A TY-Type Clamp for Rapid Repair of Disconnected Downlead Conductors on Overhead Ground Wires in Ice-Melting Lines

Mingzhen Lei*, Dejun Qin, Haifan Li
Liuzhou Bureau of Ultra-high Voltage Transmission Company, China Southern Power Grid Co., Ltd., Liuzhou, Guangxi, China
**Corresponding Author*

Abstract: In recent years, the challenge of ice accumulation on power lines in southern China has been increasingly prominent due to frequent occurrences of extreme cold weather conditions. During the ice-melting process of the 500kV lines under the Southern Power Grid jurisdiction, there have been several instances of fuse blowing at the junctions between tower ground wires and NY-type clamps, particularly when the contact resistance between the downlead conductors and tension-resistant clamps is excessively high. This leads to a rapid temperature increase in the joint area due to Joule heating effects, resulting in interruptions in the ice-melting process and an expansion of ice formation along the transmission lines, posing a threat to the operational safety of tower equipment. Addressing the critical issues affecting the anti-icing capability of the power grid, and considering the high current intensity, concentrated operating time, and demanding conductive performance of the ice-melting process, a structurally optimized, superbly conductive, and conveniently installable TY-Type Clamp has been devised to replace the existing downlead line clamps and form an ice-melting line. By optimizing contact pressure and conductive area, this clamp markedly reduces contact resistance, effectively suppressing localized overheating during ice-melting, achieving the objective of swift repairs for disconnected downlead conductors on overhead ground wires in ice-melting lines. It furnishes a reliable technical solution for rapidly restoring ice-melting operations and preventing accidents from escalating during ice accumulation periods, holding vital engineering significance in enhancing the power grid's resilience against ice disasters.

Keywords: Transmission Lines; Ice-Melting; Rapid Repair of Downlead Conductors; TY-type Clamps

1. Introduction

Under the persistent influence of severe cold weather, as transmission line equipment gradually becomes covered in ice, the gravitational load borne by the ground wires of these transmission lines continues to escalate. When ice accumulation on the transmission lines reaches a critical level, the gravitational load on the ground wires and towers may exceed their limits, posing a threat to the operation of the power grid and potentially triggering incidents such as line breakages [1] and tower collapses [2]. Currently, the most widely employed and effective method in China for addressing extensive ice accumulation on transmission lines involves the transmission of ice-melting currents (high currents) [3] through the transmission line conductors, utilizing the heat generated by the conductors themselves to facilitate ice melting [4].

Based on an analysis of ice-melting failures in previous years and on-site temperature measurements, it has been observed that the connection point between the downlead conductors and the tension-resistant clamps for the ground wires experiences elevated temperatures during the flow of ice-melting currents [3]. Case studies and risk analyses conducted in this regard have indicated that connection point failures during the ice-melting process represent a significant systemic risk [5]. Particularly, when the contact between the downlead conductors and the tension-resistant clamps is not sufficiently tight, the temperatures at the connection point soar even higher. Under the influence of ice-melting currents, the sustained high temperatures at the connection point between the downlead conductors and the tension-resistant clamps can lead to fuse blowing, causing interruptions in the flow of ice-melting currents [6-8]. This, in turn, can result in the gradual expansion of ice accumulation during the winter season, leading to damage to transmission line towers, detachment of ground wires, and tower collapses, ultimately causing widespread power outages. Therefore, the rapid elimination of defects at fuse-blowing points during ice accumulation periods to swiftly restore ice-melting operations is crucial in ensuring the safe operation of equipment and the continual and stable delivery of power through the grid.

This paper delves into this critical ice-melting issue, drawing upon the design experience of existing compression-type line clamps, to introduce a TY-Type clamp capable of swiftly addressing defects in downlead conductors, ensuring reliable ice-melting of the lines, and safeguarding operational safety.

2. Selection of the TY-Type Clamp

To facilitate the connection between the ground wires and downlead conductors, we have engineered a TY-type clamp [9]. The clamp's main body features a slide-in mechanism to seamlessly integrate with the existing ground wires. This design allows for direct compression onto the original ground wires, eliminating the need to cut and re-compress new tension-resistant clamps. By directly compressing the TY-type clamp onto the existing ground wires, the initial workload for ice-melting can be significantly reduced. Furthermore, the clamp is crafted from aluminum profiles, offering enhanced conductivity compared to traditional steel clamps, leading to increased current capacity and faster ice melting rates. The images before and after compression are illustrated in Figure 1 and Figure 2.

