J Electr Eng Technol Vol. 9, No. 5: 1704-1711, 2014
http://dx.doi.org/10.5370/JEET.2014.9.5.1704

ISSN(Print) 1975-0102
ISSN(Online) 2093-7423

Corona generated Radio Interference of the 750 kV AC Bundle Conductors in Sandy and Dusty Weather Condition in the High Altitude Area

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Abstract – Sandy and dusty weather condition often occurs in the high altitude areas of China, which may greatly influence the corona generated radio interference (RI) characteristics of the bundle conductors of 750 kV AC power transmission lines. Corona generated RI of the conductors of the 750 kV AC power transmission lines used in practice is measured by EMI receiver with a coupling circuit and a coupling capacitor connected between the high voltage side and the earth side in fine and sandy and dusty condition. The measuring frequency is 0.5 MHz, and the quasi-peak detection is used. RI excitation function is calculated based on the corona RI current measured by the EMI receiver. Corona generated RI characteristics were analyzed from sand concentration and sand particle size. The test result shows that the corona generated RI excitation function is influenced by the sandy and dusty condition. Corona discharge of the conductors is more serious in sandy and dusty condition with an ultraviolet (UV) detector. Corona generated RI excitation function increases with the increase of sand concentration and also increases with the increase of particle size.

Keywords: Sandy and dusty condition, 750 kV bundle conductor, Radio interference, Excitation function, Sand concentration, Particle size

1. Introduction

The electromagnetic interference problem is one of the key technical problems in the construction of the extra-high voltage (EHV) and ultra-high voltage (UHV) power transmission lines. Corona generated RI of the transmission line plays a key role in the conductor type selection, conductor arrangement method, determining the height of the conductor to the ground, and determining the height of the tower [1-3].

Many studies were done on the radio interference of the UHV / EHV power transmission line conductors before 1990s. In 1970s, BPA Corporation in America and CIGRE put forward the RI excitation function of the single conductor in the heavy rain condition [4-5]. CISPR put forward the RI excitation function of the bundle conductors with bundle number more than 4 in the heavy rain condition [6]. IREQ in Canada and EPRI in America utilized corona cages and test lines to study the corona effect of the AC power transmission lines and gained the empirical formula of the corona generated RI excitation function based on the large quantities of experimental data [7-8]. After 1980s, CRIEPI in Japan used the UHV and EHV corona cages to study the radio interference of the UHV DC power transmission line conductors [9].

Air density has closely relationship with the corona onset characteristics of conductors. The air density in high altitude area is lower, corona discharge occurs more easily in high altitude areas, and the electromagnetic environment problem is more serious [10]. On the basis, the sandy and dusty weather conditions may further increase the corona generated RI of the 750kV power transmission line conductors.

Research on the operating of power system in sandy and dusty condition mainly focused on the breakdown characteristic of the air gaps and the surface flashover characteristics of the insulators. The research results show that sandy and dusty condition will influence the breakdown characteristics of the air gaps, and the influence degree is related to the distance between the electrodes, the electrode geometry, the particle sizes; flashover voltage of the insulator is lower in sandy and dusty condition [11-14]. Besides, in [15], the electric field distribution near the power transmission lines and electric tower was calculated. The result shows that the sand particles will influence the surface electric filed strength of the grading ring and bundle conductors. Researchers did research on comparing the corona characteristic differences between long term operating transmission line conductors and new conductor, the test result shows that corona discharge of the long operating conductors is stronger, and the corona generated

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Received: February 23, 2014; Accepted: April 18, 2014

RI and audible noise are larger than that of the new conductors [16].

Under both high altitude and sandy and dusty weather conditions, there is no relevant research on the corona-generated RI of the 750 kV bundle conductors. The altitudes of the EHV AC power lines are mainly higher than 1000 m in northwest China, and the altitudes of some areas are higher than 3000 m (for example Qing-Zang Plateau). Most regions in northwest China are experiencing sandy and dusty weather condition especially in spring. The number of days that sandy and dusty weather condition occur would exceed 20 in some areas, so studying on corona generated RI of the 750 kV AC power transmission line conductors in the high altitude and sandy and dusty condition is of practical significance.

