High-altitude fall prevention method and device for power transmission line

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Abstract. This paper analyzes the structure of transmission line towers and live working conditions, and draws conclusions on the importance and necessity of studying the methods and devices of high-altitude fall prevention for transmission lines. Combining the actual situation of the pole and tower, in view of the poor manufacturing technology of the pole and tower anti-falling track, the size of the anti-dropping device and the track are not matched, and the connection point is misplaced, a new type of adjustable anti-dropping device is developed to address the cross-arm movement of personnel during live work. The alternate use of backup protection ropes and seat belts is cumbersome. An alternative safety rope was developed. Aiming at the transmission line towers without anti-falling tracks, a drone-based high-altitude fall prevention method was developed, and an anti-fall manipulator for high-altitude operations.

1. Introduction
The transmission line poles and towers of our country are composed of cement poles and iron towers, and the height is basically above 20 meters, and some high poles are nearly 100 meters [1]. Operators generally reach dozens of high working positions by climbing with bare hands and vertically arranging foot nails along the tower body. During the process of up and down the tower, there is no protective measure to prevent personal fall, and safety accidents are very likely to occur. Falling, there is little hope of survival. In order not to lose the protection during the displacement of the cross arm of the pole and tower, the operator needs to alternately use the back-up protection rope and the seat belt, which is cumbersome to operate and easily lead to unstable mounting and loss of protection [4]. With the improvement of people’s safety awareness, track or rope fall prevention devices have gradually appeared, but due to the high cost, at present, only some UHV and training lines have installed fall prevention rails [2], and none of the 500kV and below transmission line towers have been installed. Fall prevention track.

Although some poles are equipped with anti-falling rails, the existing anti-falling devices cannot be used normally due to poor product manufacturing technology and poor quality on-site installation. In order to ensure the safe and stable operation of transmission lines and ensure the normal use of electricity for national production and life, line maintenance personnel face great personal safety challenges. Therefore, in view of the different characteristics of power transmission lines, it is of great significance to explore
the methods of power transmission line fall prevention, and to develop a complete set of anti-fall devices with simple structure, complete functions, and safety and reliability.

2. Adjustable fall arrester
Some power transmission towers have anti-falling rails to ensure the safety of maintenance personnel. However, due to poor product manufacturing technology and poor on-site installation quality, most of the existing anti-falling devices cannot be used normally [3].

A new type of adjustable anti-dropping device can adjust the width of the rail inside the anti-dropping device, which can solve the problem of poor track manufacturing technology and mismatch of the size of the anti-dropping device with the track, and can also solve the problem of unqualified installation quality and rail connection points. The problem of dislocation.

After the adjustable fall arrester turns the knob to obtain the required inner rail width, the rail width locking function can also avoid the change of the inner rail width of the fall arrester. At the same time, considering that when the operator leaves the fall arrester and enters the working position, the fall arrester may fall along the track, resulting in the loss of safety protection measures during the lowering of the tower, and the position locking function of the fall arrester is added to prevent it from falling.

![Figure 1 The physical diagram of the adjustable anti-dropping device for high-altitude operations on transmission lines](image1)

3. Alternate safety rope
Regarding the cumbersome problem of alternate use of backup protection ropes and safety belts during live operation, an alternative safety rope that relies on personal safety belts can be used as a new device for preventing falls during high-altitude operations on transmission lines.

The working principle of the alternate fall protection rope is that one end of the two safety ropes is fixed to the chest buckle of the personal safety belt, and the other end reaches the palms along the arm and is attached with a safety hook. The safety hook is attached during the climbing process. The hook is hung on a reliable tower and can be used for horizontal and vertical movement of high-altitude workers to achieve the effect of falling prevention. The device can be widely used in live high-altitude operations such as lines and substations.

![Figure 2 Alternate safety rope](image2)
4. High-altitude anti-fall method based on UAV
The drone-based high-altitude fall prevention method uses the drone to lift the angle iron block to install
the angle iron block on the transmission line tower cross arm, and pull a personal back-up protection
rope from the angle iron block. Back-up protection for operators when they get on and off the poles, the
angle iron pulley adopts a gravity automatic locking device, which is suitable for 7-shaped angle irons
and inverted 7-shaped angle irons, and can be mounted on any part of the power transmission tower,
and has a wide range of applications.

