Evaluation Method of Investment Effect of Combined Production Technical Transformation Project Based on Analytic Hierarchy Process

Sanwei Liu\textsuperscript{1,*}, Liu Zhang\textsuperscript{1}, Feng Wang\textsuperscript{2}, Yishi Yue\textsuperscript{1}, Haiyue Wang\textsuperscript{2}, Cheng Wang\textsuperscript{1} and Fuyong Huang\textsuperscript{1}

\textsuperscript{1}State Grid Hunan Electric Power Company Limited Research Institute, Changsha, Hunan, China, 410007
\textsuperscript{2}State Grid Hunan Electric Power Company Limited, Changsha, Hunan, China, 410007

*Corresponding author. Email: 604208086@qq.com

Abstract. The research results of the investment effect evaluation methods of a variety of production technology reform measures can be applied to evaluate a variety of external risk coexistence scenarios, and provide auxiliary support for the investment decision making for the transmission channel to consider the overall effect of multiple measures. This paper first analyzes the theory of lightning strikes and wind deviation prevention measures, and draws the correlation between two types of risk management measures, and establishes an evaluation model of investment effects of various measures under the risk superposition scenario, and 40 sets of lightning strikes and wind bias treatment projects. Substitute the evaluation model for case study. Among the four types of governance measures to be assessed, taking into account the effectiveness and efficiency indicators of governance, the third type of governance measures can achieve the best investment benefits.

Keywords: risk portfolio, investment benefit risk, assessment.

1. Introduction
Years of power grid operation experience show that overhead transmission lines and other transmission and transformation equipment are exposed to the external environment for a long time, and are vulnerable to meteorological disasters such as thunderstorms, ice disasters, wind disasters, etc. Whether the power grid can operate safely and reliably is closely related to the external environment. In the practice of production technical transformation projects, for the lines in the same section, there are multiple external risks coexisting. Correspondingly, in terms of actual investment requirements, there are situations in which the investment requirements of multiple measures coexist, while the current corresponding investment only considers technical needs, does not consider economics, and only considers the individual effects of each of the multiple measures, and the interplay between multiple measures is not taken into account.

In this paper, the scenario of transmission line lightning strike and wind deflection is used as an example, an investment risk evaluation method and steps that are intuitive in the calculation process and
easy for decision makers to accept are proposed, and an investment evaluation model of governance measures in multiple risk overlay scenarios is established. Forty groups of lightning strikes and wind deflection treatment projects were substituted into the evaluation model for example analysis. Provide auxiliary support for the transmission channel to make investment decisions that take into account the overall effects of various measures.

2. Theoretical analysis of lightning strike and wind deviation risk management
Common measures for lightning protection of transmission lines include overhead ground wires, pole tower grounding devices, line arresters, parallel gaps, pole tower lightning rods, coupling ground wires, and reinforced insulation selections [3-4]. The types of wind damage include: wind-biased trips, damage to insulators and fittings, broken strands and wires of ground lines, and damage to pole towers. Commonly used control measures include changing insulator strings, installing wind-proof insulators, and installing wind-proof stays. The interaction between two types of risk governance measures and risks is analyzed to determine the type of combination of measures to be evaluated in the context of risk overlay.

The measures that need to be evaluated in the combined scenario of lightning strike and wind deflection risk are: ① overhead ground wire, changing insulator string; ② line lightning arrester, grounding device; ③ lightning rod, grounding device; ④ install heavy hammer, install wind-proof insulator; ⑤ install heavy hammer, install wind-proof stay.

The evaluation objects of the combined control measures for the lightning strike and wind deviation risk are divided into four categories: ①②④, ①②⑤, ①③④, ①③⑤.