2. Corona Generated RI Test

2.1 Corona generated RI test method in the corona cage

The corona generated RI test system in sandy and dusty condition is composed of two parts: sandy and dusty condition simulation system and radio interference test system. The RI test method and the parameters of the test equipments could be determined according to [17]. There are two ways to measure RI of the transmission line conductor: one is to measure the emitted field and the other is to measure the conducted quantities (current or voltage) with a prescribed test circuit. For the practical transmission line, the former method is generally used, and the loop antenna and EMI receiver are used to measure the corona generated RI field.

In corona cage, the conducted radio interference current of the conductor is measured by the EMI receiver, and the real RI interference could be gained with the excitation function method. The test equipments include coupling circuit, EMI receiver, wave trapper, and coaxial cable. The coupling circuit could be connected in two connection ways: one is connecting the high voltage coupling capacitor and coupling circuit between the high voltage test conductor and the ground; the other is connecting the coupling circuit between the corona cage wall and the ground. The connection method of the RI coupling circuit in this paper is shown in Fig. 1. In the figure, 1 is the test power source, 2 is the capacitive voltage divider, 3 is the wave trapper, 4 is the radio interference meter, and 5 is the corona cage. The parameter of the measuring circuit is determined according to [17], and in the test the matching impedance R_2 is 50 Ω the series impedance R1 is 275 Ω, the capacitance of C is 4000 pF, and the input impedance of EMI receiver R0 is 50 Ω. The measuring terminal impedance which consists of an input impedance of EMI receiver R_2 and R_0 is 25 Ω. In the reference frequency, the value of L is larger than 1 mH.

The radio interference meter is the calibrated FCKL 1528 made by Schwarzbeck Mess Corporation. The reference frequency is 0.5 MHz, and quasi-peak detection method is used.

2.2 Movable corona cage

Corona generated RI data are generally gained from the conductor in a short test line or in a corona cage. Also, a corona cage has the following advantages: reproducing the corona discharge status with a much lower test voltage, lower investment, convenience to transport (especially for high altitude test) and convenience in adjusting the experiment conditions. The parameters of the corona cage in this test are: measuring part 8 m, shielding part 1 m, and

Fig. 2. Movable corona cage

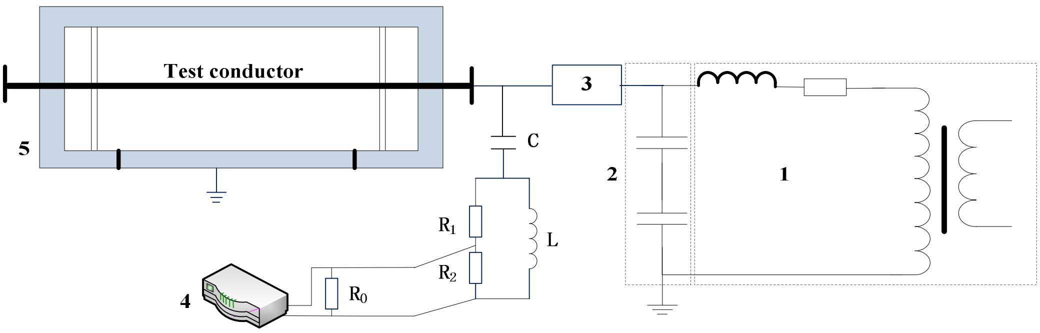


Fig. 1. Schematic diagram of radio interference measurement

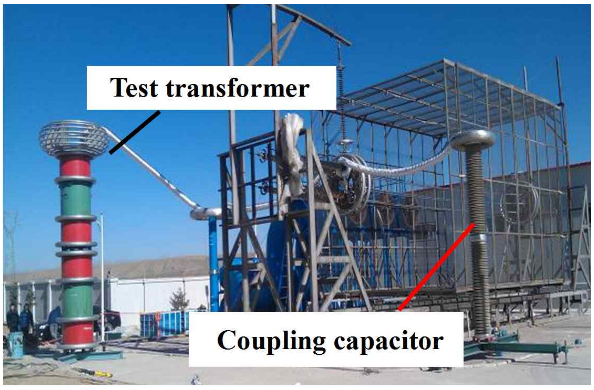


Fig. 3. Test arrangement

side length of the square section 6 m. Corona loss, RI, and audible noise generated by corona discharge of the bundle conductors of different dimensions and structures in different altitudes could be done using the cage in this study, as shown in Fig. 2.

