Study Committee B2

Overhead Lines

10632_2022

CHUBU Electric Power Grid

Evaluation of residual mechanical performance of damaged conductor strands due to AC fault arcs for rational repair of overhead line

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Introduction

- Some strands of conductor for overhead transmission lines passing through various environments are sometimes melted by an AC fault arc.
- The tensile strength of the melted conductor is weakened due to a decrease in cross-sectional area and heating.
- Melted strands in a conventional internal rule are evaluated as being completely broken regardless of the level of melted damage.
- This report introduces a method for visually estimating the residual strength of a conductor by evaluating the relationship between the damage level in a visual inspection and the mechanical residual performance of the melted conductor.

Evaluation target and test method

- The specimens are conductors that have been actually damaged by AC fault arcs (ACSR 80–610 mm^2 applied to transmission lines of 77 kV or less).
- The tests were carried out by disassembling the conductor into straighter strands and the tensile strength of the strands was measured with a tensile strength tester.

Estimation of residual tensile strength of melted strands

- It is known that the tensile strength of the strand depends on the cross-sectional area. However, it is not easy to determine the cross-sectional area of the melted strand. In order to simply index the damage level, the results of the strand tensile test were evaluated as parameters of “melt length”, “melt width” and “melt depth” respectively.

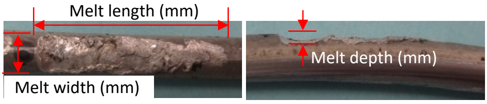


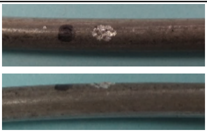
Figure 1 An example of a strand damaged by an AC fault arc

- It was confirmed that the residual tensile strength of the melted strand was well correlated with the melt depth. Therefore, certain tensile strength can be expected depending on the appearance of damage level. (Table I and Table II are criterion of residual strength based on test results)

Table I Criterion for determining the residual strength of the melted strand

Damage level	Major	Minor	
Strand diameter	All strand diameter	Diameter < Φ3.8mm	Diameter ≥ Φ3.8mm
Evaluation of strength ratio	0%	50%	66%
Number of strands evaluated as broken	1	1/2	1/3

Table II Comparison of appearance of damage level

level	Major	Minor
Appearance		 Melt depth is nothing

Evaluation of repair method for damaged conductor using new method

- In the conventional method, a strand is evaluated as broken even if there is only minor damage. On the other hand, according to the new method, minor damage to a strand is estimated to reduce the tensile strength by 1/2 or 1/3.
- The equivalent number of broken strands is 20% or less of the total number, and a simple repair (Repair with armor-rod) can be applied based on technical internal rules.

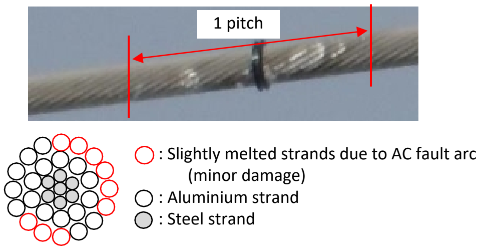


Figure 2 An example of appearance of a damaged conductor for evaluating repair method (ACSR 410 mm^2)

Figure III Comparison of repair methods (ACSR 410 mm^2)

Category	Conventional method	New method
Damage level	Minor	Minor
Number of strands evaluated as broken by damage level	1	1/3
Number of melted strands	9	9
Equivalent total number of broken strands	9	3
Repair methods※	Conductor replacement	Repair with armor-rod

*Internal rule in a simple repair test with an armor-rod
- Equivalent number of broken strands is within 6 (within 20% of the total number of aluminium strands) ⇒ Repair with armor-rod
- Equivalent number of broken strands is 7 or more (over 20% of the total number of aluminium strands) ⇒ Replace conductor
- Total number of aluminium strands of ACSR 410 mm^2 is 26

Conclusion

- This paper shows a simple method by which the residual tensile strength of an (T)ACSR that has melted due to an AC fault arc can be estimated by looking at the strand damage level in a visual inspection.
- The applicable conductor size for this method is 160 mm^2 and over and this method is also applicable to electrical damage (lightning damage and so on) not only to AC fault arc.
- The new method has achieved significant results such as paving the way for expanding simple repairs of damaged conductors and reducing the costs of replacing damaged conductors.

