Study Committee B2

OVERHEAD LINES

10631_2022

Evaluation of long-term reliability of the carbon fiber core wire and development of technologies to expand its application

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Motivation

- We had installed ACFR on a 66 kV transmission line about 8 km from the coast for 16 years from December 2002 to January 2019. Subsequently, various evaluation tests were conducted.
- This paper aim to evaluate the reliability of the ACFR and the compression-type dead-end clamp that had been used over a long-term service of overhead lines.
- Furthermore, the authors have developed SBTACFR (SB: Smooth Body) and so on to expand of the application of ACFR.

Method/Approach

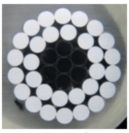
- The following table shows the sample summary of the various evaluation tests.

Sample	Electric conductor		Compression clamp
Date collected	January 2019		
Transmission line	66kV transmission line (1 circuit) / ACFR was installed at 4 span.		
Conductor type and size	ACFR 160 mm^2		
Date of wire installation	December 2002		
Number of years passed	16 years and 1 month		
Estimated maximum salt attachment density	0.25 (mg/cm^2) / The span used by the ACFR was located about 8 km from the coast.		
Sample quantity	60 m	30 m	3 sets
Sample location	Lowest part of the sag	Suspension clamp, damper grip	1 steel tower

Experimental setup & test results

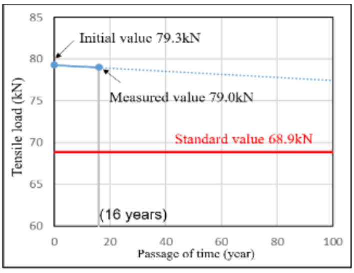
- No abnormality such as damage or corrosion was observed at the lowest part of the sag and the gripping area of the suspension clamp and the damper.

CFCC at the lowest part of the sag



ACFR cross section at the lowest part of the sag

- The tensile load of ACFR was almost the same as the initial value.



- No abnormalities such as broken conductors or corrosion were observed for the aluminum conductor and CFCC inside the clamp.

ACFR inside the aluminum clamp

CFCC inside the aluminum clamp

Discussion

- The tensile load of ACFR was almost the same as the initial value, and from the tendency of a slight decrease in tensile load, it is concluded that the ACFR can be used without any problem during the service life of the transmission facility.
- In order to expand the application of ACFR, an SBTACFR and a compression-type dead-end clamp that passes through a sheave were developed, and counterweights and Christmas tree-shaped dampers were verified for application.

1. SBTACFR

- The authors have developed SBTACFR in which the aluminum strand is formed into a trapezoidal shape to enlarge the cross-sectional area of the aluminum portion, thus reducing power losses and increasing the transmission capacity.

Item		Unit	SBTACFR 190 mm^2
Strand configuration	Aluminum strand	Number/mm	1/4.14+9/3.82+8/3.52
	Core strand		7/2.6 CFCC
Tensile load (UTS)		kN	79.5
Outer diameter	Conductor	mm	18.2
	Core	mm	7.8

	SBTACFR 190 mm^2	TACSR 160 mm^2	ACSR 160 mm^2
Allowable continuous current	800 A	705 A	454 A
Conductor cross section			

Conclusion

- ACFR could be used without any problem during the service life of transmission facilities.
- We also developed an SBTACFR which is capable of reducing power losses and increasing the transmission capacity, and verified the sheave passing compression-type dead-end clamp, counterweights, and the anti-vibration damper for application.
- The expansion of the application of ACFR has been foreseen.

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continued

Motivation

- In 2002, the authors developed an ACFR that uses CFCC instead of conventional steel cores in order to secure the conductor clearance above ground by replacing the conductors with ones with less sagging.
- We had installed ACFR on a 66 kV transmission line about 8 km from the coast for 16 years from December 2002 to January 2019. Subsequently, various evaluation tests were conducted.
- This paper aim to evaluate the reliability of the ACFR and the compression-type dead-end clamp that had been used over a long-term service of overhead lines.
- Furthermore, the authors have developed SBTACFR (SB: Smooth Body) and so on to expand of the application of ACFR.

Method/Approach

- The following table shows the sample summary of the various evaluation tests.

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Sample quantity	60 m	30 m	3 sets
Sample location	Lowest part of the sag	Suspension clamp, damper grip	1 steel tower

- Contents of evaluation tests; “Appearance, structure, and cross-sectional testing”, “Tensile load test”, “Electrical resistance test”, “Stress- elongation test” “Temperature-elongation test”

Objects of investigation

- The following table shows the test items and quantities for the conductor and compression clamps.

