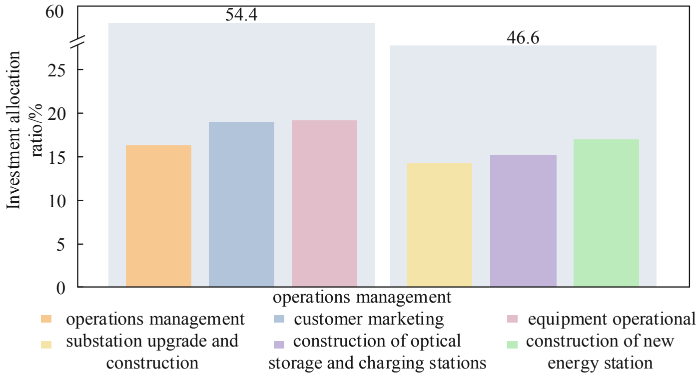

Fig. 6. Proportion of investment allocation

Table 3. Time-of-use electricity price

Power grid business		Actual investment/10,000yuan	Original plan to allocate investment			Model calculates investment allocation		
			Amount/10,000 yuan	Relative error/%		Amount/10,000 yuan	Relative error/%	
internal	All	40593.21	40593.21	0.0		40593.21	0.0	
	Operations management	6395.79	6262.52	2.56	2.13	6200.46	0.23	3.25
	Customer marketing	7620.63	8565.59		−11.03	7708.65		−1.14
	Equipment operation	7616.09	7357.14		3.52	7773.60		−2.03
external	Substation upgrade and construction	5524.64	5039.03	−2.92	9.64	5821.07	−0.26	−5.09
	Optical storage charging station construction	6464.37	5720.97		12.99	6186.41		4.49
	New energy station construction	6971.71	7647.97		−8.84	6908.96		0.91

To sum up, the relative error between the investment allocation result calculated by the investment allocation model in this paper and the actual investment is in a small range, which meets the requirements of the power grid for the accuracy of investment estimation. Carbon banks meet the requirements of digital transformation and can improve the accuracy, low carbon and economy of grid business investment.

6 Summarize

In this paper, focusing on the economic benefits and low-carbon benefits of internal and external business investment in the power grid, an evaluation method combining the entropy weight method and the analytic hierarchy process is introduced to determine the index weights, and on this basis, an investment allocation account suitable for the characteristics of the power grid business is constructed. Compared with the method, the investment scale allocation model of the enterprise is formed. Through the calculation and analysis of the calculation example, the investment results of each business are more reliable and accurate than the planned investment, which effectively improves the traditional power grid's shortcomings in business investment allocation and improves the grid business investment level of low-carbon, economic and accuracy. It provides guidance, methods and theoretical reference for the investment scale and allocation decision of power grid business, and helps power grid enterprises to clarify the investment orientation of digital transformation and allocate investment funds rationally, which is of great significance for further optimizing investment planning.

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