Research on investment decisions model of trans-regional transmission network based on the theory of NPV

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Abstract. The investment decision model of trans-regional transmission network in the context of Global Energy Internet was studied in this paper. The key factors affecting the trans-regional transmission network investment income: the income tax rate, the loan interest rate, the expected return on investment of the investment subject, the per capita GDP and so on were considered in the transmission network investment income model. First, according to the principle of system dynamics, the causality diagram of key factors was constructed. Then, the dynamic model of transmission investment decision was established. A case study of the power transmission network between China and Mongolia, through the simulation of the system dynamic model, the influence of the above key factors on the investment returns was analyzed, and the feasibility and effectiveness of the model was proved.

1. Introduction
In the background of the Global Energy Internet, the factors that face the power supply and the investment decision making of the power grid are more complex. Generally speaking, Global Energy Internet investment decisions involve more subjects, and consider a wider range. The relationship between the domestic power supplies, power supply and power grid should not only be considered, but also the interaction between countries and between the continents. The decision factors are also more. In addition to consider the various countries and regions of the power grid, power supply in the planning, operation, security and other aspects of the factors, the resource system, fiscal terms, economic and technical requirements, environmental protection, market, international cooperation level and other factors in different countries should also be considered. The power system planning principles and clean energy policies are different in each country, which makes the connection of power grid and power supply more closely, and the investment of the two collaborative decision-making is of great significance.

There are many researches on investment decisions making of power system under the environment of electricity market in domestic and foreign. After considering the inherent uncertainty and risk factors of industrial users in power planning investment decision, the difference between different investment cost and investment project is compared, by using the dynamic stochastic model of investment decision, the relationship between the optimal selection and the time sequence is analyzed [1]. From the perspective of cost and benefit, the net present value (NPV) model of power grid investment is constructed [2], by using set pair analysis theory, the set pair coefficient of these uncertainties is
calculated, and the set pair analysis theory is deduced, and the risk evaluation model of power grid investment is constructed. Trine Krogh Boomsma[3] adopts a real options approach to analyze investment timing and capacity choice for renewable energy projects under different support schemes. Considering the influence of wind power electricity price uncertainty, wind farm investment and operation cost, investment policy, investment time and other factors on the investment risk, the use of portfolio investment theory for the investment decision-making model of quantitative evaluation of wind power project was established in [4], the quantitative evaluation of different factors on the influence of different power investment decision stages. S Lopez [5] proposes a transmission system expansion approach focused on analysis and management of the risks which impact on the assessment of transmission investments. Based on behavioral economics view, study on the different risk preference of the investor, modify the limitation of the changeless discounting rate in the option-game theory, and a model of generation investment decision-making based on different risk preference and option-game theory was constructed in [6]. In summary, there are little literature on the economic analysis and economic dispatch of large power grid interconnected by global energy resources, and almost no literature on investment decisions specifically aimed at the global energy internet.

This paper mainly aims at the characteristics of investment decision-making under the global energy Internet, the transmission investment models of different investment subjects are constructed, and the net present value is used as an economic indicator to evaluate the feasibility of investment returns and investment. According to the principle of system dynamics to simulate, the influence of the key factors such as the income tax rate of the transmission network on investment benefit is analyzed, the corresponding reference value for the investment decision of the global energy internet is provided.

2. Trans regional transmission network system

The purpose of the global energy Internet is to use the solar energy, wind energy and water energy in the energy rich region to form a multi-energy complementary system, to improve the performance of clean energy. The clean energy is converted into electric energy, which is delivered to the load concentration area, which can alleviate the energy crisis and improve the environmental quality. The development process of energy Internet is: the inter regional energy interconnection→near the national energy interconnection→intercontinental energy interconnection→cross Island energy interconnection→global energy interconnection, as shown figure 1. In this process, the energy across multiple time zones production, transportation, consumption, involves many subjects. There is a causal link between the factors that affect the investment returns. In this paper, we set up an investment benefit model from the point of view of system dynamics.
2.1. Transmission and distribution price

Electricity prices are generally composed of power costs and earnings (include profits and taxes). The power costs [7] refers to the normal production and operation of enterprises in the process of consumption of fuel costs, depreciation charges, water charges, the cost of materials, wages and welfare, maintenance fees, reasonable management fees, sales expenses and financial expenses and other costs. Tax is expense of taxation that the electric power enterprise according to the national tax law should pay and can be included in the electricity price. Profit is the reasonable profit that the electric power enterprise should obtain in normal production and operation.

