UTILITY HYBRID OVERHEAD GROUND WIRE FOR ICE MELTING WITH HIGH VOLTAGE AND LARGE CURRENT

Lu Jiazheng, Zhao Chun *, Li Bo, Fang Zhen, Zhang Hongxian, Xu Xunjian, Li Xiaochun
Power Transmission and Distribution Equipment Anti-icing & Reducing-disaster Technology Laboratory, Hunan Electric Power Test and Research Institute, Changsha, China
*Email: zhaochunmail@tom.com

***Abstract**:* A hybrid overhead ground wire with embedded current-carrying conductors is proposed. A sample hybrid overhead ground wire is designed and fabricated. The experiments show that this new kind of ground wire is with good insulation and is very beneficial to achieve efficient ice melting.

1. INTRODUCTION

Serious icing on overhead ground wires often causes them break and fall down on the conductors, resulting in many power transmission line tripping accidents. Common overhead ground wires are inconvenient for heat de-icing because of their special structure and large resistance [1].

2. PRINCIPLE OF HYBRID OVERHEAD GROUND WIRE

A utility hybrid overhead ground wire for ice melting with high voltage and large current is proposed. It consists of the supporting structure wire and the embedded current-carrying conductor, shown in Fig. 1. The former is to realize load bearing and lightning arresting just as common overhead ground wire, the latter is to conduct large current and lead to the temperature rising of the ground wire and the ice melting.

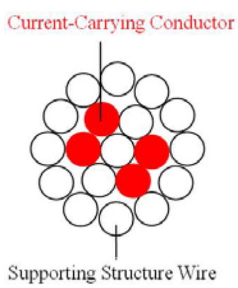

Figure 1: Schematic of hybrid overhead ground wire

Table 1: Parameters of Hybrid Overhead Ground Wire.

Parameter		Value
Structure	Entire	1×19
	Number of steel wires	13
	Number of copper wires	6
Nominal diameter	Entire (mm)	12.5
	Steel wire (mm)	2.5
	Copper wire[a] (mm)	2.0
Nominal cross-sectional area	Entire (mm2)	95
	Steel wires (mm2)	63.81
	Copper wires (mm2)	18.84

Figure 2: Sample hybrid overhead ground wire

3. DESIGN AND FABRICATION

A hybrid overhead ground wire with the structure of 1×19 and the nominal cross-sectional area of 95 mm2 is designed. The detailed parameters of the hybrid overhead ground wire are shown in Table 1.

Sample hybrid overhead ground wire is fabricated. Fig. 2 shows the cross-section of the sample ground wire.

4. EXPERIMENTS AND DISCUSSIONS

Experiments are performed on the sample hybrid overhead ground wire to study the characteristics of this new kind of ground wire.

DC high voltage withstanding tests show the good insulation level of the current-carrying conductors. Each conductor withstands 10 kV for 5 minutes, with the leakage current less than 1 μA.

In the ice melting experiment, the 9.11 mm thick ice on the sample ground wire can melt in 60 minutes under a 110 A current through the current-carrying conductors, i.e. under the power of 45 W per meter ground wire.

5. CONCLUSION

A hybrid overhead ground wire with embedded current-carrying conductors is proposed and fabricated. The experiments show that this new kind of ground wire is with good insulation and is very beneficial to achieve efficient ice melting.

6. REFERENCES

[1] Zuohua Liu, "De-icing scheme of overhead transmission lines", Popular Utilization of Electricity, no. 2, pp. 28-29, 2009 (in Chinese).

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Power Transmission and Distribution Equipment Anti-icing & Reducing-disaster Technology Laboratory
Hunan Electric Power Test and Research Institute
Changsha, China
zhaochunmail@tom.com

***Abstract*—Serious icing on overhead ground wires often causes them break and fall down on the conductors, leading to many power transmission line tripping accidents. Common overhead ground wires are inconvenient for heat de-icing. A utility hybrid overhead ground wire for ice melting with high voltage and large current is proposed. It consists of the supporting structure wires and the embedded current-carrying conductors. A hybrid overhead ground wire with the structure of 1×19 and the nominal cross-sectional area of 95 mm2 is designed and fabricated. The experiments show that the sample ground wire can withstand a 10 kV DC voltage and an apparent ice melting effect can be acquired under a power of 45 W per meter ground wire. The new kind of ground wire is with good insulation and is very beneficial to achieve efficient ice melting.**