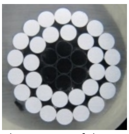
Line type	Test Items	Test quantity	Bottom of sagging	Suspension clamp gripping area	Damper gripping area
Hard aluminum wire	All items*	all	all		
CFCC	Appearance and structure	n=1	n=1		
	Tensile load	n=2	n=1	n=1	
	Stress - Elongation	n=1	n=1		
	Temperature - Elongation	n=1	n=1		
ACFR	Appearance and structure	n=3	n=1	n=1	n=1
	Cross-section	n=6	n=2	n=2	n=2
	Tensile load, electrical resistance	n=1	n=1		
	Stress - Elongation	n=1	n=1		
	Temperature - Elongation	n=1	n=1		

Sample	Test Items	Test quantity
Compression clamp	Appearance	n=3
	Cross-section	n=1
	Tensile load	n=2
	Electrical resistance	n=3

Experimental setup & test results

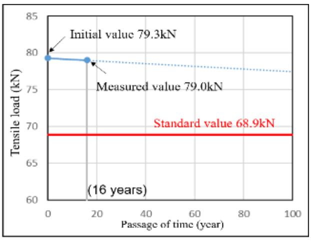
- No abnormality such as damage or corrosion was observed at the lowest part of the sag and the gripping area of the suspension clamp and the damper.

CFCC at the lowest part of the sag



ACFR cross section at the lowest part of the sag

- The tensile load of ACFR was almost the same as the initial value.



- No deterioration in electrical performance was observed.

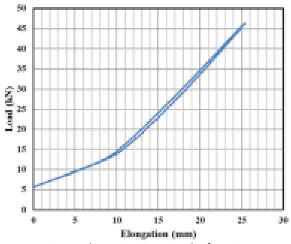
Electrical resistance test results for ACFR

Item	Electrical resistance (Ω/km at 20 °C)
Calculated value	0.182 or less
First time	0.184
Second time	0.184
Third time	0.183

Conductivity test results of hard aluminum strands

Item	Conductivity (%)
Standard value	61 or more
Maximum value	62.4
Minimum value	61.6
Average value*	62.1

- The modulus of elasticity of ACFR was almost the same as that of the initial value, although it was lower than the calculated value.



Stress-elongation test results for ACFR

Modulus of elasticity for CFCC and ACFR

Sample	Calculated value	Measured value	Initial value (2002)
CFCC	137 GPa	139 GPa	142 GPa
ACFR	76.0 GPa	63.0 GPa	60.2 GPa

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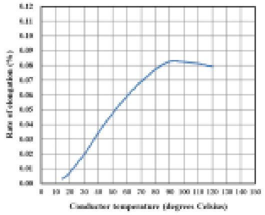
- The thermal expansion coefficients of CFCC and ACFR are negative above the transition point temperature, but this is not abnormal because it is widely known that the thermal expansion coefficient of polyacrylonitrile (PAN)-based carbon fiber, which is the material of CFCC, is negative.



Temperature-elongation characteristics of ACFR

Thermal expansion coefficient of CFCC and ACFR

Sample	Calculated value	Measured value	Initial value (2002)
CFCC	1.0×10^{-6}/°C	-1.6×10^{-6}/°C	0.7×10^{-6}/°C
ACFR	15.5×10^{-6}/°C	12.4×10^{-6}/°C (Above transition point: -1.6×10^{-6}/°C)	20.5×10^{-6}/°C

- No abnormalities such as broken conductors or corrosion were observed for the aluminum conductor and CFCC inside the clamp.

ACFR inside the aluminum clamp

CFCC inside the aluminum clamp

Discussion

- The tensile load of ACFR was almost the same as the initial value, and from the tendency of a slight decrease in tensile load, it is concluded that the ACFR can be used without any problem during the service life of the transmission facility.
- In order to expand the application of ACFR, an SBTACFR and a compression-type dead-end clamp that passes through a sheave were developed, and counterweights and Christmas tree-shaped dampers were verified for application.

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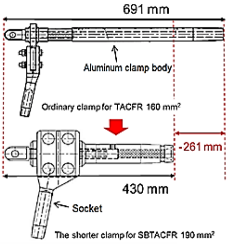
Conductor cross section			

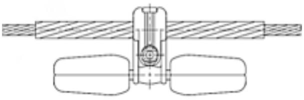
2. Sheeve passing compression-type dead-end clamp

- This clamp can pass through the sheave after being installed on the conductor by compression.



3. Counterweight

- This counterweight was designed to suppress heavy snow accumulation on overhead lines.



4. Anti-vibration damper

- This damper is a type of anti-vibration damper and is designed to suppress the wind vibration of transmission lines.

Two-loop type

Three-loop type

Conclusion

- ACFR could be used without any problem during the service life of transmission facilities.
- We also developed an SBTACFR which is capable of reducing power losses and increasing the transmission capacity, and verified the sheave passing compression-type dead-end clamp, counterweights, and the anti-vibration damper for application.
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