2.3 Test arrangement

The test arrangement is shown in Fig. 3. The altitude of the test spot (Haibei Tibetan Autonomous Prefecture, Qinghai Province) is 3042 m. The parameters of the series resonance transformer are: rated input voltage 380 V, rated output voltage 600 kV, and apparent power 1200 kVA.

Two capacitors in series connection are used as the coupling capacitors and the withstand voltage is 400 kV.

2.4 Corona generated RI excitation function

RI excitation function can characterize corona discharge, which takes into account the nature of corona currents, depends only on space charges and electric field distribution and is not influenced by conductor parameters or line configuration. RI excitation function has the advantage of independent of the conductor capacitance per unit length. The excitation function which is related to the current in the bundle conductor could be calculated by the following Formula 1 [5].

$$\Gamma = I \cdot \frac{2\pi\varepsilon_0}{C} \tag{1}$$

Where, Γ is the excitation function in $\mu A/m^{1/2}$;

I is high frequency current injected into the bundle conductors in $\mu A/m^{1/2}$;

C is the unit length capacitance between the bundle conductor and the corona cage.

Γ (in dB) in this test could be calculated in reference [18]

$$\Gamma = U_{RI} - 20 \cdot \lg(Z_{eq} \cdot \sqrt{l}) + 20 \cdot \lg(2\pi\varepsilon_0 / C) \tag{2}$$

Where, the unit of Γ becomes in dB/1 $\mu A/m^{1/2}$;

U_{RI} is the radio interference voltage recorded by the receiver in dB/1 μV;

Z_{eq} is the equivalent impedance of the measure circuit (Ω); l is the length measurement of the corona cage.

3. Sandy and Dusty Condition Simulation in the High Altitude Area

3.1 Sandy and dusty condition simulation system

In order to simulate sand particles blowing across the conductors, a sandy and dusty condition simulation system is established. The main parts of the system are shown in Fig. 4. Fig. 5 is the actual figure of the system.

6 axial industrial fans, divided into 3 groups, are taken as the wind sources, which can generate wind with enough speed. The rated air volume is 65000 m^3/h, and rated total pressure is 4000 Pa. The electric power is supplied by a power source of 380 V. Elbow structure is taken in designing the wind tunnels, which can save the land that this sandy and dusty simulation system covers and ensure the security of the system.

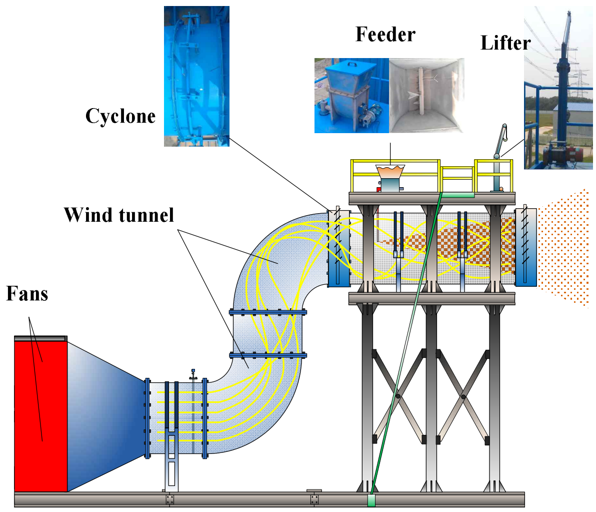


Fig. 4. Schematic diagram of the sandy and dusty condition simulation system

Fig. 5. Actual figure of the system

Sand particles are screened into different particle sizes, and drop into the wind tunnel from the spiral sand particle feeder. As Fig. 4 shows, the functions of the cyclones in the upper wind tunnel is generating a whirl airflow which can enlarger the diffuse range of sand particles.

