

Construction Technology of Tower Erection with Mobile Crane Adopting the Relaying Auxiliary Device

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Abstract: The use of cranes to complete the tower assembly in the plain and hilly areas has been widely used in the construction of the tower assembly. But its construction safety hazards are obvious. Tower erection by using crane based on docking device is an advanced construction technology in the field of power grid construction at home and abroad. It has the advantages of high construction efficiency and good safety. This construction technology has certain requirements on construction technology, supporting docking auxiliary devices, and crane operator skills. In this paper, the design and feasibility of the docking device and construction technology are discussed in combination with the tower erection construction of Qinglong-Liangzhuang 220kV line project. Successful application through engineering shows: The docking device is safe and reliable, and the construction process is reasonable and feasible. This experience provided reference for the erection of other types of transmission towers using crane based on docking device in power grid construction.

Keywords: Power transmission line, Relaying auxiliary device, Construction device; Tower erection with crane.

1. Introduction

The erection of iron tower of power transmission line is an important link with big work quantity, high construction difficulty and many technical links during the power grid construction. Conducting iron tower erection of power transmission line with mobile crane is a kind of construction technology of iron tower erection widely adopted in the plain and hilly area. However, with the large-area using of tower erection with mobile crane, the construction safety hazards are also increasingly prominent [1]. When the lifting boom of the mobile crane is lifting tower materials, several construction personnel shall conduct installation operation at the lower part of the lifted tower materials at height [2-3]. In this case, if there is any fault of mobile crane, the safety of construction personnel will be threatened and the economic loss will also be caused easily.

To prevent construction personnel from constructing below the lifting boom with load at height, and to reduce the number of operators on the tower and the number of times going up the tower during the construction process of iron tower erection with mobile crane, and to shorten the operation duration on tower, the State Grid Corporation of China has organized relevant departments to research the construction technology of segmented tower erection with mobile crane based on relaying auxiliary device by combining the construction experience of segmented tower erection with helicopter. This construction technology is shown as below: install relaying auxiliary devices at the upper and lower connections of the lifted tower section during the segmented lifting of iron tower based on the concept of segmented tower erection and relying on the auxiliary system, so as to guarantee that the lifted tower section can slide into the preset position automatically during the relaying of tower sections, thus realizing that the tower materials can be in place without assistance of operation personnel at height during the tower erection.

By combining the construction project of segmented tower

erection with mobile crane in the Qinglong – Liangzhuang 220kV Line Engineering, this Paper discusses and researches the construction technology of segmented tower erection with mobile crane adopting relaying auxiliary device.

2. Construction Characteristics of Tower Erection with Mobile Crane Adopting Relaying Auxiliary Device

At present, the frequently adopted construction methods for iron tower erection of overhead power transmission line include construction of iron tower erection with holding pole, construction of tower erection with regular mobile crane, construction of tower erection with tower crane dedicated for tower erection and construction of tower erection with helicopter [4]. During the construction of the tower erection with holding pole, it is necessary to set multiple passes of control rope and stay wire for the holding pole, there are many construction participants, the requirements for cooperation among personnel are relatively high [5], while the safety is relatively poor. For the construction of tower erection with tower crane dedicated for tower erection, the safety is high, but the overall construction efficiency is lower than that of the tower erection with holding pole, and it is only applied to the erection site where the traffic is convenient or the erection site of Daxing iron tower [6]. The construction of tower erection with helicopter is featured by relatively high construction efficiency and high safety, but its construction cost is extremely high, so it hasn't been widely applied at home [7].

Compared with the construction technology mentioned above, the construction of tower erection with regular mobile crane adopts mobile crane for lifting; the mobile crane can shift and be in place conveniently, and its actions such as lifting, amplitude variation and rotation are flexible; it can enter the lifting status without special preparation or erection. Therefore, it has become the preferred mode of tower erection construction of various construction units in the plain and hilly area [8]. However, along with the large-area using of the

mode of tower erection with mobile crane, its construction safety hazards are also increasingly prominent. For the existing mode of tower erection with mobile crane, when the lifting boom is lifting tower materials, several construction personnel are required to conduct installation operation at the lower part of the lifted tower materials. In this case, if there is any fault of mobile crane, the safety of construction personnel will be threatened and the economic loss will also be caused easily.

Compared with construction of tower erection with regular mobile crane, the construction of tower erection with mobile crane adopting relaying auxiliary device has the following characteristics and advantages: (1) Make the lifted tower section slide into its position automatically via the relaying auxiliary device, no operation personnel at height is required to assist below the tower section, which reduces the construction safety risk, and the construction safety is high. (2) Complete the assembly of iron tower or tower section on the ground, so as to reduce the time consumption of auxiliary in-place of operation personnel at height and enhance the working efficiency of iron tower lifting.

