Schedule Risk Analysis of EPC Project for Power Transmission and Transformation Project Led by Design Enterprise

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Abstract. The advantage of the EPC model is that it can alleviate the contradictions of all parties, integrate resources, and release the owners from management pressure. However, the various risks in the whole life cycle of the power transmission and transformation project are complicated, and the schedule management is the weak point of the EPC general contractor with the design as the leader, and the management of the project schedule is directly related to the profit and reputation of the general contractor. Therefore, this paper will comprehensively analyze the potential schedule risk in combination with the characteristics of power transmission and transformation engineering, and use the set pair analysis principle to establish a fault tree risk analysis model to evaluate the schedule risk of the EPC project of the power transmission and transformation project led by the design enterprise.

1. Introduction

Generally speaking, the static investment required for power transmission and transformation projects is huge, the construction period and operation and maintenance cycle of the project are long, and the risk of uncertainty is high. It is necessary to use the EPC model to save money, improve efficiency, and reduce the advantages of divergence. At present, the EPC general contractor is generally led by the design unit and actively plays a key role in the design of the project. However, due to the lack of corresponding management talents and management experience in such general contractors, in the actual schedule management process, it is not good at comprehensive planning and timely identification of risk factors, and often problems arise before they are solved. Therefore, in order to maximize the role of the EPC general contractor, which is led by the design enterprise, in the power transmission and transformation project, it is necessary to strengthen its ability to control the schedule risk \cite{1}.

In recent years, Chinese researchers have also conducted some meaningful explorations on the risks of power transmission and transformation projects and EPC models. By comparing the EPC model led by the design enterprise with the traditional model, the company uses the risk identification to establish a risk list, and uses the expert scoring method and the RPN risk importance method to quantitatively analyze the project risk \cite{2}. Li Zhihong introduced the quality influencing factors of power transmission and transformation engineering from the aspects of personnel, machinery, materials, methods and environment, and gave corresponding solutions \cite{3}. Zhang Canjiang expounded the risks of each stage through the analysis of the characteristics of EPC mode and power transmission and transformation engineering, and proposed the overall layout of the EPC mode. 

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adopted by the design institute for power transmission and transformation projects [4]. Wu Ying builds an evaluation index system for risk classification of power transmission and transformation projects, and evaluates a power transmission and transformation project based on fuzzy evaluation and proposes risk countermeasures [5]. Wang Jialu introduced risk management in the schedule management of the project, established a risk identification list, and proposed a corresponding solution [6]. Xiao Wei analyzed the risk factors of the time schedule of power transmission and transformation projects, and proposed a method from the two aspects of image control and mathematical control [7]. Wang Hao and others have shown the relationship between completion time and project completion rate by simulating the Gaussian curve for the main problems such as long construction period and imperfect management mechanism in power transmission and transformation projects [8]. However, in the EPC model risk research of various power transmission and transformation projects, the research on the project schedule risk assessment of the general contracting with the design enterprise as the leader is not perfect, and the related literature is too small, and further exploration is needed.

This paper considers that the general contracting with design enterprises as the main body has too many uncertain factors in the specific implementation stage of the project. The schedule of the project is too much interference with external factors, which makes the contractor in a passive position. Therefore, this paper will combine the characteristics of power transmission and transformation engineering, and use the set-to-fault tree model to quantify the uncertainty of schedule risk, and provide reference for the subsequent research work.

2. Analysis of the Risk Factors of the Schedule of Power Transmission and Transformation Projects

2.1. Fault Tree Analysis
Fault tree analysis is to calculate the risk degree of the whole system by constructing a logical diagram of inverted branches from top to bottom and analyzing the relationship of various influencing factors. The basic steps of its analysis are as follows:

- Determining the top event: The top event is the topmost event in the inverted tree structure created by the fault tree.
- Building a fault tree: Find all events that have an impact on the top event, determine intermediate and bottom events based on each other's logical relationships, and build a fault tree relationship diagram.
- Analysis of the fault tree: In general, the fault tree uses the downlink to describe the logical relationship between events.