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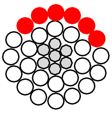
Evaluation target

- Short-circuit faults resulting from ice or snow accretion occur mainly on transmission lines of 77 kV or less in our service area. Therefore, ACSR 80–610 mm^2, which is applied to transmission lines of 77 kV or less was selected as the evaluation target.
- The specimens are conductors that have been actually damaged by AC fault arcs (Table IV).

Table IV Specimens

Conductor type and nominal aluminium area (mm^2)	Stranding and strand diameter (mm)		Age (years)
	Aluminium	Aluminium clad steel	
ACSR/AC 80	15/ϕ2.6	7/ϕ2.6	10
ACSR/AW 160	30/ϕ2.6	7/ϕ2.6	32
ACSR/AW 410	26/ϕ4.5	7/ϕ3.5	32
TACSR/AC 610	54/ϕ3.8	7/ϕ3.8	25



: Slightly melted strands due to AC fault arc (have been evaluated as broken so far)

: Aluminium strand

: Steel strand with aluminium cladding

Figure 3 An example of a conductor damaged by an AC fault arc (ACSR/AW 160 mm^2)

Image of the test method

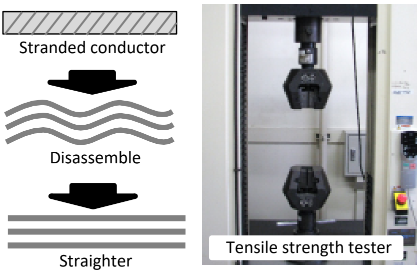


Figure 4 Test method

Test result

- As shown in Table IV, the ages are different, and the initial strength in routine tests is unknown. Therefore, the tensile strength of the melted strands was estimated based on undamaged strands of the same conductor to determine mechanical performance.

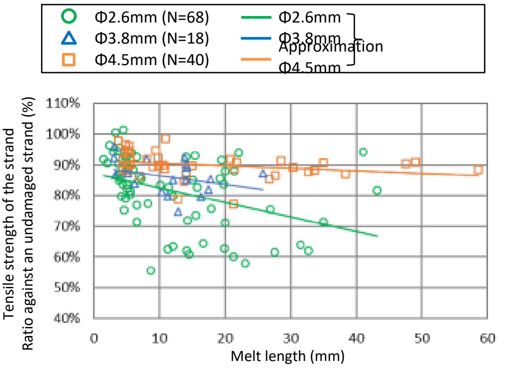


Figure 5 (a) Relationship between melt length and residual tensile strength

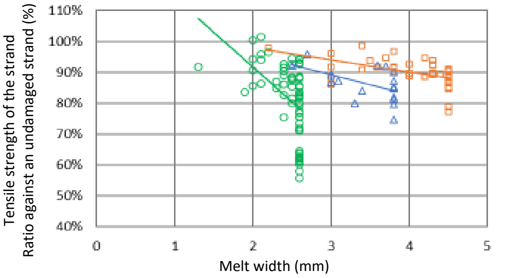


Figure 5 (b) Relationship between melt width and residual tensile strength

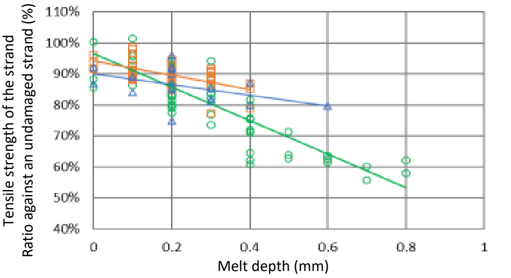


Figure 5 (c) Relationship between melt depth and residual tensile strength

Table V Correlated variation of the relationship between damage level and tensile strength of the melted strands

