Postprint of an Efficient Construction Method for Replacing Carbon Fiber Conductors in Transmission Lines

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Abstract

Owing to their numerous advantages such as large current-carrying capacity and high temperature resistance, new-type carbon fiber conductors can effectively achieve line capacity enhancement without replacing or with only minimal replacement of towers, thereby offering substantial economic benefits. In the carbon fiber conductor replacement project for the 500kV Jiangjin/Jiangling line, a puller-tensioner was utilized as the main traction equipment, employing the old conductor to directly pull and string the carbon fiber conductor. This scheme effectively improved the efficiency of conductor replacement construction, shortening the construction period by one-third compared with conventional construction schemes. This paper analyzes and summarizes the key control points of this construction scheme from aspects including tool and equipment selection and conductor connection, and compares its economic and social benefits with traditional construction schemes to facilitate its promotion and application.

Full Text

Method for High-Efficiency Replacement of ACCC Wires in Transmission Lines

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Abstract

Aluminum conductor composite core (ACCC) wires offer significant advantages including high current capacity and temperature resistance, enabling effective line capacity upgrades without replacing or with minimal replacement of towers, thereby delivering substantial economic benefits. In the ACCC wire replacement project for the 500 kV Jiangjin/Jiangling transmission line, a stretch-one machine was employed as the primary traction device to directly pull and deploy ACCC wires using the existing conductors. This approach significantly improved construction efficiency, reducing the project duration by one-third compared to conventional methods. This paper analyzes and summarizes the critical control points for this construction method from the perspectives of equipment selection and wire connection, and compares its economic and social benefits against traditional construction schemes to facilitate broader application.

Keywords: ACCC wires, old wire traction for ACCC wire, stretch-one machine, wire connection, project duration

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1 Introduction

Aluminum conductor composite core (ACCC) wires represent a new generation of energy-saving, capacity-increasing conductors. Compared with conventional wires, ACCC offers numerous advantages including light weight, high tensile strength, excellent heat resistance, low thermal expansion coefficient, minimal high-temperature sag, high conductivity, low line losses, large current capacity, superior corrosion resistance, and reduced ice accumulation. These features comprehensively address technical bottlenecks in overhead power transmission, representing the future development trend of overhead conductor technology and contributing to the construction of safe, environmentally friendly, and efficient transmission networks. ACCC wires can be widely applied in capacity upgrade projects for existing lines and substation busbars, new line construction, and special climatic and geographical conditions such as long spans, large elevation differences, heavy ice regions, and heavily polluted areas. In new line applications, ACCC can increase the unit transmission capacity, ensure grid robustness, and provide better long-term economic performance. Consequently, the widespread adoption of ACCC wires can effectively alleviate the conflict between increasing electricity demand and increasingly constrained line corridors, making them an effective solution for future overhead transmission line capacity upgrades.

2 Project Background and Construction Scheme

2.1 Project Background

This study is based on the capacity upgrade project for the 500 kV Jiangjin 5291/Jiangling 5292 lines in Jiangsu Province. The line runs from the 500 kV Jiangdu Substation to the 500 kV Jinling Substation, with the Jiangjin 5291 line spanning 29.066 km and the Jiangling 5292 line spanning 31.661 km, both constructed as single-circuit lines. The original conductor for Jiangjin 5291 was 4×LGJ-400/50, while Jiangling 5292 used 4×LLBJ-400/35. Both lines were upgraded to 4×JLRX/F2A-460/40-26 ACCC wires.

2.2 Construction Scheme Optimization

The conventional overhead transmission line replacement process involves: construction preparation; manual removal and recovery of old conductors; installation of stringing blocks; manual deployment of initial pilot ropes; tension stringing of traction steel ropes; tension stringing of conductors; sagging and hardware installation; and site demobilization. In contrast, the proposed scheme using old conductors to pull new ACCC wires follows this process: construction preparation; installation of stringing blocks; removal of spacers and conductor connection; tension stringing of new wires using old conductors; sagging and hardware installation; and project completion.

Comparing these two approaches, the scheme employing old conductors to pull new wires offers a simpler construction process and shorter cycle, providing clear advantages. Moreover, manual removal of old conductors requires coordination with important crossings beneath the line, including multiple 35 kV+ energized lines, railways, highways, provincial roads, and navigable rivers, which would necessitate additional power outages, road closures, and navigation restrictions.

