

# Research on the Investments Allocation of Comprehensive Plan of Power Grid Enterprises under the Electricity Transmission and Distribution Price Reformation

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**Abstract.** The reform of the transmission and distribution price affects the allocation of comprehensive investment plan of power grid enterprises, so it is necessary to combine the historical data and experts' experience to study the investment allocation strategy with different development objectives. Based on the practical background, we established the system dynamics model to analyze the relationships between different variables. It can make simulations to calculate the investment in professional sectors under the condition that the transmission and distribution price remains stable. In addition, by changing the relevant variables of the model, we can compare the investments of professional departments in different scenarios. The method can provide decision-making support for enterprises. At last, a numerical example is used to illustrate the method.

## 1. Introduction

In March 2015, the CPC Central Committee and the State Council promulgated the “Opinions on Further Deepening the Reform of the Power System” (2015. 9), which marked the official launch of the new round of electric power system reform. At the end of June 2017, all the provincial power grids have carried out the reform of transmission-distribution price [1]. On the basis of the overall balance and optimization of the core resources and needs of the company, the comprehensive plan is the annual business development goals that lead the overall company's management, aiming to implement the systematic strategies and plans of the company. The comprehensive plan can be divided into 16 sectors, including power grid infrastructure, production technical reformation, and so on [2]. The new reform of transmission and distribution price has changed its profitable business model from “purchase and sale price differentials” into “allowable costs and reasonable income”, which was regulated by the government. Based on the grid assets, the system will directly and comprehensively control the income, costs and transmission-distribution prices. The permitted costs and allowable benefits of the grid will be verified on the basis of the effective assets of the grid [3]. In the context of electricity price reform, we need to take the enterprise development goals, operating conditions and electricity prices into consideration and put forward optimal investment allocation plan according to



the regulatory cycle. Therefore, the strategy of allocating the comprehensive plan must be taken seriously.

Some scholars focus on the income of enterprises and the fairness of distribution, and they conduct research from the aspects of management and grid construction indicators or projects. In addition to investment allocation among various professional sectors, the investment allocation of power grids is also reflected in the distribution of investment among different voltage levels and the distribution of investment among subsidiaries. Wang, Chen (2014) [4] and Zhu (2016) [5] evaluated the contribution of the projects by constructing the evaluation index system and then set up optimization model to maximize the comprehensive score or maximize the investment benefit. In addition, there are some scholars analyze the relationship between the allocation of investment and related indicators based on historical data. They usually formed investment allocation plans by fitting historical data or setting weights. Li Meng et al. (2016) [6] and Chen Xiang (2016) [7] follow the way to make research.

The above articles focus on single stage investment allocation strategy. During the reformation of electricity price, the regulatory cycle is three years. Take each year as a stage and the investment strategy of the previous stage will also affect the next stage of investment. Therefore, the comprehensive investment allocation strategy needs to take the background of electric reform and the multi-stage investment allocation in the regulatory cycle into consideration. The system dynamics method has combined the qualitative and quantitative methods to deal with complex systemic problems. Modeling is a good way to describe the linkage and feedback between variables [8]. Some scholars adopted the simulation methods to analyze measurement method of investment but they ignore the problem of investment distribution. He Kelei, Zeng Ming et al [9] established the linkage and feedback relationship between the indicators by constructing the system dynamics model and obtain the minimum amount of investment under certain constraints. Wang Liang [10] and Duan [11] made use of the system dynamics model to construct the relationship between the various decision-making factors that affect the investment of power grid enterprises, and further to measure the investment in the power grid and make dynamic adjustments.

Therefore, with reference to the total input of historical comprehensive plan, various professional sectors, relevant management index data and the related parameters of transmission-distribution price, this paper builds the system dynamics model to construct the linkage and feedback relationship between professional sector, construction scale, permitted income and approved electricity price and analyzes the characteristics of special investment in three years, which provides the decision-making support for the optimal allocation of the comprehensive plan investment.

## 2. Flowchart of the system

System dynamics model variables are divided into state variables, rate variables, constant and auxiliary variables. State variables are cumulative variables that change over time. The causal relationship between the main variables in the model will be described as follow.