![Figure 1. Schedule risk fault tree.](image)

According to the characteristics of power transmission and transformation engineering and EPC mode, the schedule risk fault tree constructed is shown in Figure 1. The intermediate events and bottom events are shown in Table 1 and 2.
2.2. Schedule Risk Factor Analysis

2.2.1. Natural Risks
Unfavorable weather conditions. If the construction time is in the “Meiyu” season in the south, then it is necessary to wait until the soil is dry after the weather to carry out the filling and excavation of the foundation pit.

Unfavorable hydrological conditions. Hydrological conditions are directly related to the risk of the project, and the high groundwater level is not conducive to the treatment of the foundation part of the project.

Unfavorable geological conditions. If a rock layer is encountered during the construction of the foundation project, the excavation must rely on explosives. These are time-consuming and laborious tasks, and it is a big problem for units with tight construction schedules.

Other risks. During the construction process, natural disasters such as earthquakes, tsunamis and hail may be encountered. Although the probability is very small, once the impact on the construction period is irreversible.

Table 1. Fault tree intermediate events.

| \( C_i \) | Intermediate event | \( C_i \) | Intermediate event | \( C_i \) | Intermediate event |
|---|---|---|---|---|---|
| \( C_1 \) | Natural risk | \( C_5 \) | Management risk | \( C_9 \) | Owner risk |
| \( C_2 \) | Social risk | \( C_6 \) | Other risks | \( C_{10} \) | Construction risk |
| \( C_3 \) | Technical risk | \( C_7 \) | Other risks | | |
| \( C_4 \) | Economic risk | \( C_8 \) | Construction risk | | |

Table 2. Fault tree bottom events.

| \( X_i \) | Bottom event | \( X_i \) | Bottom event | \( X_i \) | Bottom event |
|---|---|---|---|---|---|
| \( X_1 \) | Meteorological risk | \( X_8 \) | Policy change risk | \( X_{15} \) | Financial risk |
| \( X_2 \) | Hydrological risk | \( X_9 \) | Traffic risk | \( X_{16} \) | Monetary policy risk |
| \( X_3 \) | Geological risk | \( X_{10} \) | Design change risk | \( X_{17} \) | Incomplete procedures |
| \( X_4 \) | Earthquake risk | \( X_{11} \) | Construction drawing design rationality risk | \( X_{18} \) | Incomplete procedures |
| \( X_5 \) | Tsunami risk | \( X_{12} \) | Construction drawing design rationality risk | \( X_{19} \) | Low construction efficiency risk |
| \( X_6 \) | Hail risk | \( X_{13} \) | "Four new" technology application risks | \( X_{20} \) | Improper risk of subcontracting |
| \( X_7 \) | Material equipment price rise risk | \( X_{14} \) | Site survey risk | | |

2.2.2. Social Risk
Risk of rising prices of materials and equipment. When the price of equipment materials rises more than the capacity of the general contractor, some companies with no adjustments will choose to stop working.

Risk of policy changes. If in unstable countries and regions, we must attach great importance to the study of relevant local policies, and do not let the owner’s policy to avoid unnecessary losses.

Traffic risk. When the vehicle is restricted by the location of the project, it will affect the movement of the machinery and the transportation of materials, increase the transportation distance and cost, and lead to the delay of the construction period.

2.2.3. Technical Risk
Design risk. There are many processes in the power transmission and transformation project, and the operating environment is complex and changeable. It is often encountered that the original design does not match due to construction topography, causing design changes. Design changes will not only affect the schedule of the project, but also increase the amount of engineering.
Construction risk. The immature or unreasonable technology used in the construction will also lead to delays in the construction. The construction team should apply the technology according to national requirements and industry requirements.

2.2.4. Economic Risk
Capital risk. During the construction process, due to the shortage of funds of the owner or the general contractor, the capital chain will be broken, which will affect the schedule of the project.

Monetary policy risk. If you are in an unstable country and region, you should attach great importance to the study of local monetary policy and be familiar with the big environment of investment.

2.2.5. Management Risk
Owner's risk. The owner provide the construction site with basic site conditions before the start of construction. Otherwise, the preparation of the construction party will not delay the construction period.

Construction party risk. The insufficiency of the construction organization, or the rework of quality and safety accidents, the failure of the professional quality of the construction personnel are important factors that cause delays in the construction period.