In conventional tension stringing operations, a main tensioner is typically deployed at the tension field. Due to limitations in the traction machine' s drum size, conductors cannot enter the traction machine drum, which prevents the conventional method from using old conductors directly as traction ropes. Instead, old conductors must first be removed before manually or aerially deploying pilot ropes, then transitioning to traction ropes for conductor stringing. The stretch-one machine' s primary advantage is that conductors can pass directly through its drum when used as a traction device, allowing the existing old conductors to serve as traction ropes. After passing through the stretch-one machine drum, old conductors are recovered at the tension field, eliminating the need for extensive manual removal along the line and saving significant costs associated with small-scale transportation and road repairs. [Figure 1: see original paper] shows the SA-ZY-2×70 stretch-one machine.

3 Main Construction Parameter Verification

3.1 Main Tensioning Equipment Selection and Verification

This construction method differs most significantly from conventional replacement methods in its use of a new type of equipment—the stretch-one machine—at the tension field. Verification is performed based on the project' s maximum control tension, maximum traction force, and conductor parameters.

Main Traction Machine Rated Traction Force Verification

P mKpTp = 2 !112.791! 0.2kN = 45.11kN

where P is the rated traction force of the main traction machine (kN); m is the number of sub-conductors pulled simultaneously; Kp is the coefficient for selecting the rated traction force of the main traction machine, typically 0.2-0.3 (0.2 for flat terrain); and Tp is the guaranteed calculated breaking force of the conductor being pulled (kN).

Main Tensioner Rated Braking Tension Verification

T 18.34 ! 4kN = 73.36kN

Stretch-One Machine/Tensioner Wheel Diameter Verification

D40d !100mm = 40 " 26mm !100mm = 940mm

where D is the groove bottom diameter of the conductor wheel (mm) and d is the diameter of the conductor being deployed (mm).

Based on these verification results, the tension field selected one 811/180/21 FR266-type four-wire main tensioner with maximum continuous tension of 180 kN and wheel groove bottom diameter of 1,500 mm. The traction field selected two SA-ZY-2×70 type two-wire stretch-one machines, which provide maximum continuous traction force of 140 kN and wheel groove bottom diameter of 1,700 mm when used as traction machines. All parameters meet tension stringing construction requirements. Tension field equipment layouts are shown in [Figure 2: see original paper] and [Figure 3: see original paper], with ACCC wire deployment shown in [Figure 4: see original paper].

3.2 Wire Connection Tools Selection and Verification

Using old conductors to pull new ACCC wires involves three connection types: old-to-old conductor connections, old-to-ACCC connections, and ACCC-to-ACCC connections.

Old Conductor-to-Old Conductor Connection

When connecting old conductors at tension towers, the original conductor tension clamps are utilized. The clamp drainage plates are cut off and filed smooth. Two tension tubes are connected using two 14 wire rope slings (verified for length) and one 50 kN anti-bending connector, as shown in [Figure 5: see original paper].

Old Conductor-to-ACCC Connection and ACCC-to-ACCC Connection

When connecting old conductors to ACCC wires, the old conductor end uses the original tension clamp with drainage plate removed and filed. For the ACCC wire end, because the outer soft aluminum strands and inner carbon core have significantly different elasticity, the core rod tends to retract inward under tension during pulling. Therefore, a core rod clamp (core grip) must be installed at the conductor end. Two steel hoops matching the conductor are crimped at 100 mm and 400 mm from the ACCC wire end. At approximately 60 mm from the end, the outer aluminum strands are neatly stripped to install the core grip for end protection. The core grip consists of three parts: base plate, steel hoop, and cone. The base plate is first fitted onto the core rod against the outer aluminum strands, followed by the steel hoop with its smaller-diameter side facing the base plate. Finally, two cone pieces are inserted into the steel hoop and tapped in place. After installation, a pulling sock is fitted over the conductor end in the conventional manner. Due to the smoother surface of ACCC wires compared to conventional conductors, these pulling socks are typically longer than standard ones, and using undersized socks is strictly prohibited. The sock end must be secured with at least 20 turns of binding wire per requirements in *Safety Code for Electric Power Construction Part 2: Power Lines*, or alternatively fixed using sleeve crimping. When using crimping, three test specimens should be produced to verify tensile performance, and process standard specimens should be made to establish crimping process standards. The compressed sections must be cut off after deployment, so these lengths should be deducted during wire layout planning.

ACCC-to-ACCC connections use the same method. Old-to-ACCC or ACCC-to-ACCC connections use swivel connectors, as shown in [Figure 6: see original paper].