Strand diameter (aluminium)	Coefficient of determination (R^2)		
	Melt length	Melt width	**Melt depth**
Φ2.6mm	0.1572	0.2215	0.7526
Φ3.8mm	0.1060	0.2690	0.2119
Φ4.5mm	0.0788	0.2760	0.3492
Total strand diameter	0.0337	0.0424	**0.6536**

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Estimation of residual tensile strength of melted strands

- If the melting depth is not found even for damaged strands, it is deemed that there is certain residual tensile strength.
- The melt depth that was considered to not be recognized was set at 0.5 mm in consideration of variations in visual inspection (set at a value of approximately -3σ in consideration of the variations in the test).
- The results of the studies make it easier to evaluate residual strength in a visual inspection.

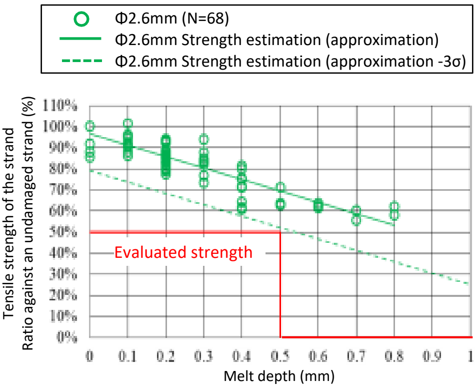

Figure 6 (a) Tensile strength of the melted strand (ϕ2.6 mm)

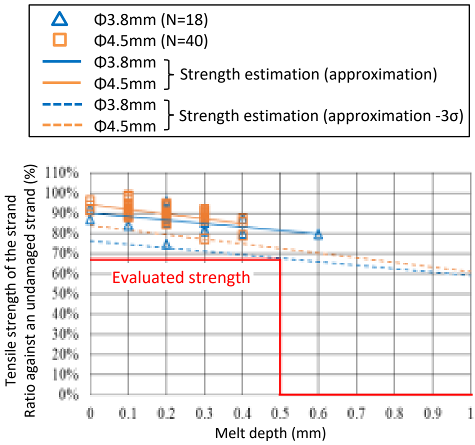

Figure 6 (b) Tensile strength of the melted strand (ϕ3.8, ϕ4.5 mm)

Estimation of residual tensile strength of Stranded conductor

- Two kinds of strength estimation methods were examined.
- In order to meet the strength required by safety regulations without fail, method Ⅱ which calculated the residual strength as being lower than the test results, was applied.

【Method I】
Counting the number of deemed broken strands in each melt cross section of damage area and determining the residual strength from the minimum strength cross section.

Equivalent number of broken strands in following Figure
= 1.0
A (minimum strength section in damage area)

【Method II】
Calculating the residual strength by excluding the sum of deemed broken strands within 1 pitch.

Equivalent number of broken strands in following Figure
=1.0 + 1/2 + 1/2 = 2.0
A B C Sum of broken strands in 1 pitch

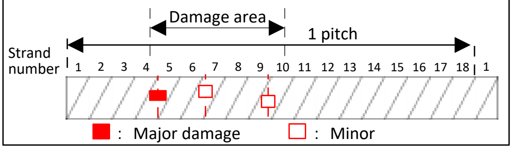

Figure 7 Concept of the estimating the residual strength

Table VI Comparison of methods to estimate residual tensile strength of a damaged stranded conductor

Conductor type	Test value	Estimated value			
		Method I		Method II	
	Strength	Strength	Validity*	Strength	Validity*
ACSR/AC 80mm2	36.2	39.7	×	36.3	×
ACSR/AW 160mm2	76.5	77.0	×	68.2	○
ACSR/AW 410mm2	144.5	145.9	×	133.2	○

*○ : Test value ≥ Estimated value × : Test value < Estimated value