3. Effectiveness evaluation model of risk portfolio governance project
The first grade indexes is the project governance effect. The second index includes two parts, efficiency and effectiveness. The efficiency indicator refers to the technical indicators that reflect the technical performance of the project such as safety and reliability and project quality. The benefit index refers to the contribution of the project to the enterprise and the national economy. The third grade indexes is to classify the fourth-level indicators according to its own attributes and functional extends. Among them, the reliability index, quality index, and economic benefit indices can be quantitatively calculated. The fourth-level indicators is the specific data or calculation results that are actually collected on site. In the end, five evaluation indexes were constructed, namely the usable coefficient promotion rate, the decrease rate of failure outage rate, the power risk grade, the defective number decrease rate, and the unit investment reduces loss benefits (full life cycle cost). Table 1 shows the evaluation index system for the effects of the lightning strike and wind deviation risk management.

| First grade indexes | Second index | Third grade indexes | Four-level indicators |
|---------------------|--------------|---------------------|-----------------------|
| Risk Management     | Effectiveness Index | Reliability Index  | Availability Factor                |
|                     |               |                     | Fault outage rate          |
|                     |               |                     | Power risk grade            |
| Benefit index       | Economic benefit indices | Number of defects | Unit investment reduces loss benefits |

According to the risk-benefit theory, if the life-cycle cost of the lightning strike and wind deflection treatment plan is reduced to avoid the economic loss caused by the lightning strike and wind deflection fault, the reduced cost is the economic benefit of the project. The general idea is to treat governance and non-government as two options, and calculate the life-cycle costs of the two options separately. In order to make projects with large differences in governance
investment comparable, a "unit investment reduction loss benefit" indicator was constructed to reflect the project unit investment economic benefits.

The process is to compare the annual costs of the two plans over their entire life cycle, find the difference between the annual costs of the two plans, and then divide by the cost of lightning protection and wind deviation control to find the benefits of unit investment to reduce losses.

In order to construct a project effect evaluation index system, it is necessary to give weight to each individual index according to the degree of importance and obtain a comprehensive evaluation result. The determination of index weights uses AHP [17-20]. The evaluation index variables are set as shown in Table 2. The expert group unanimously discussed and analyzed, and constructed an expert scoring table, as shown in Table 3.

**Table 2. Evaluation indicator variable setting.**

| C1 | C2 | C3 | C4 | C5          |
|----|----|----|----|------------|
| Usable coefficient promotion rate | Decrease rate of failure outage rate | Power risk grade | Defective number decrease rate | Unit investment reduces loss benefits |

**Table 3. Expert score table.**

| B | C1 | C2 | C3 | C4 | C5 |
|---|----|----|----|----|----|
| C1 | 1  | 1  | 1/5| 1  | 1/3|
| C2 | 1  | 1  | 1/5| 1  | 1/3|
| C3 | 5  | 5  | 1  | 5  | 3  |
| C4 | 1  | 1  | 1/5| 1  | 1/3|
| C5 | 3  | 3  | 1/3| 3  | 1  |

The final weights of the five indicators are determined as follows: the usable coefficient promotion rate is 8.76%, the decrease rate of failure outage rate is 8.76%, the power risk grade is 50.07%, the defective number decrease rate is 8.76%, and the unit investment reduces loss benefits is 23.64%. In addition, considering that important transmission channel projects should be given priority treatment, after the weighted average of the five indicators, additional points should be added. The necessity of governance of important transmission channels is affirmed and reflected in the evaluation results.

In order to verify the rationality of the calculation of the evaluation indicators, capital collection was carried out. During the calculation, multiple rounds of verification were performed. Dynamically improve the income statement and revised calculation formulas for indicators. Table 4 shows the evaluation system under the scenario of lightning strike and wind deflection.