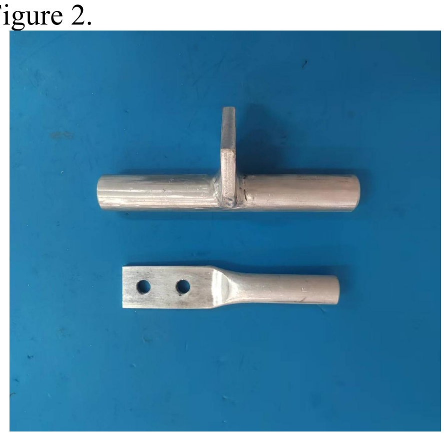

Figure 1. Schematic Diagram of the TY-Type Clamp before Compression

Figure 2. Schematic Diagram of the TY-Type Clamp after Compression

The TY-type clamp consists of the main body and the downlead conductor clamp, connecting the ground wire and downlead conductor, respectively. Both components are manufactured using aluminum alloy profiles, enabling efficient current flow, minimal resistance, and reduced temperature elevation of the clamp. The main body of the clamp features a slide-in mechanism that can rapidly introduce ice-melting currents into the ground wire without damaging the original ground wire circuit. The downlead conductor clamp securely connects the downlead conductor, facilitating the flow of ice-melting currents. A bolt connection is employed between the downlead conductor clamp and the main body of the clamp.

3. Electrical Resistance Temperature Rise Test

To validate the electrical resistance temperature rise of the clamp, we conducted an electrical resistance temperature rise test on the TY-type clamp post-compression [10].

3.1 Measurement of Resistance before Temperature Rise

Stable 20A and 30A direct currents in both forward and reverse directions were introduced into the circuit. Using the direct current voltage drop method, we measured the resistance values of the clamp and an Equidistant Wire before temperature rise. The experimental setup is depicted in Figure 3, and the results are presented in Table 1.

From the data in Table 1, it can be observed that at a room temperature of 30°C, the resistance values for Sample 1 and Sample 2 are nearly equal, significantly lower than the resistance of the Equidistant Wire. They are approximately

0.27 times the resistance of the Equidistant Wire, meeting the requirements outlined in the GB/T 2317.3-2008 standard.

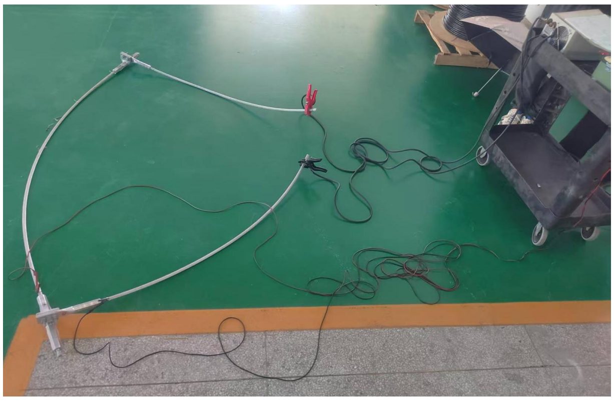

Figure 3. Measurement of Resistance before Temperature Rise for the Clamp and Equidistant

Table 1. Resistance Values before Temperature Rise for the Clamp and Equidistant Wire

Current A \ Test point Resistance μΩ	Sample 1	Sample 2	Equidistant Wire	Room Temperature ℃
20	1.46	1.54	5.69	30
30	2.22	2.29	8.47	
-20	1.48	1.53	5.64	
-30	2.23	2.29	8.52	
Average	1.85	1.91	7.08	

3.2 Temperature Rise Test

To verify the ice-melting effectiveness, we introduced a stable direct current of 400A into the test circuit. Temperature values at various test points were measured at 5 minutes, 10 minutes, 15 minutes, and 20 minutes. Three test points were selected for each set of clamps, located at the clamp body, the terminal board joint, and the downlead clamp terminal. The measurement points for wire temperature were situated more than 1000mm away from the test specimen. The experimental setup is displayed in Figure 4, and the results are detailed in Tables 2 to 4.