The function of the converter is to control the rotating speed of the fans and the speed of the feeder, which will in turn change the wind speed and sand concentration. Finally the wind speeds generating by this system are 5 m/s-16 m/s and the sand particle concentration of this system is 133 mg/m^3 and above.

3.2 Selection of sandy and dusty parameters

Three main factors that influence the intensity of the sandy and dusty conditions are: the wind speed, the concentration of the sand, and the particle sizes of the sand. Different levels of the sandy and dusty weather conditions are simulated by combining the parameters above.

Sand particles could not be blown to the air without enough wind speed, which is determined according to the criterion of different levels of sandy and dusty weather conditions in northwest of China, as shown in Table 1 [19].

Sand particles are purchased from the local area not far from the 750 kV power transmission lines in northwestern China, the sizes of the sand particles are referred to [20], in which the particle sizes of the sand are found to be <0.2 mm in sandy and dusty condition, and the sand particle size could be higher in extremely serious sand storm. Different sizes of sand particles are separated by industrial sieves. After taking the sieving difficulty into consideration, the final three grades of sand particle sizes are: <0.125 mm, 0.125-0.25 mm, 0.25-0.5 mm.

Sand concentration is also an important parameter of the sandy and dusty weather condition. The sand concentration and visibility of different levels of sandy and dusty weather conditions were studied in [21-24]. The sand concentrations in the test are chosen as 200 mg/m^3, 330 mg/m^3, and 460 mg/m^3. Sandy and dusty condition simulation effect is presented in Fig. 6.

Table 1. Criterion of the sandy and dusty weahter

Level	Maximum wind speed
Extra strong	Scale 10 and above(25 m/s)
Strong	Scale 8 and above(20 m/s)
Medium	Scale 6 and above(15 m/s)
Common	Scale 4 and above(10 m/s)

Fig. 6. Sandy and dusty condition simulation

Salt contents of the sand of different particles sizes are shown in Table 2. Salt content of the sand particles in the test is measured with similar method as measuring the salt content in contaminations of insulators.

Table 2. Salt content of particles in the test

	Particle size		
	<0.125	0.125-0.25	0.25-0.5
Salt content (g/kg)	0.125	0.1	0.115

The ambient humidity and temperature during the test were also recorded, as shown in Table 3.

Table 3. Temperature, relative humidity and air temperature

Conductor	Temperature (°C)	Relative humidity (%)	Air pressure (kPa)
LGJ400-50	5.6-9.8	32.5-19.7	70.3

4. Test results

4.1 Influence of sand condition on corona discharge intensity

Generally, UV corona discharge imager is used to detect

Fine condition sandy and dusty condition

(a) 240kV

Fine condition sandy and dusty condition

(b) 280kV

Fine condition sandy and dusty condition

(c) 320kV

Fig. 7. Comparison of corona discharge intensity in different conditions

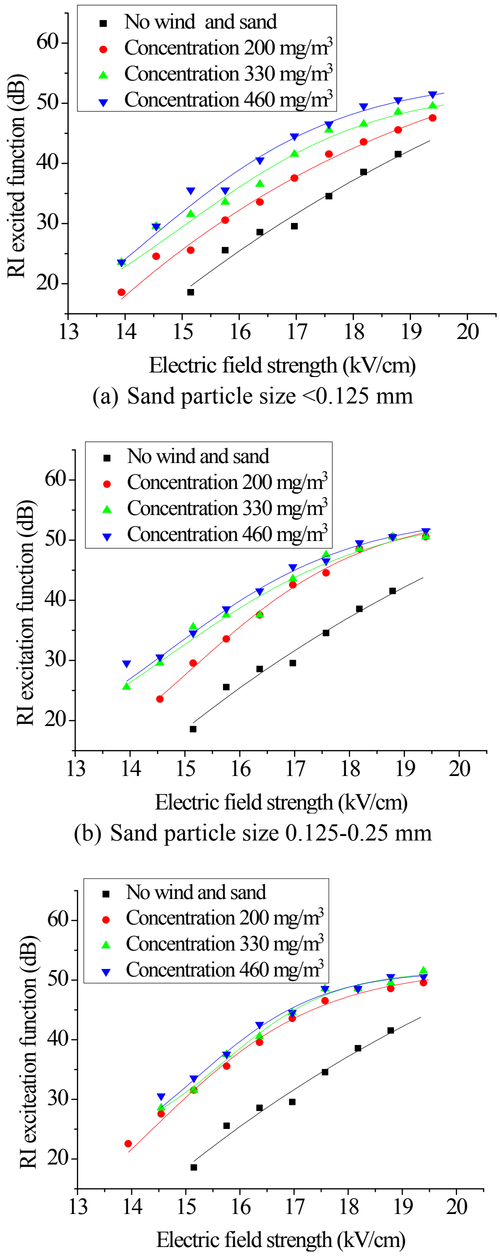
the discharge intensity of the conductors. In this study, the UV corona discharge imager (DayCor 'Superb' corona module, made in Israel) is used to test the corona discharge intensity in sandy and dusty condition and in fine condition. As could be seen in Fig. 7, the photon counting results are higher in sandy and dusty condition, which could prove that corona discharge become more serious and corona discharge occurs in a lower voltage in sandy and dusty condition. Sand particle parameters in the corona discharge intensity test are: sand concentration 460 mg/m^3 and particle size 0.25-0.5 mm.