**Table 4. Evaluation system under the scenario of lightning strike and wind bias.**

| Four-level indicators | Index weight | Evaluation standard |
|-----------------------|-------------|---------------------|
| Usable coefficient promotion rate | 8.76% | 1. 0% and below: 70 points; 2. 0%-0.1%: 75 points; 3. 0.1%-0.7%: 80 points; 4. 0.7%-1%: 85 points; 5. 1%-2%: 90 points; 6. 2%-3%: 95 points; 7. above 3%: 100 points |
| Decrease rate of failure outage rate | 8.76% | 1. 0% and below: 0 points; 2. 0%: 70 points; 3. empty: 85 points; 4. 0%-100%: 90 points; 5. 100%: 100 points |
| Power risk grade | 50.07% | 1. 1-4: 100 points; 2. 5: 90 points; 3. 6: 80 points; 4. 7: 75 points; 5. 8: 70 points |
| Defective number decrease rate | 8.76% | 1. 0% and below: 0 points; 2. 0%: 70 points; 3. empty: 85 points; 4. 0%-100%: 90 points; 5. 100%: 100 points |
| Unit investment reduces loss benefits | 23.64% | 1. -0.03 and below: 70 points; 2. -0.03-0: 75 points; 3. 0-0.03: 80 points; 4. 0.03-0.1: 85 points; 5. 0.1-0.4: 90 points; 6. 0.4-0.7: 95 points; 7. above 0.7: 100 points |
4. Analysis of examples

Based on the establishment of an evaluation model of the effectiveness of the risk combination governance project in Section II, the analysis and evaluation of different combinations of governance measures for the line under the scenario of lightning and wind deflection risks are being carried out. For each type of combination of governance measures, 10 sets of relevant engineering case data were selected, and a total of 40 evaluated items were substituted into the evaluation model for calculation and analysis.

The average score of each indicator in the sample is shown in Table 5. The indicator with the highest average score is the defective number decrease rate score of 97.5 points, followed by the unit investment reduces loss benefits score of 90.38 points, and the lowest score is the usable coefficient promotion rate of 73.13 points.

|                | Usable coefficient promotion rate | Decrease rate of failure outage rate | Power risk grade | Defective number decrease rate | Unit investment reduces loss benefits | Total points |
|----------------|----------------------------------|--------------------------------------|-----------------|--------------------------------|--------------------------------------|--------------|
| Average value  | 73.13                            | 87.25                                | 76.88           | 97.50                          | 90.38                                | 83.50        |
| Number of cases| 40                               | 40                                   | 40              | 40                             | 40                                   | 40           |
| Standard deviation | 5.393                          | 5.424                                | 5.511           | 4.385                          | 7.372                                | 4.64298      |

The data analysis shows that the lightning strike and wind deflection treatment project has obvious effects on improving the quality of the line; the unit investment has a higher loss benefit score, which indicates that the investment efficiency of the treatment project is higher, and the necessity of line treatment has been confirmed again. The reason for the low usable coefficient promotion rate may be that the line itself is unlikely to be shut down due to the risk of lightning strikes and wind deflections, and there is not much difference between the outage time and the planned maintenance time before and after treatment.

Table 6 shows the comparison table of the index average scores of the evaluation models for the four types of governance measures in the scenario of lightning strike and wind deflection in the overall sample scoring results.

|                | Usable coefficient promotion rate | Decrease rate of failure outage rate | Power risk grade | Defective number decrease rate | Unit investment reduces loss benefits | Total points |
|----------------|----------------------------------|--------------------------------------|-----------------|--------------------------------|--------------------------------------|--------------|
| First kind     | 71.00                            | 88.00                                | 75.50           | 96.00                          | 88.00                                | 82.62        |
| Second kind    | 73.00                            | 86.50                                | 76.00           | 99.00                          | 90.00                                | 81.98        |
| Third kind     | 73.00                            | 88.00                                | 82.50           | 98.00                          | 91.00                                | 88.03        |
| Fourth type    | 75.50                            | 86.50                                | 73.50           | 97.00                          | 92.50                                | 81.36        |
| Ensemble       | 73.13                            | 87.25                                | 76.88           | 97.50                          | 90.38                                | 83.50        |

According to the comparative analysis of the data in the table, among the four types of governance measures, the highest score of the usable coefficient promotion rate is 75.5 points for the fourth type of governance measures, and the highest score of decrease rate of failure outage rate is 88 points for the first and third types. The highest score of power risk grade is 82.5 points of the third type of governance measures. The highest score for the defective number decrease rate is 99 points for the second type of
governance measures, followed by 98 points for the third type of measures. The highest score of the unit investment reduces loss benefits is 92.5 points for the fourth type of governance measures. The highest total score is 88.03 points for the third type of governance measures, which is consistent with the analysis results of the evaluation model.