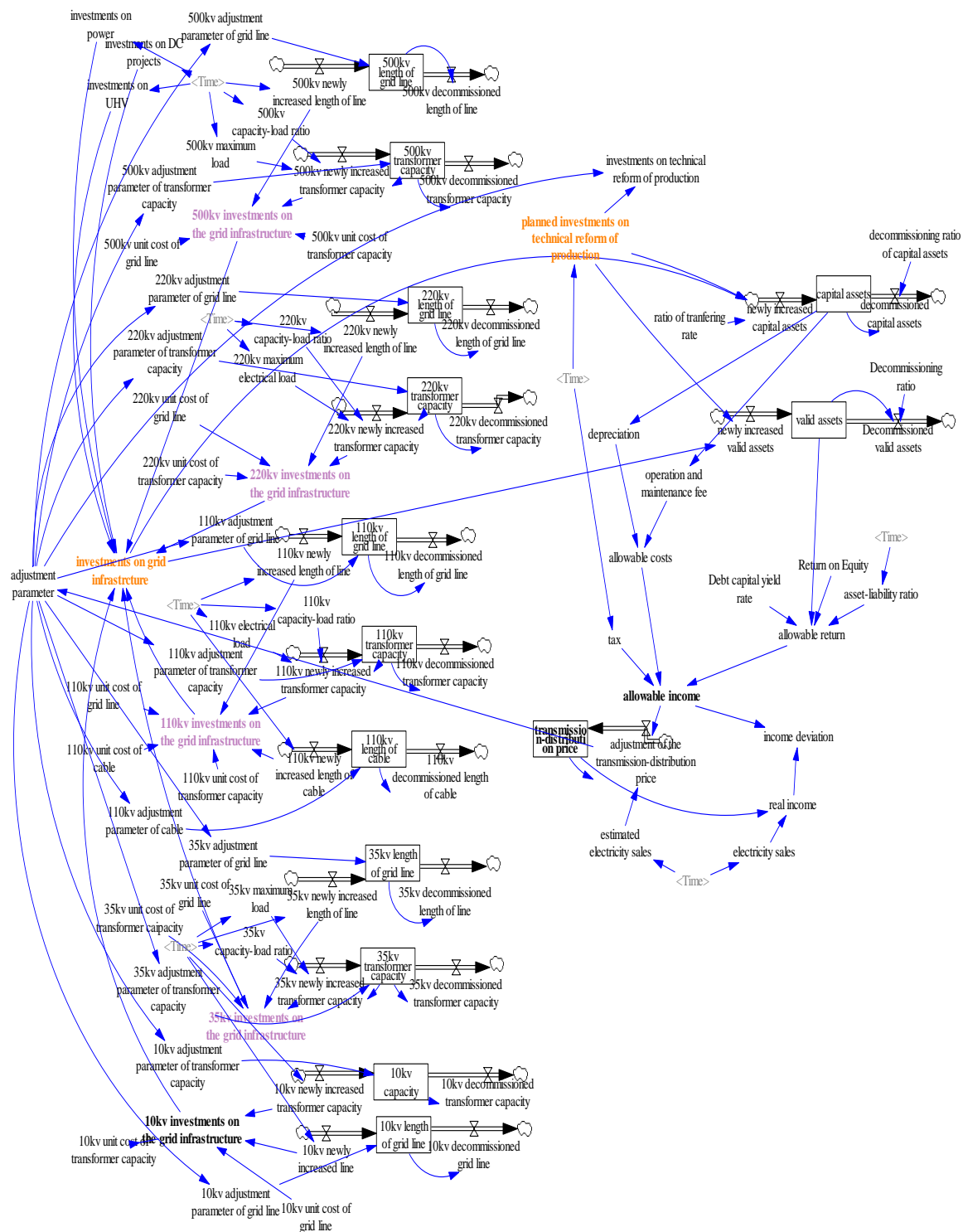
The feedback relations come into being in system flowchart constructed by Vensim according to the relationship between the variables. For example, investments on grid infrastructure → newly increased valid assets → allowable return → allowable income → adjustments of the transmission-distribution price → adjustment parameter → 500kv adjustment parameter of grid line → 500kv newly increased length of grid line → 500kv investment on grid infrastructure → investment on grid infrastructure. Other voltage levels also have the similar feedback relationships, that is, the construction goals and investments of various voltage levels will affect the transmission-distribution prices. On the contrary, in order to make sure the stability of transmission-distribution price, its fluctuations and adjustments will affect the investments of voltage levels.