Similarly, transmission and distribution price is composed of transmission and distribution costs and profits. Transmission and distribution costs [8] include: loss of equipment, maintenance costs, maintenance costs, material costs, administrative expenses, net loss, re arrangement of power generation plans and economic dispatch costs, reliability costs and other costs.

Calculation formula of transmission and distribution price

\[ \text{price} = \text{Cost} + \text{profit} \]  

Where: price - transmission and distribution price, Cost- the Cost of power transmission and distribution, profit - income.

Transmission price calculation methods are summarized in two categories, namely, the comprehensive cost method and marginal cost method [9]. Comprehensive cost method first calculates the investment data, annual operating cost and reasonable profit, and obtains the comprehensive cost of power transmission and distribution. And then according to the transmission and distribution price, the comprehensive cost is assessed. Marginal cost method is generally divided into long-term marginal cost method and short-term marginal cost method. Long term marginal cost pricing method is based on the total cost of the Power Grid Corp in the implementation of the transmission and distribution business caused by the marginal changes, as the basis for the calculation of transmission and distribution price, including the two parts of the marginal cost of capacity and marginal cost of electricity. Short term marginal cost method does not consider the power of fixed assets depreciation and recovery, only considering the change caused by incremental transmission business operation cost of transmission network, according to the power of short-term marginal cost calculation of transmission charges.

2.2. Factors affecting the investment of trans regional transmission network

The development of global energy Internet is a complicated system, which is influenced by various factors, such as economy, technology, policy, infrastructure, environmental protection and so on. In the process of construction of cross regional transmission investment projects, we need to screen key factors which affect the investment decision of transmission projects. This paper selects the Delphi method by experts in different fields of knowledge, technology, experience and ideas of all kinds of factors for anonymous selection, scoring evaluation according to the important degree of influence. Using expert opinion concentration and dispersion as the criteria to determine the evaluation index, the calculation is as follows

\[ \tilde{E}_i = \frac{1}{Y} \sum_{j=1}^{n_i} n_j E_j \quad i = 1, 2, \ldots, X \]  

\[ \sigma_i = \sqrt{\frac{1}{Y} \sum_{j=1}^{n_i} (\tilde{E}_i - E_j)^2} \quad i = 1, 2, \ldots, X \]  

Among them, there are X indicators, Y expert scoring evaluation, \( E_i \) as the index of the value of the important level of the first J (generally between 1 to 5); \( n_j \) is the number of experts in the evaluation of the important degree of grade \( n_j \) for the first i index. According to the actual situation of the Global Energy Internet, \( E_i \leq 3 \) and \( \sigma_i \leq 5 \) as the conditions of the index system in the comprehensive evaluation
index system, the final establishment of the impact of transmission investment is the core factors: GDP, tax rates, rate of return, the loan period, the cost of demolition, the project construction cost, the project construction period, the land right cost, loan interest rates and other factors.

The net present value is an important indicator to measure the status of a project funding status. The difference of project income and project expenditure in transmission investment projects is the net present value of each year. The causal relationship between the core factors associated with the net present value is shown in Figure 2. As can be seen from Figure 2, there are two closed loops, one is positive feedback, the other is negative feedback, and the system becomes the upper bound model in the system dynamics.

![Figure 2. Causality diagram of transmission investment returns.](image)

And production costs associated with the core factors are: loan interest rates, tax rates, GDP, yield, etc. the causal relationship is shown in figure 3. Different countries have different GDP. From Figure 3, we can see the GDP has a great influence on the dismantle cost, equipment cost, land and right of way cost, operation maintenance and administration cost.