See Figure 1 for schematic diagram of the calculation of lifting height of mobile crane. Under the working condition that the main boom is lifting, see the Formula 1 for the calculation method of the height of iron tower lifted by the mobile crane.

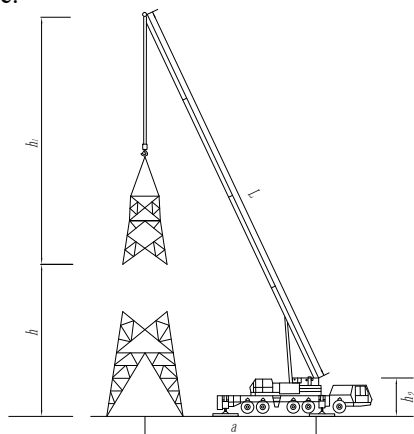


Figure 1. Schematic Diagram of Calculation of Lifting Height

$$h = \sqrt{l^2 - a^2} - h_1 + h_2 \quad (1)$$

Wherein:

h - Height of iron tower lifted by mobile crane, m;

l - Maximum extension of main boom of mobile crane, m;

a - Working amplitude of mobile crane, m;

h_1 - Vertical height of middle connection part for lifting, m;

h_2 - Ground clearance of hinged point of lifting boom of mobile crane, m.

3. Research on Relaying Auxiliary Device

During the construction process of tower erection with mobile crane adopting relaying auxiliary device, when the lifted tower section is lifting or lowering, the function of the relaying auxiliary device is to enhance the misplace compatibility of relaying part of tower section, so as to guarantee that the lifted tower section can slide into the preset position smoothly [9]. Meanwhile, the relaying auxiliary device is installed and fixed at the relaying position between

the lifted tower section and the tower section which has been in-place; it is necessary to not only guarantee that the installation is firm, but guarantee that various parts of the relaying auxiliary device and accessories such as the connection bolt will not intervene or impact the relaying process. Meanwhile, the relaying auxiliary device shall possess relatively high relaying compatibility. Therefore, the design of relaying auxiliary device is very important.

The design of relaying auxiliary device shall meet the following requirements:

3.1. Limit & Positioning Function

The relaying auxiliary device shall limit the position of the lifted tower section during the relaying, so as to make sure that the lifted tower section can be in place smoothly. Meanwhile, it shall position the lifted tower section, and guarantee that the connection screw holes of the lifted tower section, connection angle steel and the tower section which has been in-place are of accurate alignment after being in place, so as to facilitate the subsequent installation of connection bolts conducted by the construction personnel.

3.2. Automatic Guide Function

The relaying auxiliary device shall play its role of automatic guide to the lifted tower section during the relaying, so as to guarantee that the lifted tower section can slide into the design position automatically without artificial assistance, and guarantee that the subsequent construction can be conducted smoothly.

3.3. Support & Bearing Function

The relaying auxiliary device shall have the function of support & bearing; after the lifted tower section is in place and before the construction personnel go up the tower for installation of connection bolts, it shall support the relaying auxiliary device temporarily, and shall be able to bear the weight of the lifted tower section. Meanwhile, the relaying auxiliary device shall be able to bear the collision of the lifted tower section during the relaying.

Besides design requirements mentioned above, it is still necessary to design control rope for the relaying auxiliary system, and then the construction personnel can control the position and posture of the lifted tower section in the air on the ground conveniently, thus preventing the lifted tower section from swing or waggle with great amplitude in the air.

According to the design requirements mentioned above and by combining the structural characteristics of the iron tower in the Qinglong – Liangzhuang 220kV Line Engineering, the matched relaying auxiliary device has been researched and developed, as shown in Figure 2.

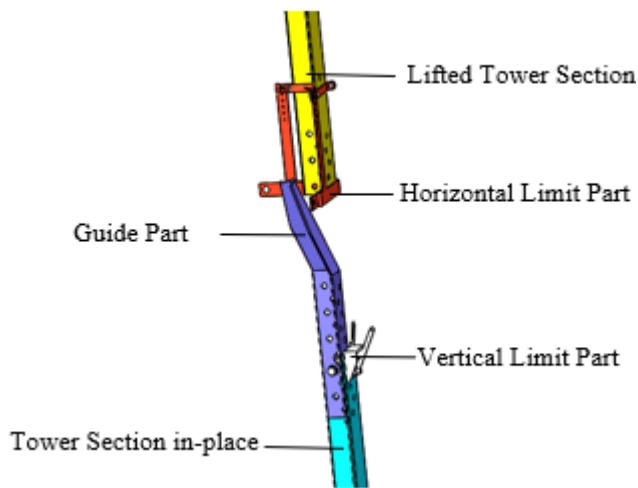


Figure 2. Schematic Diagram of Relaying Auxiliary Device

During the relaying, the horizontal limit part interacts with the guide part to limit the horizontal position of the lifted tower section and plays its role of guiding. The vertical limit part has the function of bearing and it can limit the lifted tower section in the vertical position. All parts act commonly to guarantee that the lifted tower section can reach the preset position.