### 2.1. The Equations of the Model

Equations related to the variables are defined according to the approved method of transmission-distribution price and the relationship between the variables. Due to the large number of variables, only some of the main equations are listed as follows:

(1) 500kv transmission line length = INTEG (newly increased 500kv line length- decommissioned 500kv line length, 4654);

(2) 500kv substation capacity = INTEG (newly increased 500kv transformer capacity - decommissioned 500kv substation capacity, 2.68e + 7);



**Figure 1.** Flowchart of the model

(3) 500kv grid infrastructure investment = 500kv unit capacity cost  $\times$  newly increased 500kv transformer capacity + 500kv unit cost of grid line  $\times$  newly increased length of grid line;

(4) Capital assets = INTEG (newly increased capital assets - decommissioned capital assets, 1.276e + 11);

(5) Valid assets = INTEG (newly increased valid assets, decommissioned valid assets, 8.65e + 10);

(6) Grid Infrastructure investment = 10kv Grid infrastructure investment + 110kv Grid infrastructure investment + 220kv Grid infrastructure investment + 35kv Grid infrastructure investment + 500kv Grid infrastructure investment + UHV investment + power investment + DC investment;

(7) Allowable income = allowable cost + allowable profits + tax;

(8) Allowable costs = depreciation expense + operation and maintenance expenses;

(9) Allowable return = total value of valid assets  $\times$  (asset-liability ratio  $\times$  debt-to-equity ratio + (1 - asset-liability ratio)  $\times$  return on equity);

(10) Transmission-distribution price adjustment = allowable income / projected sales volume-DELAY1I (transmission-distribution price, 1, 0.21);

(11) Transmission-distribution price = INTEG (transmission-distribution price adjustment, 0.21);

(12) Adjustment coefficient = if then else (abs (transmission-distribution price adjustment) > 0.05, 1-abs (Transmission-distribution price adjustment) \* (abs (Transmission and distribution price adjustment)-0.05/ \*(Transmission-distribution price adjustment\*abs (Transmission and distribution price)), 1) ;

(13) Real income = transmission-distribution price  $\times$  electricity sales.

### 3. Simulation

#### 3.1. Parameters of the Model

Taking a provincial power grid enterprise as an example, its first supervision period of electricity reform is from 2016 to 2018. Based on its data from 2010 to 2015, analyzing the relationship between variables and conducting the example simulation of its professional sector allocation in 2016-2018. Related state variables, constant assignment as shown in Table 1, Table 2 below.

**Table 1.** Initial values of model state variables

Parameter (unit)	Data	Parameter (unit)	Data
500kv Line length (km)	4654	500kv Variable capacitance(0.01 million KVA)	2685
220kv Line length (km)	14150	220kv Variable capacitance(0.01 million KVA)	5592
110kv Line length (km)	16265	110kv Variable capacitance(0.01 million KVA)	4420
35kv Line length (km)	19481	35kv Variable capacitance(0.01 million KVA)	1643
10kv Line length (km)	168488	10kv Variable capacitance(0.01 million KVA)	5502
Fixed assets (100 million yuan)	1276	Valid assets (100 million yuan)	865

**Table 2.** Constants assignment

Parameter (unit)	Data
Transfer rate	88%
Debt capital rate of return	4.35%
Return on equity capital	4.00%

When it is difficult to describe the relationship between variables by analytic functions, the table function can show the nonlinear relationship between variables and transform the nonlinear relationship into piecewise linear relationship. In the process of building the model and the variable assignment, some variables such as each voltage level grid capacity ratio in the future, the length of

new lines and asset-liability ratio should be taken into account. It will be affected by many factors, such as economy and enterprise development. Research can set table functions based on expert opinions, and can simulate by changing the value of variables and building a variety of future development scenarios.

### 3.2. Simulation Process

Based on the opinions of experts and historical data, we set the goal of grid development and construction for 2016-2018 and defined the allowable fluctuation threshold value of transmission-distribution price. In order to analyze the impact of variables on the allocation of professional sectors and transmission-distribution prices, the following factors should be taken into consideration: the asset-liability ratio, the capacity-load ratio of each voltage level, and the length of new lines. The following 11 scenarios need to be set up and simulated separately.

Scenario 1: The baseline scenario, state variables, constants, etc. are set according to Table 1 and Table 2;

Scenario 2: High asset-liability ratio scenario, asset-liability ratio increased by 20%, other variables remain unchanged;

Scenario 3: Low asset-liability ratio scenario, asset-liability ratio decreased by 10%, other variables remain unchanged;

Scenario 4-7: Keeping the capacity of the other three voltage levels unchanged, 500kv, 220kv, 110kv, 35kv capacity-load ratio increased by 5%;

Scenario 8-11: Keeping the new line length of other three voltage levels unchanged, 500kv, 220kv, 110kv, 35kv and make the new line length of one voltage level increase by 5%.