From the data gathered in the three sets of experiments, it is evident that at the intervals of 5 minutes, 10 minutes, 15 minutes, and 20 minutes, the temperatures of the clamps and wires are steadily increasing without reaching a plateau. The rise in temperature of the clamps is relatively gradual, with the largest increase observed at the junction between the clamp body, the terminal board, and the downlead current-carrying clamp outlet. However, this temperature rise remains significantly lower than that of the ground wire, which experiences a rapid elevation in temperature, reaching a high of 255°C at the 20-minute mark. This indicates that within the permissible temperature range of the clamps, the elevated temperature of the ground wire effectively facilitates ice-melting within a short duration.

Figure 4. Layout of the Electrical Resistance Temperature Rise Test

Table 2. Temperature Values at Each Test Point for the First Set of Temperature Rise Tests

Time \ Temperature Sensing Point Temperature℃	Sample 1-1	Sample 1-2	Sample 1-3	Sample 1 Average	Sample 2-1	Sampl e 2-2	Sample 2-3	Sample 2 Average	Wire	Room Temperature (℃)
5min	40	34	44	39	40	33	46	40	108	30
10min	47	41	57	48.3	47	40	59	48.7	180	
15min	56	45	63	54.7	51	44	65	53.3	216	
20min	62	52	71	61.7	57	51	75	61	253	

Table 3. Temperature Values at Each Test Point for the Second Set of Temperature Rise Tests

Time \ Temperature Sensing Point / Temperature°C	Sample 1-1	Sample 1-2	Sample 1-3	Sample 1 Average	Sample 2-1	Sample 2-2	Sample 2-3	Sample 2 Average	Wire	Room Temperature (°C)
5min	40	34	44	39	40	33	46	40	109	30
10min	46	39	52	45.7	45	38	54	45.7	141	
15min	52	43	60	51.7	51	42	64	52.3	233	
20min	61	50	70	60.3	58	49	75	60.7	247	

Table 4. Temperature Values at Each Test Point for the Third Set of Temperature Rise Tests

Time \ Temperature Sensing Point / Temperature°C	Sample 1-1	Sample 1-2	Sample 1-3	Sample 1 Average	Sample 2-1	Sample 2-2	Sample 2-3	Sample 2 Average	Wire	Room Temperature (°C)
5min	40	34	44	39	40	33	46	40	109	30
10min	49	40	56	48	48	39	60	49	175	
15min	57	47	56	53	55	46	70	57	222	
20min	65	53	74	64	63	53	80	65	255	

3.3 Measurement of Resistance Values Post Temperature Rise

To elucidate the electrical resistance changes in the clamps and wires post temperature rise, a stable bidirectional direct current of 20A and 30A was passed through the clamps and wires from the three temperature-risen sets. Employing the direct voltage drop method, the resistance values of the clamps and wires were measured before and after the temperature rise, referencing the experimental setup as depicted in Figure 2. The outcomes are tabulated in Table 5, while the average resistance values of the clamps and wires pre and post temperature rise are detailed in Table 6.

Table 5. Resistance Values of Clamps and Equidistant Wires Post Temperature Rise

Current A \ Test point / Resistance μΩ	Sample 1	Sample 2	Equidistant Wire	Room Temperature (°C)
20	1.56	1.54	5.65	30
30	2.35	2.31	8.46	
-20	1.57	1.54	5.64	
-30	2.35	2.32	8.48	
Average	1.96	1.93	7.79	

From Table 5, it is evident that post temperature rise at a room temperature of 30°C, the resistance of Sample 1 and Sample 2 remains nearly equal, significantly lower than the equidistant resistance of the wire, approximately at 0.25 times the equidistant wire resistance, meeting the requirements of standard GB/T 2317.3-2008. Analyzing the average post-temperature rise resistance values of the clamps and equidistant wires, it is observed that the resistance change in the two sets of clamps and wires themselves post temperature rise is minimal. The increase in clamp resistance is around 5%, while wire resistance sees about a 10% increase.

Table 6. Average Resistance Value Changes of Clamps and Equidistant Wires Pre and Post Temperature Rise

Average \ Test point / Resistance μΩ	Sample 1	Sample 2	Equidistant Wire	Room Temperature (°C)
Average (Pre)	1.85	1.91	7.08	30
Average (Post)	1.96	1.93	7.79	

From Table 5, it is evident that post temperature rise at a room temperature of 30°C, the resistance of Sample 1 and Sample 2 remains nearly equal, significantly lower than the equidistant resistance of the wire, approximately at 0.25 times the equidistant wire resistance, meeting the requirements of standard GB/T 2317.3-2008. Analyzing the average post-temperature rise resistance values of the clamps and equidistant wires, it is observed that the resistance change in the two sets of clamps and wires themselves post temperature rise is minimal. The increase in clamp resistance is around 5%, while wire resistance sees about a 10% increase.