![Figure 3. The causal relationship between core factors and project cost.](image)

2.3. System Dynamics

Under the global energy Internet, Tran’s regional transmission network investment involves many investment subjects and many factors, which affect the transmission project investment, so the system dynamics is studied. System dynamics from the system of micro structure to study the system, according to the structure and function of the system, the model of the system is constructed; the system will form the causal relation model for structure and function, and further design feedback loop reflecting the behaviour of the system by using feedback, regulation and control principle. Finally, the computer simulation model is established and with the help of computer simulation, high-order, nonlinear, multiple feedback complex time-varying systems are quantitative studied. The process of solving the problem is to find the optimal process, and the final goal is to find a better structure of the system, in order to optimize the system function [10].
In this paper, the key factors of transmission project investment is considered, the transmission project investment model is constructed based on the principle of system dynamics.

3. A Case Study of System Dynamics Modeling

A case study of power transmission network in China and Mongolia, the transmission investment model is established, the effects income tax rate on investment returns are simulated and analyzed. Assume that China to Mongolia transmission mode for AC transmission, the construction year of the transmission investment projects is 5 years, the transmission distance of transmission network is 1000KM, the maximum transmission capacity of transmission network (grid capacity) is 20000MW, the loan period is 20 years, the interest rate is 7%, the interest rate is 30%. The cost of equipment per KM per MW transmission grid is related to the economic life cycle of transmission investment projects. The net present value of investment in the model established in China and Mongolia is expressed by GRID CMGL, which is the difference between the investment income and the cost of the project.

Vensim software uses the equation rule of the DYNAMO language to write. In the equation, L is expressed in the horizontal variable equation; R expressed rate variable equation; C representation of the constant equation; A expressed auxiliary variable equation; N represents the initial value equation.

- \( L = \text{INTEG} (\text{CI growth}, \text{CI growth initial value}); \)
- \( N = \text{CI growth initial value} = 0; \)
- \( R = \text{CI growth} = (\text{TDlocal income} + \text{TGlocal income} + \text{Twider income})/(1+\text{benchmark return ratio u})^\text{Time}; \)
- \( C = \text{benchmark return ratio} u = 0.04; \)
- \( A = \text{policy strength} = \text{IF THEN ELSE} ((0.2-\text{Time}^0.008)>0, 0.2-\text{Time}^0.008, 0). \)

Global energy Internet transmission projects across countries, tariff as an important factor to restrict the economy, could significantly improve the price, reduce the internal rate of return of capital and funds of its own internal rate of return, the investment recovery period is extended. The effects of income tax rate on investment returns is analyzed.

The tax system of various countries is different, the tax category is also different, such as the United States does not increase the value added tax, but collects the business income taxes, and also some countries to levy consumption tax, but our main taxes for the value-added tax, enterprise income tax. In the context of the global energy interconnection, cross-border cross regional sales of electricity related to tariff. The following will be integrated into a variety of taxes equivalent to levy taxes and fees in accordance with a certain percentage of sales revenue. Selecting a tax rate of 50%, 30% and 15% to study the impact of the tax rate on the economic indicators of the project, as shown in figure 4. The horizontal coordinate is the economic life cycle of the project, and the vertical coordinate is the net present value income. In figure 4, with the reduction of tax rates, the investment income is gradually increasing.

![Figure 4. The effect of income tax rate on investment income.](image)
Each country according to their own tax returns, formulate the corresponding investment strategy, to obtain the maximum economic and environmental benefits. Different national systems are different, so the data can be brought into the specific country, according to the results of the simulation to determine whether it has investment value, if it has value of investment, and how to invest.

4. Conclusions
Trans regional transmission network investment decision-making involves a variety of factors, the traditional method is difficult to carry out a comprehensive consideration. The advantage of the system dynamics method is that it takes into account a lot of complex factors that are difficult to quantify, which can be calculated by the causal relationship between the factors and a certain structure. In this paper, the method of system dynamics is used to study the investment decision of Tran’s regional transmission network, which can comprehensively consider the influence of various factors on the investment income, and the results have reference value. The case simulation intuitively shows the change situation of the net present value of investment with the key factors. The simulation result shows the lower the tax rate, the higher the net present value of the investment project.

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