### 3.3. Results Analysis

Transmission-distribution prices and infrastructure construction investment under each scenario are as follows:

**Table 3.** Simulation results of different asset-liability ratio

	Transmission-distribution price (Unit: yuan)			Infrastructure investment (Unit: 100 million yuan)			Investment in production technology (unit: 100 million yuan)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Scenario 1	0.270	0.270	0.274	112.15	163.60	171.50	14.96	15.83	16.41
Scenario 2	0.271	0.270	0.274	112.15	163.77	171.67	14.96	15.83	16.41
Scenario 3	0.270	0.269	0.274	112.15	163.51	171.41	14.96	15.83	16.41

As can be seen from the above table, when the asset-liability ratio changes, the capital construction investment and transmission and distribution price will fluctuate to a certain extent, while the investment in production and technological transformation remains unchanged. Compared with the high asset-liability ratio, transmission-distribution price and grid infrastructure investment of the benchmark scenario or low asset-liability ratio scenario is low. In addition, with the goal of grid construction unchanged, the change of asset-liability ratio has little or no effect on the transmission-distribution price and grid infrastructure investment.

When the capacity ratios of 500kv, 220kv, 110kv and 35kv are respectively increased by 5% and the other variables keep unchanged, the input and output prices of grid infrastructure are shown in Table 4. It can be seen that the transmission-distribution price will increase slightly compared with the baseline scenario when capacity-load ratio is enlarged in 2018. Investment in infrastructure construction of the grid increased in 2016 and 2017 while it decreased in 2018. Due to the small

fluctuation of transmission-distribution prices, the annual adjustment coefficient is 1 and the investment in production and technological transformation remains unchanged.

**Table 4.** Simulation results when capacity-load ratio of voltage levels enlarged by 5%

	Transmission-distribution price (Unit: yuan)			Infrastructure investment (Unit: 100 million yuan)		
	2016	2017	2018	2016	2017	2018
Scenario 1	0.270	0.270	0.274	112.15	163.60	171.50
Scenario 4	0.270	0.270	0.275	115.44	164.50	169.79
Scenario 5	0.270	0.270	0.276	119.19	165.76	168.17
Scenario 6	0.270	0.270	0.277	119.85	166.09	167.04
Scenario 7	0.270	0.270	0.275	116.07	165.21	169.61

When new line of 500kv, 220kv, 110kv, 35kv voltage levels increased by 5%, while other variables keeping unchanged, the case of grid infrastructure investment and transmission-distribution prices as shown in Table 5. Compared with the baseline scenario, the transmission-distribution prices increased slightly by no more than 0.01 yuan in 2017 and 2018, while the infrastructure investment in power grids increased during the three years with a growth rate of about 1% and Special investment in production technology remains unchanged.

**Table 5.** Simulation results when new line length of voltage levels increased by 5%

	Transmission-distribution price (Unit: yuan)			Infrastructure investment (Unit: 100 million yuan)		
	2016	2017	2018	2016	2017	2018
Scenario 1	0.270	0.270	0.274	112.15	163.51	171.41
Scenario 8	0.270	0.270	0.275	112.90	163.96	171.94
Scenario 9	0.270	0.271	0.276	112.42	163.79	171.67
Scenario 10	0.270	0.271	0.277	112.75	164.11	172.02
Scenario 11	0.270	0.272	0.276	112.36	180.97	171.97

Due to the uncertainty of some variables, different construction and development goals will lead to different special allocation of inputs. By calculating the above special investment and electricity price, this research can provide decision-making support for the special distribution of enterprises under multiple scenarios.

#### 4. Conclusion

This study puts forward a practical method to allocate comprehensive plans under the reform of electricity transmission and distribution price. According to the development goals of enterprises in the regulatory cycle, the system dynamic model is built to analyze the relationship between the variables of grid professional sectors. On the premise of keeping the electricity price relatively stable, the simulation of the special investment and the change of electricity price during the three-year supervision period is carried out. The model combines qualitative and quantitative analysis and is easy to operate and adjust. Taking into account the parameter disturbances, simulations are carried out under different scenarios to provide decision support for the allocation of comprehensive plan under different development goals.

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