4. Research on Construction Technology of Tower Erection with Mobile Crane Adopting Relaying Auxiliary Device

To guarantee the construction quality and construction safety of the Engineering, it is necessary to conduct research on the construction technology of tower erection with mobile crane adopting relaying auxiliary device, analyze the construction flow to be completed during the construction and conduct technical disclosure about the construction scheme to the driver of mobile crane and the operation personnel on the ground, thus guaranteeing smooth liaison among various parties during the construction.

By combining the tower erection with mobile crane adopting relaying auxiliary device in the Qinglong – Liangzhuang 220kV Line Engineering, main construction steps are shown as below:

1) Before construction, it is required to complete relevant technical preparation, such as determining the scheme of segmentation of iron tower, preparing construction scheme, completing relevant lifting calculation, etc. Meanwhile, it is required to map the on-site plane layout and complete the appearance inspection and trial assembly of the relaying device.

2) Operate the mobile crane to enter the site, inspect the status of counter weight, and determine the status of each working device of the crane; make sure that the mobile crane can be grounded reliably during the operation; finally, keep the driving and operation site level and solid, and the mechanical inclination degree cannot exceed relevant rules.

3) Complete the assembly of the lifted tower section in the assembly region on the ground and then measure dimensions, and make sure that the connection positions and dimensions of the lifted tower section meet the requirements for relaying. To prevent the root part of the tower section from bending and deformation due to overstress of the part contacting the ground when the tower section is rising, it is required to install

a tower leg boot at the root of the tower section.

4) Complete the assembly of the bottom tower section piece by piece or in the way of overall lifting. In addition, install a set of guide part and vertical limit part at the top end of 4-corner main material of the bottom tower section, and it is required to guarantee that various parts mentioned above are all installed accurately and stably. After completion of installation, fasten the foundation bolts and conduct grounding installation well.

5) The main lifting hook is connected to the binding point of the lifted tower section with 2 pieces of steel wire rope of the same length in the way of 4-point lifting, so as to prevent the lifted tower section from twisting during the lifting. Operate the mobile crane to complete the rising of the lifted tower section, remove the tower leg boot, and complete the installation of horizontal limit part at the bottom of the 4-corner main material. In addition, connect a limit rope between two adjacent horizontal limit parts, so as to provide the limit of a larger scope for being in-place of the lifted tower section. The limit rope shall be loosened slightly, so as to prevent the main material of iron tower from deformation thus making change of dimensions. In addition, it is necessary to connect a control rope at the ear plate of horizontal limit part.

6) After completing the connection and installation mentioned above, operate the mobile crane to lift the lifted tower section to the point a certain distance vertically above the tower section which has been in-place, control the posture of the lifted tower section via the control rope, and make the center of the lifted tower section align with the center of the tower section which has been in-place.

7) Operate the mobile crane to drive the lifted tower section to lower slowly at a certain speed, and under the interaction between the guide part and the horizontal limit part, the lifted tower section will fall to the bearing platform of the vertical limit part, thus completing the relaying in-place of the lifted tower section and the tower section which has been in-place.

8) After the lifted tower section is relaying in-place, unfasten the binding point and then shift the lifting boom away. The construction personnel shall go up the tower and complete installation and fastening of partial bolts by using the reserved holes of guide part, and then remove the horizontal limit part, vertical limit part and guide part successively, and complete the fastening of all connection bolts.

9) Refer to the above mentioned steps for erection of the subsequent tower sections, thus completing the erection construction of the whole-base iron tower.

10) The mobile crane can leave the site after the erection of the whole-base iron tower is completed; in addition, it is required to supplement the auxiliary materials and accessories for unfastening in time, and re-tighten the bolts at the same time. Finally, the site shall be recovered well.

5. Engineering Examples and Application Analysis

Relying on the Qinglong – Liangzhuang 220kV Line Engineering, the construction of tower erection with mobile crane adopting relaying auxiliary device is applied to the engineering. In this Engineering, the applied tower type is the 2B5-J1-30 type angle tower, with nominal height of 30m, full height of 39.5m and total weight of iron tower of about 11,564kg. See Figure 3 for the schematic diagram of the iron tower.