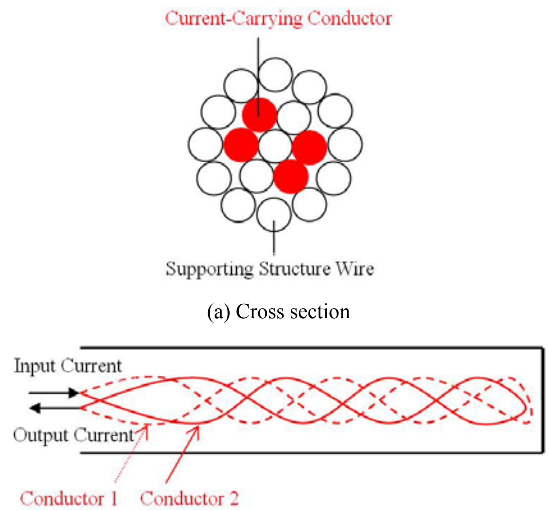
Keywords-overhead ground wire; ice melting; hybrid structure; current-carrying conductor; supporting structure wire

I. INTRODUCTION

Owing to the impacts of serious icing disaster, the overhead ground wires frequently broke and fell down on the conductors, leading to many power transmission line tripping accidents. In order to prevent such kinds of accidents, measures must be taken to remove the ice from the power transmission lines and overhead ground wires. Heating de-icing and mechanic de-icing are usual methods [1]. The heating method is used more and more widely in recent years, which is to apply large AC or DC current to the ground wires to cause ice melting. However, because of the special structure of overhead ground wire and the special installation, the insulation level of the overhead ground wire to the ground is not high enough, resulting in the limitation of the applied voltage. Furthermore, as the resistance of overhead ground wire is very large, the short-circuit current through the wire cannot reach very high and the temperature of the wire cannot increase very much. Therefore, common overhead ground wires are difficult to achieve efficient ice melting [2].

II. PRINCIPLE OF HYBRID OVERHEAD GROUND WIRE

A utility hybrid overhead ground wire for ice melting with high voltage and large current is proposed in this paper.



(a) Cross section

(b) Longitudinal section

Figure 1. Schematic of hybrid overhead ground wire.

The structure of the new ground wire is shown in Fig. 1. The hybrid overhead ground wire consists of two main parts, the supporting structure wire and the current-carrying conductor, whose cross section is shown in Fig. 1 (a). The current-carrying conductors are embedded in the supporting structure wires. The main function of the supporting structure wire is to realize load bearing and lightning arresting just as common overhead ground wires, to ensure the normal operation of transmission lines. The main function of the current-carrying conductor is to lead high voltage and large current, as will apparently increase the temperature of the overall hybrid overhead ground wire. There are insulation films on the conductor surfaces, which can realize the insulation between the supporting structure wires and the current-carrying conductors.

From the longitudinal section of the hybrid overhead ground wire in Fig. 1 (b), we can see the connection of the current-carrying conductors. There are two pairs of current-carrying conductors in the schematic, connected in the same way. The input and output ports of the current-carrying conductors are at the same end. Each current-carrying conductor is connected in the other end, forming a closed circuit to lead large current.

When power transmission lines are in normal operation, the current-carrying conductors are connected with the

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supporting structure wires to keep the same potential, so that the hybrid overhead ground wires act as common overhead ground wires. When power transmission lines and hybrid overhead ground wires are covered with ice in winter days, the current-carrying conductors are disconnected with the supporting structure wires to keep the insulation between them, so that a high voltage can be applied to the current-carrying conductors to create a large current, resulting in the temperature rising of the hybrid overhead ground wire and the ice melting.

III. Design and Fabrication of Hybrid Overhead Ground Wire

As described above, the hybrid overhead ground wire includes two main parts, the supporting structure wire and the current-carrying conductor. The supporting structure wire is made of stranded galvanized steel wire, whose cross-sectional area is determined by the design thickness of ice on the ground wire. The current-carrying conductor is made of copper wire, whose cross-sectional area is determined by the design ice melting current. A polyimide film is coated on the current-carrying conductor surface to realize the insulation, and another polyethylene layer is added to protect the polyimide film. The supporting structure wire and current-carrying conductor have same winding process same with common overhead ground wire.

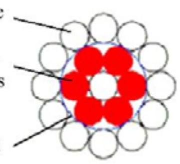

Figure 2. Design of the hybrid overhead ground wire with the structure of 1×19 and the nominal cross-sectional area of 95 mm2.

TABLE I. Parameters of Hybrid Overhead Ground Wire

Parameter		Value
Structure	Entire	1×19
	Number of steel wires	13
	Number of copper wires	6
Nominal diameter	Entire (mm)	12.5
	Steel wire (mm)	2.5
	Copper wire[a] (mm)	2.0
Nominal cross-sectional area	Entire (mm2)	95
	Steel wires (mm2)	63.81
	Copper wires (mm2)	18.84

a. Considering the thickness of the polyimide film and the polyethylene layer, the nominal diameter of the copper wire is designed smaller than that of the steel wire.

Figure 3. Sample hybrid overhead ground wire.