Among them, the angled iron pulley is composed of the UAV pylon, the steering gear, and the main
body of the pulley. The assembly diagram is shown in Figure 4.

1. The UAV pylon is designed according to the DJI UAV M600, with a load capacity of 11 kg, which
is installed on the UAV body;
2. The drone operator operates the drone to be mounted on the steering gear of the hanging angle
iron block;
3. The UAV hoisting angle iron pulley is installed on the cross arm of the transmission line tower,
and the lower pulley pulls a Φ8 traction rope;
4. Ground operators use a Φ8 traction rope to pull a Φ14 insulated rope as a backup protection rope
for the operators on the tower
5. After the completion of the operation, the drone operator will operate.

5. Fall prevention manipulator for high altitude operation
For power transmission towers with anti-falling rails, during the use of the anti-falling rails, on the one
hand, it is affected by the technical skills of the maintenance personnel. When the climbing movements
are not coordinated, the anti-falling device may be locked by mistake, and the maintenance personnel
must manually restore the anti-falling device To the normal state, it takes time and effort; on the other
hand, the installation process of the anti-falling track is affected by the technical level. If the connecting
parts are misaligned or not connected, it will seriously affect the climbing process of the maintenance
personnel; secondly, the anti-falling track High investment and long installation cycle. A new type of
anti-falling manipulator developed in this paper can reliably cooperate with the safety belt, fasten the
foot nails on the surface of the pole and tower, and assist the maintenance personnel to complete the
climbing and realize the safe climbing and climbing of the tower.

1. Before climbing the tower, the maintenance personnel wear the manipulator with both hands, the
manipulator A is attached to the thumb, the manipulator B is attached to the index finger, the two seat
belts are respectively passed through the lower ring of the left and right manipulators, and the
electromagnetic lock is in standby state;
2. Respectively define the right manipulator occlusion, the left manipulator release, and the
electromagnetic lock in the working state as the initial state of the movement; define the manipulator
occlusion, which is equal to the hand holding the nail, equal to the manipulator arm A tenon A2 and the
manipulator arm B mortise B2 is engaged, and the latch is in the extended state; it is defined that the
5. The maintenance personnel release the right hand and climb up to hold the foot nail. The control device detects that the right manipulator has been engaged, and sends an electrical signal to control the left manipulator to release, the latch retracts, and the signal lasts for 2 seconds;

6. The maintenance personnel release the left hand and climb up to hold the foot nail. The control device detects that the left manipulator has been engaged, and sends an electrical signal to control the right manipulator to release, the latch retracts, and the signal lasts for 2 seconds; and the cycle is completed to complete the tower climbing Task, reverse operation when going down the tower.

6. Mechanical test

Inventor software is used to simulate the mechanical simulation of the adjustable fall arrester for high-altitude operations, the angled iron pulley, and the anti-fall manipulator for high-altitude operations. The mechanical simulations are performed on three states of force 5000N, 7000 N, and 10000 N:

From the simulation results, it can be seen that all mechanical components of the three tools are normal under a force of 5000N, mechanical fatigue occurs at some of the force points under a force of
7000N, and mechanical fatigue of the force point is more serious under a force of 10000N. Mechanical deformation of the force point of the adjustable fall arrester hanger jack. The weight of the personnel is calculated at 80kg, and the safety factor is taken as 5. Each device must meet the mechanical requirements of bearing load not less than 4000N, and the results show that they are all satisfied.

7. Conclusion
This article proposes a method and device for preventing a fall in power transmission lines at high altitude. By collecting different tower type parameters, a set of high-altitude fall prevention methods suitable for different tower structures are summarized and corresponding high fall prevention methods are developed through structural design, mechanical simulation verification. It solves the shortcomings of low practicality of the existing anti-falling device and cannot meet the safety protection of the whole process, and realizes the safety protection of the whole process, all-round, and no dead ends of the maintenance operation, and has a wide range of application and promotion value in the system.

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