3. Set up the Fault Tree Model of the Team

3.1. Set Pair Analysis

3.1.1. Set Pair Analysis Principle
The definition of set pair analysis: set two sets A, B, and form set pair T = (A, B). In a certain background, T has N characteristics, among which: S characters are shared by A and B, P characteristics are A and B opposite, and the remaining F=NSP characteristics are neither opposite nor identical, then T can be connected. Expressed as:

\[ u = a + bi + cj \] (1)

In the formula, \( S(T)/N \) is the same degree, \( F(T)/N \) is the degree of difference, and \( P(T)/N \) is the degree of opposition. i and j are markers used to measure the degree of difference and the degree of opposition, respectively, and are assigned according to different backgrounds. In general, \( j = -1 \), the range of \( i \) is [-1.1]. We can also abbreviate the equation (1) as:

\[ u = a + bi + cj \] (2)

It can be known from the nature of the degree of connection: \( a + b + c = 1 \). However, sometimes it is not rigorous to divide the research object into three. Therefore, the equation (2) can be developed in multiple levels, for example, multi-level development of \( b \) can be obtained.

\[ u = a + b_1i_1 + b_2j_2 + \ldots + b_ni_n + cj \] (3)

3.1.2. Connection Degree Algorithm
The algorithm of connection degree has four kinds of addition, subtraction, multiplication and division. This paper mainly introduces the principle of addition. The two degrees of association \( u_1 \) and \( u_2 \) add the following rules:

\[ u_1 + u_2 = a_1 + b_1i_1 + c_1j + a_2 + b_2j + c_2j = 2 \left[ \frac{a_1 + a_2}{2} + \frac{b_1 + b_2}{2}i + \frac{c_1 + c_2}{2} j \right] \] (4)

This equation can also be extended to the case where \( n \) connections are added.
\[ u_1 + u_2 + \ldots + u_n = n \left( \frac{a_1 + a_2 + \ldots + a_n}{n} \right) + \frac{b_1 + b_2 + \ldots + b_n}{n} + \frac{c_1 + c_2 + \ldots + c_n}{n} \]  

(5)

### 3.1.3. Fault Tree and Gate Set Pair Operator

When the probability of occurrence of the bottom event \( k \) of the power transmission and transformation project is represented by the degree of association \( u(X_k) = a_k + b_k + c_k \) of the set pair analysis, then according to the set pair analysis algorithm, the AND operator is calculated.

\[ u(X_1 + X_2 + \ldots + X_n) = u(X_1) + u(X_2) + \ldots + u(X_n) = n \left( \frac{\sum_{i=1}^{n} a_i}{n} + \frac{\sum_{j=1}^{n} b_j}{n} + \frac{\sum_{k=1}^{n} c_k}{n} \right) \]  

(6)

### 3.2. Fault Tree Set Pair Operation

According to Figure 1, using the criteria in 3.1, the bottom-up event from the bottom event starts from the bottom event to the intermediate event until the top event. Calculated as follows:

\[
\begin{align*}
C_6 &= X_4 + X_5 + X_6 = \sum_{i=4}^{6} X_i, \\
C_7 &= X_9 + X_{11} + X_{12} = \sum_{i=9}^{12} X_i, \\
C_8 &= X_{13} + X_{14} = \sum_{i=13}^{14} X_i, \\
C_9 &= X_{17} + X_{18} = \sum_{i=17}^{18} X_i, \\
C_{10} &= X_{19} + X_{20} = \sum_{i=19}^{20} X_i, \\
C_{11} &= X_1 + X_2 + X_3 + X_4 = \sum_{i=1}^{4} X_i, \\
C_{12} &= X_7 + X_8 + X_9 = \sum_{i=7}^{9} X_i, \\
C_{13} &= X_5 + X_9 + X_6 = \sum_{i=5}^{6} X_i, \\
C_{14} &= X_3 + C_{12} = \sum_{i=12}^{14} X_i, \\
C_{15} &= C_{10} + C_{11} = \sum_{i=10}^{20} X_i.
\end{align*}
\]

(7)

Thus the expression of the top event \( T \) can be obtained.

\[ T = C_1 + C_2 + C_3 + C_4 + C_5 = \sum_{i=1}^{20} X_i \]  

(8)

### 4. Case Analysis

A power transmission and transformation project adopts the EPC general contracting mode. The fault tree constructed by the impact risk factors is shown in Figure 1.

