Study On Dynamic Simulation Of 1250mm² Conductor Stringing System

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Abstract—In order to study the mechanical properties of 1250mm² conductor in the process of stringing. The numerical simulation results show that the maximum axial tension of conductor and traction rope is 1.2 ~ 1.4 times of the theoretical calculation value. The amplification coefficient of traction overload protection is improved.

1. INTRODUCTION
With the rapid development of Chinese electric power industry, the contradiction between transmission capacity and line tension tends to ease with the emergence of large-sectional conductor. In the existing construction process, the conductor is usually regarded as completely flexible, so the influence of the conductor stiffness on the stringing of the conductor is ignored. Feng yingchun comprehensively considered the electrical characteristics, mechanical characteristics and economic aspects of 1000mm² large-sectional conductor, demonstrated the use of larger transmission capacity of uhvdc transmission lines in the future [1]. Wang dongyang studied the suspension mode of stringing pulley. According to the characteristics of 1250mm2 conductor, the suitable pulley and conductor hanger were developed by experiment. It greatly improves the spreading efficiency and makes the construction of wires safer, more efficient and safer [2].

The calculated result of wire stiffness is drag in numerical simulation. when the conductor is stringing on the large elevation span, the conductor passes through the side of the pulley with a lower horizontal height, the conductor on the side with a lower height is easy to rise [3]. The study of the dynamic tension change of the conductor when the conductor goes through the pulley on the large elevation span can provide reference for the problems of conductor jump in the construction, such as considering the conductor as a completely flexible catenary. On the basis of summarizing the previous dynamic simulation of tension wire, this paper analyzes the dynamic tension fluctuation of conductor in the initial stage of traction and the moment when the tractional plate passes the pulley, so as to provide reference for the construction of 1250mm² large-section conductor.
2. MODEL ESTABLISHMENT OF THE LARGE ELEVATION SPAN

2.1. Mechanical modeling
The undulations of the terrain or the difference in the height of the towers result in the conductor suspension points of the adjacent two towers not at the same horizontal height. The height between two suspension points of adjacent towers is called altitude difference, and the distance between two suspension points is called skew span. In the cabling design of large elevation span, in order to make it form large altitude difference, the altitude difference ratio is 0.2. The formula of conductor length in the span is calculated as formula (1).

\[ L = \frac{l}{\cos \psi} + \frac{\omega^2 l^3}{24 H_i} \]  

\( L \) is the line length required for \( i \) span in the construction, m; 
\( l \) is the \( i \) span length in the construction, m; 
\( \psi \) is the angle between the horizontal line connecting the support point of \( i \) span in the construction, \(^\circ\); 
\( \omega \) is the gravity of stringing line per unit length, N/m; 
\( H \) is the horizontal stringing tension of \( i \) span in the construction, N.

No. 1 tower and no. 2 tower are an isolated span, using a tension stringing method of one pull two. The left side of tower 1 is set as a tension field, and the horizontal distance from the conductor outlet of tension machine to the pulley of tower 1 is 30m, with the altitude difference of 8m. The horizontal distance between tower 1 and tower 2 is 120m, and the altitude difference is 24m. The right side of tower 2 is set as a traction field, and the horizontal distance between the pulley of tower 2 and the entrance of traction rope of the tractor is 35m, and the altitude difference is 8.5m. The pulley of No. 2 tower suspension point is 48m from the ground. The traction speed is 1m/s and the simulation time is 120s. The mechanical model is shown in figure 1.

![Mechanical model of large elevation span](image)

Figure 1. Mechanical model of large elevation span.

2.2. Numerical modeling
In the simulation, Bushing connection mode is applied to connect the conductor and traction rope respectively. Then add the contact between the conductor and the traction rope with the tension machine, the tractor and the pulley. The Bushing force connection mode fully takes into account the various stiffness of conductor and traction rope, which can reflect the mechanical characteristics of stretching, shearing and torsion in the simulation.

Bushing connection can endue the interaction force between adjacent cylindrical elements, and apply a flexible force between two components by defining 6 components of force and torque \( \{ F_x, F_y, F_z, T_x, T_y, T_z \} \), while the stiffness and other characteristics of 1250mm² conductor can be endue in the conductor and traction rope model through these six components. Actual Bushing force connection.