4.2 Influence of sand concentration on corona generated RI excitation function

The stranded conductors used in the test are LGJ400-50 (bundle space 400 mm), the diameter of which is 27.63mm. The abscissas of the figures are the maximum surface electric field strengths of the LGJ400-50 conductors, which are calculated with the finite element method using the software ANSYS. When the voltage is 100 kV (effective value) the maximum surface electric field strength of the smooth conductors, which have the same diameters as the stranded ones, is 6.06 kV/cm. In the sandy and dusty condition, the wind speed is 16 m/s. Sand particle sizes are <0.125 mm, 0.125-0.25 mm, and 0.25-0.5 mm. Sand concentrations are 200 mg/m^3, 330mg/m^3 and 460 mg/m^3. The variations of corona generated RI of the test conductor with the test electric field strength are shown in Fig. 8. The operating electric field strength is generally 80-85% of the corona onset electric field strength of the power line conductor [25], so the operating electric field strength will mostly not exceed 17 kV/cm with the method in [26]. So in the range of operating electric field strength, the corona generated RI of the conductors of the 750 kV power transmission lines increase by 6-15 dB. As shown in Fig. 8, the corona generated RI increases with the increase of the sand concentration. With the increase of electric field strength, the differences of the RI with different sand concentrations tend to decrease.

4.3 Influence of sand particle size on corona generated RI

Sand particle sizes considered in this work are <0.125 mm, 0.125-0.25 mm, and 0.25-0.5 mm. Fig. 9 show the influence of particle size on corona generated RI excitation function when the sand concentration is 200 mg/m^3. Similar tendencies are found in other two sand con-centrations. As shown in Fig. 9, the corona generated RI excitation function increases with the increase in particle sizes. For LGJ400-50 conductor, when the electric field is 16 kV/cm, the corona generated RI excitation functions are respectively 32dB, 35.25dB and 37.66dB with the increase of particle size. With the increase of the electric field strength, the corona generated RI excitation function in the



(a) Sand particle size <0.125 mm

(b) Sand particle size 0.125-0.25 mm

(c) Sand particle size 0.25-0.5 mm

Fig. 8. Influence of sand concentration on RI excitation function of LGJ400-50

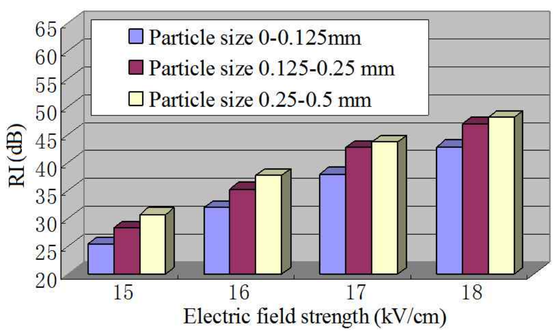


Fig. 9. Influence of particle size on corona generated RI excitation function of LGJ400-50 conductor

sandy and dusty condition of different particle sizes tend to be close.