**Table 3. Bottom event set pair coefficient.**

| \( X_i \) | Bottom event | Connection degree | \( X_i \) | Bottom event | Connection degree |
|---|---|---|---|---|---|
| \( X_1 \) | Meteorological risk | [0.15, 0.67, 0.18] | \( X_{11} \) | Construction drawing design rationality risk | [0.22, 0.36, 0.42] |
| \( X_2 \) | Hydrological risk | [0.06, 0.54, 0.40] | \( X_{12} \) | Technical maturity risk | [0.18, 0.43, 0.39] |
| \( X_3 \) | Geological risk | [0.09, 0.62, 0.29] | \( X_{13} \) | “Four new” technology application risks | [0.15, 0.45, 0.40] |
| \( X_4 \) | Hydrological risk | [0.05, 0.35, 0.60] | \( X_{14} \) | Site survey risk | [0.21, 0.42, 0.37] |
| \( X_5 \) | Tsunami risk | [0.03, 0.40, 0.57] | \( X_{15} \) | Financial risk | [0.13, 0.72, 0.15] |
| \( X_6 \) | Hail risk | [0.10, 0.43, 0.47] | \( X_{16} \) | Monetary policy risk | [0.10, 0.42, 0.48] |
| \( X_7 \) | Material equipment price rise risk | [0.16, 0.35, 0.49] | \( X_{17} \) | Incomplete procedures | [0.15, 0.56, 0.39] |
| \( X_8 \) | Material equipment Policy change risk | [0.35, 0.30, 0.35] | \( X_{18} \) | Incomplete procedures | [0.18, 0.37, 0.45] |
| \( X_9 \) | Traffic risk | [0.26, 0.46, 0.28] | \( X_{19} \) | Low construction efficiency risk | [0.11, 0.68, 0.21] |
| \( X_{10} \) | Design change risk | [0.25, 0.35, 0.40] | \( X_{20} \) | Improper risk of subcontracting | [0.20, 0.31, 0.49] |

Since it is difficult to accurately calculate the probability of occurrence of the fault tree bottom event, this paper uses the degree of connection analysis to indicate the probability of occurrence of each bottom event. It is assumed that the probability of occurrence of each event is independent of...
each other and there is no duplication. The bottom event set pair coefficients of the influencing factors can be obtained by referring to the on-site data and past documents as shown in Table 3.

According to the concept of the number of contacts, the probability of occurrence of the bottom event is 

\[ u(P_k) = a_k + b_k i + c_k j (k = 1, 2, ..., 20) \]

where \( a_k \) represents the probability that the bottom event must occur, \( b_k \) indicates the probability that the bottom event may or may not occur, and \( c_k \) indicates the probability that the bottom event must not occur. According to the equation (6), the set pair AND gate operator can be obtained.

\[
\sum_{k=1}^{20} a_k = 3.13 \quad \sum_{k=1}^{20} b_k = 9.19 \quad \sum_{k=1}^{20} c_k = 7.78.
\]

In general, let \( i = 0.4 \) and \( j = -1 \). Substituting these data for \( u(T) = -0.974 \).

If the threshold of the schedule risk is set to 0.1, when \( u(T) > 0.1 \), the schedule risk of the project is very high. The general contractor takes necessary measures to reduce, transfer and retain the risk. To prevent it from being converted to a higher level. For the results of this paper, the schedule risk of the EPC mode in this power transmission and transformation project is at a relatively small risk level, and the general contractor should continue to conduct reasonable control.

5. Conclusion
This paper analyzes the factors affecting the schedule of EPC transmission and transformation projects led by design enterprises, constructs a risk fault tree, and establishes a schedule risk assessment model based on the principle of set pair analysis. It is hoped that the general contracting mode with design as the leader will play a certain enlightenment in the follow-up research in the field of power transmission and transformation. At the same time, further research is needed on the dynamic conversion of risks and the critical path.

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