The length selection of connection wire ropes is critical. The length must satisfy safety distances to crossed objects while minimizing conductor tension within tension sections to prevent significant sag changes and wire slippage when connecting to old conductors. The calculation formula is:

$ cos!i + $

where li is the length of wire rope needed at the i-th tension tower (m); ΔLi-1 and ΔLi+1 are the line length changes in the tension sections on both sides of the i-th tension tower (m); and i-1 and i+1 are the lengths of insulator strings on both sides of the i-th tension tower (m).

Within a tension section controlled by k spans, the total conductor length change is calculated as:

ΔL = Σ[(lk³ ²)/(24) × (1/(cos² k) - 1/(cos² k’)) + (lk(Tk - Tk’))/(EAcos² k)]

where ΔL is the conductor length change in the tension section (m); fk is the original sag value in the control span (m); fk is the sag value during tension stringing in the control span (m); k is the elevation angle of the control span’ s suspension points; lk is the span length of the control span (m); is the conductor’ s unit weight (N/m); E is the conductor’ s elastic modulus (MPa); and A is the conductor’ s cross-sectional area (mm²).

Based on the project’ s maximum stringing control tension of 18.34 kN and a safety factor of 4.5, 14 smooth round steel wire rope with breaking force of 127 kN was selected as the connection wire rope.

4 Key Construction Control Points

4.1 Aerial Anchoring of Old Conductors

When connecting old conductors at tension towers, the conductors must first be anchored on both sides of the tower. If important crossings exist within the anchoring tension section, double anchoring measures are required: one anchor from the conductor clamping point to the tower’ s crossarm, and another from the other clamping point via the crossarm to the tower leg using a deviation pulley. The two clamping points on the conductor are approximately 10 m apart. During anchoring, to facilitate removal of tension strings, over-traction should be applied, not exceeding 100 mm.

All anchoring ropes must be numbered individually with usage records maintained. Before stringing operations, all anchors must be removed and checked against records to prevent accidents from forgotten anchors.

4.2 Wire Connection Head Passing Through Pulleys

When old conductor connection heads pass through pulleys during deployment, protective sleeves should be installed on tension tubes to prevent bending deformation that could cause wire slippage or derailment. New conductor connection heads using swivel connectors cannot pass directly through pulleys as this may cause breakage. When the connection head reaches 15 m from the pulley, the traction machine should decelerate and brake. A lifting block set or chain hoist at the pulley mouth should assist the swivel connector through the pulley before removing the lifting point binding and resuming traction.

4.3 Wire Connection Head Passing Through Stretch-One Machine

When old conductor connection tension tubes pass through the stretch-one machine drum, bending moments create slippage and derailment risks. A motorized winch can assist conductor pulling as an anchor insurance. When the connection head approaches the stretch-one machine, traction should stop. A 300 kN motorized winch and 100 m length of GJ-100 type rubber-coated steel strand should anchor the conductor. Both the stretch-one machine and winch then operate simultaneously to pull the conductor until the connection head passes smoothly through the drum. The stretch-one machine then stops again to remove the rubber-coated steel strand anchor.

5 Benefit Analysis

A comparison of construction duration between this scheme and conventional methods is shown in . This replacement project employed two stringing crews, each with 25 skilled workers and 60 assistants, totaling 170 personnel. Skilled worker costs were approximately 600 RMB per person-day, while assistants cost 350 RMB per person-day. Based on the duration comparison in , labor costs for this scheme were 648,000 RMB versus 972,000 RMB for conventional methods.

A comparison of major equipment inputs is shown in . Based on market rental rates, equipment costs were 1,242,870 RMB for this scheme versus 1,857,590 RMB for conventional methods.

In total, stringing costs were 1,890,870 RMB for this scheme compared to 2,829,590 RMB for conventional methods. Additionally, this scheme significantly reduces costs for crossing frame erection and transportation road repairs during demolition. Therefore, this approach offers clear economic advantages.

In terms of schedule, this scheme saves 45 days compared to conventional methods, which is highly beneficial for 500 kV line outage modifications. Furthermore, this method eliminates the need for coordinated shutdowns of important crossings during demolition, avoids manual pilot rope deployment, and minimizes environmental disturbance within the corridor, demonstrating significant social benefits.

6 Conclusion

The replacement construction method using stretch-one machines and existing conductors as traction ropes can substantially reduce outage duration, offering not only strong economic benefits but also significant environmental and social advantages. This construction approach can be promoted for capacity upgrade projects replacing conventional conductors with ACCC wires in grid construction, and provides valuable insights for emergency line repairs.

However, since old conductors have been in operation for extended periods, their mechanical properties contain uncertain factors that pose certain safety risks. Further research is needed to effectively eliminate these safety hazards.

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Note: Figure translations are in progress. See original paper for figures.