The calculation formula of Bushing force is as follows: (2).
\[
\begin{bmatrix}
F_x \\
F_y \\
F_z \\
T_x \\
T_y \\
T_z
\end{bmatrix} = \begin{bmatrix}
K_{11} & K_{12} & K_{13} & 0 & 0 & 0 \\
K_{21} & K_{22} & K_{23} & 0 & 0 & 0 \\
K_{31} & K_{32} & K_{33} & 0 & 0 & 0 \\
0 & 0 & 0 & C_{0} & 0 & 0 \\
0 & 0 & 0 & 0 & C_{1} & 0 \\
0 & 0 & 0 & 0 & 0 & C_{2}
\end{bmatrix}
\begin{bmatrix}
v_x \\
v_y \\
v_z \\
\theta_x \\
\theta_y \\
\theta_z
\end{bmatrix} + \begin{bmatrix}
F_x \\
F_y \\
F_z \\
T_x \\
T_y \\
T_z
\end{bmatrix}
\]  

(2)

\(R\) is the relative line displacement of the I-Marker coordinate system relative to the J-Marker coordinate system;

\(\theta\) is the relative angular displacement of the I-Marker coordinate system relative to the J-Marker coordinate system;

\(v, w\) is the relative velocity and the relative angular velocity of the I-Marker coordinate system relative to the J-Marker coordinate system;

\(F_x, T_x\) is the initial force and moment;

\(K, C\) is the coefficient of rigidity and damping.

By formula (2), the flexible force between the two cylindrical micro section is related to relative displacement, the relative angular displacement, relative velocity and relative angular velocity. To conform the conductor and the traction rope winding, vibration characteristics and dynamic characteristics to actual engineering, we have to determine Bushing connection force between small micro section of related parameters (K and C, etc.). The stiffness coefficients of tensile, shear, torsion and bending are calculated in the following formula (3).

\[
\begin{align*}
K_{11} &= \frac{EA}{L} \\
K_{22} &= K_{11} = \frac{GA}{L} \\
K_{33} &= \frac{Gd^4}{32L} \\
K_{44} &= K_{55} = \frac{EI}{L} = \frac{Emd^4}{64L}
\end{align*}
\]  

(3)

\(E\) is the elasticity modulus of the traction rope and the conductor, respectively 181.4 GPa and 65.2 GPa;

\(G\) is shear modulus of traction rope and conductor, 69.8 GPa and 28.46 GPa;

\(A\) is cross-sectional area of traction rope and conductor;

\(L\) is the length of each traction rope and conductor, 0.2m;

\(I\) is moment of inertia of each traction rope and conductor;

\(d\) is diameter of traction rope and conductor, mm.

The tension stringing system adopts the method of one pull two, requiring the length of the traction rope to be 133m and the length of the conductor to be 300m. It is composed of small cylindrical elements with different diameters of 200mm.

3. NUMERICAL SIMULATION ANALYSIS

3.1. Simulation correctness analysis

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

According to the approximate relation formula (4) of the axial tension of the traction rope, the traction force of the tractor and the tension mechanism tension [4]. The axial tension \(T_i\) of traction rope drawn on the left side of No.1 tower’s pulley and the axial tension \(T_i\) of traction rope drawn on the right side of No.1 tower’s pulley were calculated. The left side of No.2 tower pulley traction rope axial tension \(T_i\), the right side of No.2 tower pulley traction rope axial tension \(T_i\). The axial tension \(T_i\) of a single conductor on the left side of No.1 tower, and the axial tension \(T_i\) of a single conductor on the
right side of No.1 tower. The axial tension $T_2$ of a single conductor on the left side of No.2 tower, and the axial tension $T_2$ of a single conductor on the right side of No.2 tower.

$$T_i = m e_i e_0^{-i} (T_i + wh_i / \cos \phi_i) + w_0 (\pm e_i e_0^{-i} h_2 / \cos \phi_i + \cdots + h_i / \cos \phi_i)$$

$$T_i = m e_i e_0^{-i} (T_i + wh_i / \cos \phi_i) + w_0 (\pm e_i e_0^{-i} h_2 / \cos \phi_i + \cdots + h_i / \cos \phi_i)$$

$$T_i = m e_i e_0^{-i} T_2 + m w (e_i e_0^{-i} h_2 / \cos \phi_i + e_i e_0^{-i} h_2 / \cos \phi_i + \cdots + h_i / \cos \phi_i)$$

$$T_i = m e_i e_0^{-i} T_2 + m w (e_i e_0^{-i} h_2 / \cos \phi_i + e_i e_0^{-i} h_2 / \cos \phi_i + \cdots + h_i / \cos \phi_i)$$

$T_i$ is the axial tension of the single conductor, kN;
$m$ is the self-gravity per-meter of each conductor, N/m;
$\phi_i$ is the height difference Angle of two suspension points in i tower;
$w$ is the self-gravity per unit length of each sub-wire, N/m;
$w_0$ is self-gravity per unit length of traction steel rope, N/m;
$\varepsilon$ is the damping of pulley to conductor, 1.015;
$h_i$ is the suspension point height difference of i tower, m.

Extract the bushing force of traction rope and conductor. The theoretical calculation results are compared with the simulation results to verify the correctness of the simulation.