4. Clamp Force Test Post Temperature Rise

Under the condition of a direct current input with an ice-melting current of 400A, the temperatures of the clamps and wires have been continuously increasing, with wire temperatures reaching up to 255°C. To assess the impact of elevated temperatures on the gripping force of the wires [11], we conducted a grip force test on the clamps post temperature rise, with the experimental image and results depicted in Figure 5.

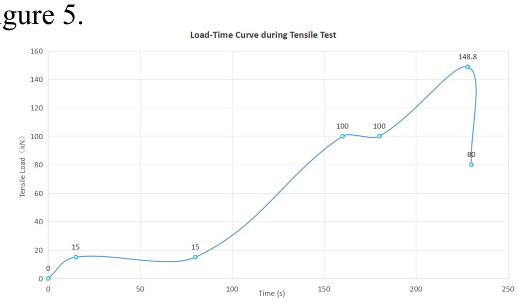

Figure 5. The Grip Force Test Results of the Clamps Post Temperature Rise

From Figure 5, it can be concluded that post temperature rise, the gripping force of the clamps on the ground wire resulted in failure at 140.8kN. This value still surpasses 95% of the calculated tensile strength of the wire, meeting the required value for the gripping force of tension-resistant clamps on wires as stipulated in GB/T 2314-2008. Post temperature rise, the clamp's grip on the wire continues to meet the standardized requirements.

5. Conclusions

This paper addresses the core issue of interruptions in ice-melting processes caused by the overheating and melting of the ground wire downlead conductor connection point. To tackle this, a novel TY clamp was designed and rigorously tested for its electrical and mechanical performance. The key conclusions are as follows:

By installing the TY clamp, the temperature rise of the clamp at 400A direct current input is significantly lower than that of the wire, with the wire experiencing a substantial temperature rise, meeting the requirements for rapid ice-melting.

Post temperature rise, the grip force of the clamp on the ground wire continues to meet the standards outlined in GB/T 2314-2008.

Through resistance temperature rise tests and grip force tests, it is evidet that the TY clamp effectively resolves the issue of wire breakage in overhead ground wire downlead conductors during ice-melting, enabling personnel to rapidly complete repairs for broken downlead conductors on ice-melting lines.

References

[1] Pan Hao, Zhou Fangrong, Geng Hao, et al. Calculation method for ice-melting current and ice-melting time of double-conductor heating ground wire. Smart Power, 2025, 53(03): 62-68.

[2] Hu Yu. Research on ice coating and melting risk analysis and improvement scheme of Zhaotong power grid transmission lines. Kunming University of Science and Technology, 2021.

[3] Li Xiaoyan, Yao Guijiao, He Mingxia, et al. Development of crimped ground wire current-carrying clamp. Mechanical and Electrical Information, 2018, (30): 128-129.

[4] Li Ronghao. Transmission line ice coating thickness early warning system based on IDBO-LSSVM. Anhui University of Science and Technology, 2025.

[5] Liu Jie. Research and application of full-process prediction method for ice coating on overhead transmission lines. Rural Electrification, 2025, (04): 46-49.

[6] Lei Mingzhen, Zhang Yuan, Xu Wentao. Research on ice-melting technology for ground wire of high-voltage transmission lines. Automation Application, 2023, 64(20): 127-129.

[7] Fang Yili, Gu Li, Li Qi, et al. Design and analysis of automatic wiring device for ground wire ice melting. Mechanical and Electrical Information, 2016, (27): 98-99.

[8] Chen Zusheng. Brief analysis on optimization and transformation method of fitting connection in ground wire ice-melting section. Telecom World, 2015, (11): 170-171.

[9] Wang Junhao, Yan Kun, Zhao Pinxian, et al. An auxiliary insulation device for live connection of section drainage wire. Electrical Engineering, 2022, (16): 97-98+101.

[10] Tong Yang, Hu Jie. Analysis on fracture problems of four types of compression-type clamps and research on prevention strategies. Hydropower and New Energy, 2021, 35(09): 52-55.

[11] Luo Yixin. Analysis on grip force composition and research on detection method of compression-type strain clamp. North China Electric Power University, 2024.