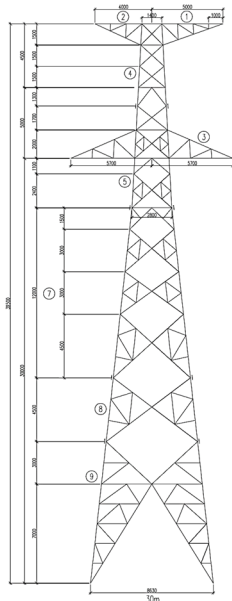


Figure 3. Iron Tower Applied to the Engineering

To verify working performances of the relaying auxiliary device and reduce the risk of tower erection, and considering the weight and height of each tower section as well as the number of lifting times and the rental fee of mobile crane, the iron tower segmentation scheme is determined as shown in Table 1.

Table 1. Tower Segmentation Scheme

No. of Lifted Tower Section	Composition of Tower Section	Installation Height (m)	Installation Weight (t)
1	8+9	14.5	4.669
2	1+2+3+4+5+7	25	6.895

After being applied to the Engineering, it is proved that the construction process of tower erection with mobile crane adopting relaying auxiliary device is safe, efficient and smooth, and the common function of various parts of the relaying auxiliary device guarantees the rapid, accurate and automatic relaying in-place in the air of the lifted tower section, which boosts the technical progress of iron tower erection construction of overhead power transmission line in our Country substantially, and lays a solid foundation for the promotion and application of construction technology of tower erection with mobile crane adopting relaying auxiliary device.

The comparison between the construction of tower erection with mobile crane adopting relaying auxiliary device and the construction of tower erection with regular mobile crane is as shown in Table 2.

Table 2. Comparison of Construction of Tower Erection with Mobile Crane

Mode of Tower Erection	New Technology	Normal Technology
Height of Iron Tower (m)	38	
Weight of Iron Tower (t)	28.1	
Personnel Allocation	16	20
Lifting Duration (h)	7	8.2
Safety	Relatively good	Ordinary

Through comparison, it can be known that the construction technology of tower erection with mobile crane adopting relaying auxiliary device has the following advantages:

1) When the lifted tower section is in-place by using the relaying device, no operation personnel at height assists below the tower section, which prevents the operation personnel at height from operating below the lifted object and lifting boom, thus reducing the construction safety risk and enhancing the safety of tower erection construction.

2) For the iron tower erection, no operation personnel at height is required to assist the tower materials to be docked in place, and it is only necessary to install connection bolts and remove the relaying device at height, thus reducing the time consumption of the operation personnel at height in assisting in-place, and enhancing the working efficiency of iron tower lifting by about 15%.

6. Conclusion

With regard to the relaying auxiliary device researched in this Paper, all parts are in good mechanical properties, and are able to guarantee the accurate, safe and automatic relaying in-place of the lifted tower section in the air, without assistance of operation personnel at height. Meanwhile, in the regions such as the plain and hilly area where the tower erection can be constructed with mobile crane, the construction of iron tower erection with mobile crane adopting relaying auxiliary device can obviously enhance the construction safety and efficiency of tower erection. This construction technology has a wide promotion and application prospect in the construction field of overhead power transmission line.

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References

- [1] Wang C L, Jin Y K, Zhang J, et al. Optimization and Application of the Assembly Scheme of $\pm 1100\text{kV}$ UHVDC Transmission Line Tower Crane [J]. QINGHAI ELECTRIC POWER, 2019, 38(1): 44-47.
- [2] Qin J, Feng L, Wan J C, et al. Research on Parameter Design of Special Mobile Crane for Transmission Line Tower [J]. HOISTING AND CONVEYING MACHINERY, 2016, (11): 21-25.
- [3] Xiao H T. Research and application of tower formation technology for UHV transmission line [J]. CONSTRUCTION MACHINERY, 2021, (546): 35-38.
- [4] Geng P P. Research and application of tower formation technology for UHV transmission line Technology of erecting transmission line tower by crane [J]. Lifting and hoisting, 2014, (12): 41-43.
- [5] Fu H F, Lu Y, Luo Y L. Cost Research of Ground Derrick for Tower Erection in UHV Transmission Line Project [J]. Electric Power Survey & Design, 2022, 1(58): 5-10.
- [6] Xia Y J, Qin J. Design and Optimization of Special-Purpose Tower Crane for Large Tower of Transmission [J]. Mechanical Engineering & Technology, 2015, 4(2): 101-107.
- [7] Cheng J H, Wang L, Ding P J. Application Research on Key Construction Technologies of Large Transmission Angle Steel

- Tower Hoisting by Helicopters [J].ZHEJIANG ELECTRIC POWER, 2019, 38(6): 89-93.
- [8] Qin J, Feng L, Wan J C, et al 2016 HOISTING AND CONVEYING MACHINERY pp 21-25.
- [9] Miao Q, Huang K X, Xia Y J. Construction Technology for the Erection of Overhead Transmission Tower Using Helicopters [J]. CONSTRUCTION TECHNOLOGY, 2012, 41(379): 96-98.