**TABLE 1 THEORETICAL CALCULATION AND SIMULATION RESULTS**

| Position tension | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_11$ | $T_12$ | $T_21$ | $T_22$ |
|------------------|-------|-------|-------|-------|--------|--------|--------|--------|
| Theoretical value| 17613 | 18006 | 18520 | 18810 | 8821   | 8954   | 9827   | 9965   |
| Part 554         | 17921 | 18456 | 18861 | 19158 | ---    | ---    | ---    | ---    |
| error            | 1.1%  | 2.5%  | 1.9%  | 2.4%  | ---    | ---    | ---    | ---    |
| Part 740         | ---   | ---   | ---   | ---   | 8542   | 8792   | 9735   | 9814   |
| error            | ---   | ---   | ---   | ---   | 3.6%   | 2.2%   | 1.0%   | 1.5%   |
| Part 750         | ---   | ---   | ---   | ---   | 8553   | 8734   | 9724   | 9875   |
| error            | ---   | ---   | ---   | ---   | 3.6%   | 2.2%   | 1.1%   | 1.2%   |

Note: Part554 is bushing of traction rope, Part740 is bushing of No.2 conductor, and Part750 is bushing of No.1 conductor.

According to the results in table 1, the numerical simulation results are in good agreement with the theoretical calculation values, and the errors are all within 5%, indicating that the simulation results have good reliability and can be used for the analysis of tension stringing in engineering.

### 3.2 Dynamic tension analysis

According to the analysis of dynamic tension of conductor and traction rope, the maximum tension moment is usually at the initial moment or when the traction plate passes the pulley. The axial tension of each bushing of conductor and traction rope is compared, as shown in Table 2. In this way, the
relationship between the maximum axial tension and the calculated value is compared. The amplification coefficient of axial tension is proposed for the theoretical formula, which is as follows (5):

$$\alpha = \frac{T_{i,\text{max}}}{T_i}$$  \hspace{1cm} (5)

$T_{i,\text{max}}$ is the maximum axial tension at position $i$, N;

$T_i$ is the theoretical value of axial tension at position $i$, N.

| Position | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|
| Theoretical value | 17613 | 18006 | 18520 | 18810 | 8821 | 8954 | 9827 | 9965 |
| Part 9 | 23238 | 24247 | 24445 | 25467 | ---- | ---- | ---- | ---- |
| $\alpha$ | 1.32 | 1.35 | 1.33 | 1.36 | ---- | ---- | ---- | ---- |
| Part 346 | 23568 | 24557 | 24415 | 25705 | ---- | ---- | ---- | ---- |
| $\alpha$ | 1.33 | 1.37 | 1.33 | 1.37 | ---- | ---- | ---- | ---- |
| Part 748 | ---- | ---- | ---- | ---- | 10877 | 11325 | 11825 | 12820 |
| $\alpha$ | ---- | ---- | ---- | ---- | 1.23 | 1.26 | 1.21 | 1.28 |
| Part 750 | ---- | ---- | ---- | ---- | 10917 | 11372 | 11875 | 12855 |
| $\alpha$ | ---- | ---- | ---- | ---- | 1.25 | 1.27 | 1.20 | 1.30 |

Note: Part9 and part 346 are bushing of traction rope, Part748 is bushing of No.2 conductor, and Part750 is bushing of No.1 conductor.

Through the numerical simulation study on the stringing of pull two mode, the tension fluctuates greatly in the initial moment or when the traction plate passes the pulley. The tension amplification ratio is between 1.2~1.4. The amplification coefficient of traction overload protection can be obtained, $\alpha = 1.4$.

According to the amplification coefficient of traction overload protection, the formula is as follows. In order to ensure that the tractor can continue to pull under the tension fluctuation of the normal operation of the stringing system, and can stop pulling when the tension increases sharply under the abnormal working state of the stringing system. The formula of traction overload protection value is as follows (6)[5] :

$$[T_F] = \alpha(T_F)_{\text{max}}$$  \hspace{1cm} (6)

4. Conclusion
Based on the parameters of the actual engineering, this paper establishes a numerical simulation model of the large elevation span. The theoretical values of tension at each position of conductor and traction rope are obtained by theoretical calculation. The axial tension of each section of conductor and traction rope in the initial traction period and when the traction plate passes the pulley is 1.2~1.4 times of the calculated value in theory. It is suggested that the amplification coefficient $\alpha$ of the axial tension of conductor and traction rope is 1.4.

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References
[1] Feng Yingchun. Research on large section conductor construction technology of uhv transmission line[J]. Electric power information, 2014, 2(2): 85-87.
[2] Wang Dongyang. Study on the suspension method of 1250mm² large section conductor pulley[J]. Science and technology innovation guide, 2015, 28(1): 107-109.
[3] Xv Shou-qi. Study on Large Cross-section Conductor Construction Techonology[J]. Electric Power Construction, 2009, 30(1): 35-37.
[4] Li Bo-zhi. Technical manual for overhead transmission line construction[M]. 1st ed. Beijing: China Electric Power Press, 2005: 287-293.
[5] Li Bo-zhi. 500 kV transmission line construction technology[M]. 1st ed. Beijing: China Electric Power Press, 1999: 147-163.