From the analysis results of the sample data of the investment benefit evaluation model, we know that in the scenario of lightning strike and wind deflection, the four types of governance measures that need to be evaluated take into account the efficiency and effectiveness of governance, and the third type of governance measures can achieve the best investment benefits. In the future combined lightning and wind deflection technical transformation projects of transmission lines, priority may be given to the third type of governance measures: overhead ground wires, changing insulator strings, lightning rods, grounding devices, installing heavy hammers, and installing wind-proof stays. In fact, this is currently the most widely used lightning strike and wind deviation control measures for transmission lines.

5. Conclusion
Theoretical analysis of lightning strike and wind deflection control measures, and the use of the established multi-risk combination evaluation model to analyze the relevant lightning strike and wind deflection risk engineering data analysis examples, the following conclusions are obtained:

1) The installation of overhead ground lines in lightning strike control measures will increase the risk of wind deflection on the line. Changing insulator strings in wind deflection measures will affect the lightning strike.

2) Lightning strike and wind deflection treatment projects have obvious effects on improving the quality of the line; higher unit investment reduction loss benefit scores indicate that the investment efficiency of the treatment project is higher, and the necessity of line management is confirmed once again. The reason for the low availability factor improvement rate may be that the line itself is unlikely to be shut down due to the risk of lightning strikes and wind deflections, and there is not much difference between the stoppage time and the planned maintenance time before and after treatment. The installation of overhead ground lines in lightning strike control measures will increase the risk of wind deflection on the line. Changing insulator strings in wind deflection measures will affect the lightning strike.

3) Among the four types of governance measures that need to be evaluated in the scenario of lightning strike and wind deflection, when adopting the third type of governance measures, the efficiency and benefit indicators of governance taking into account can achieve the best investment benefits. In the future combined lightning and wind deflection technical transformation project of transmission lines, priority can be given to the third type of governance measures: overhead ground wires, changing insulator strings, lightning rods, grounding devices, installing heavy hammers, and installing wind-proof stays.

The investment benefit evaluation model established by the combination of lightning strikes and wind deviations can be extended to other types of risk portfolios, and it can provide auxiliary support for the investment decision of the transmission channel to consider the overall effects of multiple measures.

References
[1] Jian Wang, Research on Meteorological Disaster Risk Analysis and Fault Early Warning Methods for Overhead Transmission Lines, Chongqing University (2016).
[2] Jian Wang, Xiao-fu Xiong, Zhe Li, Yun Liang, Shi-jie Weng, The Distribution of Weather-related Transmission Line Failure and its Fitting, Electric Power Automation Equipment, 2016, 36(03), pp. 109-114+123.
[3] Tian-shu Gao, Differential Lightning Protection Technology and Strategy for Transmission Lines, Plant Maintenance Engineering, 2018(21), pp. 7-8.
[4] Hao Wu, Application of Differential Lightning Protection Technology in Transmission Lines, Engineering and Technological Research, 2016(08), pp. 63+76.
[5] Qun Wang, Wei Li, Hai Yu, Cheng-ming Jin, Xin Tong, Research on the Application of Evaluation Method based on Fuzzy Analytic Hierarchy Process in Emergency Communication Plans for Power System, Power System Protection and Control, 2018, 46(22), pp. 171-177.

[6] Dong-ping Wu, Jia-feng Yuan, Jie Sun, Investment Risk Analysis of Highway Project Based on Analytic Hierarchy Process, Management and Administration, 2018(11), pp. 25-28.

[7] Dan Xu, Layout Evaluation Model of Technology Innovation Patent Based on Analytic Hierarchy Process, Science and Technology & Innovation, 2018(19), pp. 120-122.

[8] Yu-bin Liu, Jian-hua Liu, Risk Assessment of Power Networks Based on AHP and Entropy Weight Method, Electric Power Science and Engineering, 2013, 29(11), pp. 37-43.