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The effect of floating-potential conductors on the electric field near overhead transmission lines

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ABSTRACT

The use of helicopters as platforms equipped with infrared and UV detection, digital cameras and other inspection equipment is an effective method of increasing the efficiency and effectiveness of transmission line inspection. However, as a 'floating-potential conductor' near to a high-voltage transmission line, a helicopter causes distortion of the local electric field, with regions of high electric field near the helicopter's surface where the curvature is high. In this paper, these fields are investigated both by calculation and experimentally, using a simple metal sphere, and then a model of a helicopter, placed near to a short length of energized transmission line conductor.

1. Introduction

Power transmission lines are a key part of the power system and are exposed all the year round to the prevailing weather conditions. It follows that they are more prone to faults than other parts of the system. Furthermore visual monitoring of the lines may be extremely difficult where the terrain over which the lines run present great difficulties for the workers to access. This is particularly so in China where the necessarily very long transmission lines may traverse mountains, swamps, rivers and forests much of which are relatively unpopulated and hard to reach [1–4]. Meanwhile, the development of the smart grid in China requires higher stability and reliability of power delivery [5,6]. Helicopters have the ability to ascend and descend vertically and to hover motionless at any height, making them ideally suited for monitoring overhead lines [4,6–9]. Using a helicopter as a moving platform equipped with infrared, visual and UV video cameras and other equipment for line patrol duties is an efficient way to improve the efficiency and accuracy of transmission line monitoring [10–13]. The helicopter enables close observation of the conductors, insulators, fittings and towers, while with infrared and UV inspection systems, operators can clearly see where corona and other discharges are occurring [14–18].

However, when a helicopter is close to a transmission line, it will, as an isolated conductor, cause a distortion of the electric field distribution. This will be particularly important around those parts of the helicopter having a small radius of curvature where the field will be high, perhaps causing localized discharges and the possibility of a breakdown between line, helicopter and ground, with the consequent dangers to helicopter, personnel and equipment.

Calculations concerning floating conductors have been considered by several investigators [19–23]: Tadashi used a charge simulation method to determine the field near a floating conductor touching two dielectric media [19]; Lucian employed a boundary-element method to determine the field in the region between a charged body and a conducting disc at a floating-potential [20]. Also several authors have considered the fields near or below 3-phase and DC transmission lines with reference to sag and ground characteristics [24–29], but none appear to have considered the field distortion due to floating-potential conductors near transmission lines. In this paper the effect on the electric field around floating-potential conductors near to transmission lines is considered both experimentally and by numerical calculation. The two cases considered are a sphere and a model helicopter.

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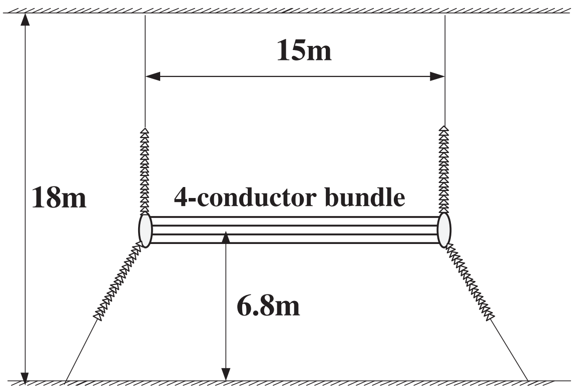

Fig. 1. The location of the quad bundle.

2. Experiments

The experiments were carried out in a shielded hall of dimensions 66 m × 30 m × 18 m. The ambient temperature was in the range 16–18 °C for the tests. The air pressure was between 100.2 and 100.6 kPa, and the relative humidity was in the range 40%–50% throughout. The overhead transmission line used was a 4-conductor bundle, type LGJ-400/35, of length 15 m, which was installed at the center of the hall about 7 m above the ground as shown in Fig. 1. The parameters of the quad bundle are shown in Table 1.

The field was measured by a Holaday HI-3604 Survey Meter which can measure both electric and magnetic fields at 50/60 Hz, and is shown in Fig. 2a [30,31]. A 1000 kV adjustable frequency transformer was used as the power supply (Fig. 3).

The field meter was connected to an insulated rod supported on an insulated trolley which could be moved to measure the field at the required point. The field meter and insulated rod may be seen in Fig. 4a.

As the external material of a helicopter is mainly metal, when it is used to observe transmission lines, it will be at a floating-potential; the charge in the field would redistribute because of polarization effect; so the floating-potential conductor would distort the surrounding electric field and potential. To study this effect, a simple geometry was used initially: a spherical metal ball with a diameter of 0.65 m. Later the experiment and calculation were extended by replacing the sphere with a simplified 1:10 model of a helicopter based on the Bell 206 line patrol helicopter. For both the experiments and calculations the sphere and the helicopter model were placed at various distances from the transmission line, but at the same height above the ground plane. The floating-potential conductors were hung with an insulating rope made up of cotton. The quad bundle, field meter and sphere may be seen in Fig. 4a. A cross-section of the hall showing the positioning of the transmission line model and the metal sphere is shown in Fig. 4b.

3. Numerical calculation

The experiments were carried out in a shielded hall which was represented in the calculation by a cuboid of the same dimensions whose six boundary faces were set to 0 V (grounded). The charge density of the air in the hall was set to zero, the metal sphere and helicopter model were regarded as floating-potential conductors with no overall charge before discharge corona. The set-up was as indicated in Fig. 5, with the transmission line 6.8 m above the ground.

Table 1
Parameter of 4 × LGJ-400/35.

External diameter of sub-conductor	Bundle spacing[a]
26.8 mm	450 mm

[a] Distance between the center of a conductor and its nearest-neighbor conductors.

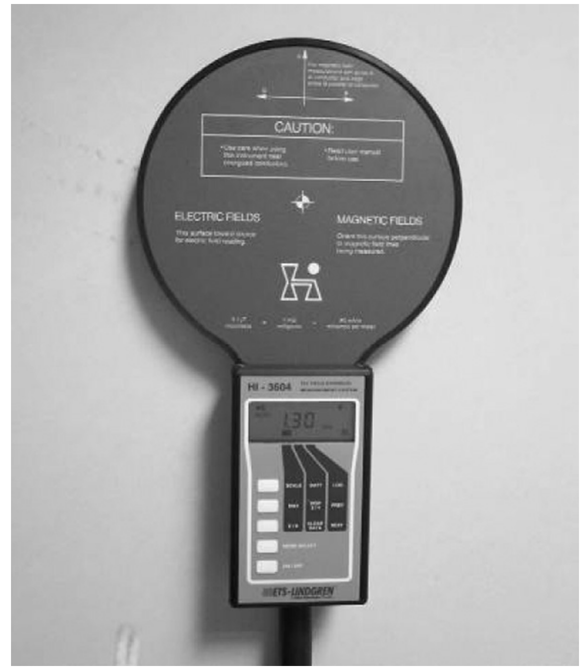

Fig. 2. The Holaday HI-3604 Survey Meter.

Fig. 3. The 1000 kV adjustable frequency transformer.