According to the common ground wire with the structure of 1×19 and the nominal cross-sectional area of 95 mm2, a hybrid overhead ground wire is designed. Six current-carrying conductors are embedded in the supporting structure wires, and a steel belt is winded around the conductors to protect them, as shown in Fig. 2. The detailed parameters of the hybrid overhead ground wire are shown in Table I.

As the resistivity of copper is 0.0175 Ω·mm2/m, the resistance per meter of a single conductor is calculated as follows:

$$R_0 = \rho \cdot L / A = 0.0175 \times 1 / 3.14 = 0.00557\ \Omega \qquad (1)$$

where R_0 is the resistance per meter of the single conductor, ρ is the resistivity of copper, L is the length of the single conductor, A is the cross-sectional area of the single conductor.

Sample hybrid overhead ground wire is fabricated. Fig. 3 shows the cross-section of the sample ground wire.

IV. Experiments and Discussions

Experiments are performed on the sample hybrid overhead ground wire to study the characteristics of this novel ground wire.

A. Insulation Experiment

There are six separated current-carrying conductors in the sample ground wire, so the insulation experiments are performed on each conductor respectively.

A 51 meters long sample ground wire is tested. The insulation resistance of each conductor is shown in Table II, tested with a megaohmmeter rated 2500 V.

DC high voltage withstanding tests are performed on the current-carrying conductors with a DC high voltage generator. Each conductor withstands 10 kV for 5 minutes, with the leakage current less than 1 μA.

TABLE II. INSULATION RESISTANCE OF CURRENT-CARRYING CONDUCTORS

No. of Conductors	Insulation Resistance (GΩ)
1	434
2	424
3	397
4	374
5	347
6	422

B. *Ice Melting Experiment*

A 1.5 meters long sample ground wire is used to demonstrate the ice melting effect. The ice melting experiment is carried out in an artificial climate chamber, where a temperature range from -15 ℃ to 60 ℃ can be achieved.

In the experiment, six current-carrying conductors are divided into two groups. Every group includes three conductors in parallel, and two groups are connected in series.

Considering that the electric power per meter of the ground wire is 45 W, and based on the result of (1), the total current through the conductors can be calculated as follows:

$$I = (P_0 / (R_0 \cdot 2/3))^{1/2} = (45 / (0.00557 \times 2/3))^{1/2} = 110 \text{ A} \quad (2)$$

where I is the total current through the conductors, P_0 is the electric power per meter of the ground wire, R_0 is the resistance per meter of the single conductor.

The experimental process is as follows:

1) By keeping the wind speed at 1 m/s and adjusting the temperature and the rainfall in the artificial climate chamber, cover the hybrid overhead ground wire with thick ice.

2) When the ice is formed on the ground wire, stop the rain and keep the environmental temperature at -3 ℃ in the artificial climate chamber.

3) Regulate an experimental power supply to apply a 110 A current to the current-carrying conductors. Measure the current through the conductors and the temperature of the ground wire every five minutes, until the ice melting is acomplished.

An ice melting experiment is carried out when the average thickness of the pre-covered ice on the hybrid overhead ground wire is 9.11 mm. The experimental results are shown in Table III.

TABLE III. RESULTS OF THE ICE MELTING EXPERIMENT

Time	Current (A)	Temperature (℃)
19:57	Start	
20:00	108	15.5
20:05	119	11.5
20:10	119	19.7
20:15	115.6	23.6
20:20	114.2	23.1
20:25	112.9	22.6
20:30	111.9	21.6
20:35	113.9	20.9
20:40	114.2	21.3
20:45	113.7	22.9
20:50	112.4	25.0
20:55	110.5	21.8
20:57	Finish	

From Table III we can see, the 9.11 mm thick ice on the sample ground wire can melt in 60 minutes under a 110 A current through the current-carrying conductors, i.e. under the power of 45 W per meter ground wire.

V. CONCLUSION

1) A utility hybrid overhead ground wire with embedded current-carrying conductors for ice melting is proposed. This new kind of ground wire is with both functions of lightning arresting and ice melting.

2) The hybrid overhead ground wire with the structure of 1×19 and the nominal cross-sectional area of 95 mm2 is designed and fabricated.

3) The experimental results show that the sample ground wire can withstand a 10 kV DC voltage and an apparent ice melting effect can be acquired under a power of 45 W per meter ground wire. This new kind of ground wire is with good insulation and is very beneficial to achieve efficient ice melting.

REFERENCES

[1] Longfu Luo and Zhiyu Zhao, "Overview of de-icing methods of high voltage overhead transmission lines," Popular Utilization of Electricity, no. 2, pp. 23-24, 2009 (in Chinese).

[2] Zuohua Liu, "De-icing scheme of overhead transmission lines," Popular Utilization of Electricity, no. 2, pp. 28-29, 2009 (in Chinese).