5. Discussion of the test results

In high altitude regions, corona-generated RI is first influenced by the altitude factor, the corona generated RI of the bundle conductors increase 3.13 dB with the altitude 1000 m higher [10]. And then corona generated RI is influenced by the particle factor in the sandy and dusty condition. In this paper, sandy and dusty condition is found to have impact on the corona generated RI of the 750 kV AC bundle stranded conductor. Corona discharge in sandy and dusty condition is discharge occurs in solid and gas mixtures. The possible explanations of this kind of discharge may be expressed as following.

Calculating the electric field strength distribution in the vicinity of the conductor with the presence of insulating particles is the essential step in analyzing the corona discharge process. Maximum electric field strength is calculated with different permittivity, particle sizes and distances between particle and conductor [27]. With the increase of sand concentration, there are more sand particles in space. Thus, there are more electric filed distorted points on the surface of the conductor. And larger particles will have more serious influence on electric field strength distribution near the conductor. So the increasing of corona generated RI with the increase of particle size and concentration could be explained from the electric field strength point of view in certain extent. There will be positive and negative ions produced in the corona discharge process, and sand particles will become charging in this process [28]. For example, sand particles will acquire positive ions in the positive half circle of the voltage. Then in the next negative half circle, sand particles with positive ions in the vicinity of the conductor will cause more serious electric field distortion than the sand with no ions. In addition, when the electric filed strength is strong enough, sand particles may produce momentary discharge, and this can increase the measured radio interference. Corona discharge mechanism of the conductor in solid-gas mixtures (such as in sandy and dusty weather condition) is complex, and needs extensive research both in the experiment aspect and in simulation aspect in the future.

6. Conclusion

Corona discharge of transmission line conductor is more serious in sandy and dusty condition. In the simulated sandy and dusty condition, the corona generated RI excitation function is larger than that in no sand condition, and the corona generated RI increases with the increase in sand particle size and increases with the increase in sand concentration. In the practical range of operating electric field strengths, the corona generated RI excitation function of the 750 kV AC transmission line conductors increases by 6-15 dB.

Acknowledgements

We want to thank the staff in China Electric Power Research Institute and Xining Electric Power Test Research Institute, who helped us a lot in the experiments. This paper is sponsored by the following projects: National Basic Research Program of China (2011CB209401), National Natural Science Foundation of China (51277073).

References

[1] P.S. Maruvada, "Corona performance of high voltage transmission lines," London, UK: Research Studies Press Ltd, 2000, pp. 91-108.

[2] J. B. Kim, D. Lee, K. Y. Shin, H. S. Ahn, and K. H. Yang, "Electromagnetic interference from a three phase double circuit 765-kV test line," IEEE Trans. Power Delivery, vol. 14, no. 1, pp. 266-271, Jan. 1999.

[3] V. L. Chartier, S. M. Lowder, S. Rodick, and M. W. Vogt, "Radio and audible noise performance of T2 conductors," IEEE Trans. Power Delivery, vol. 11, no. 3, pp. 1464-1474, Jul. 2002..

[4] G. W. Juette, L. E. Zaffanella, "Radio noise current and audible noise on short sections of UHV bundle conductors," IEEE Trans. on PAS, vol. 89, no. 5, pp. 902-913, May. 1970.

[5] G. O. Rorbert, D. S. Steven, L. C. Vernon, "Comparison of several methods for calculating power line electromagnetic interference levels and calibration with long term data," IEEE Trans. on Power Delivery, vol. 7, no. 2, pp. 903-913, Aug. 1992

[6] Radio interference characteristics of overhead power lines and high-voltage equipment. Part 3: Code of practice for minimizing the generation of radio noise, TR CISPR-3, Jun. 2010.

[7] N. G. Trinh, P. S. Maruvada, B. Poirier, "A comparative study of the corona performance of conductor bundles for 1200 kV Transmission lines," in IEEE PES Summer Meeting & UHV/UHV Conference, 1973.

[8] Electric Power Research Institute. Transmission line Reference Book: 345 kV and above, second edition. Palo Alto, CA. 1981.

[9] Y. Nakano, Y. Sunaga, "Availability of corona cage for predicting radio interference generated from HVDC transmission line," IEEE Trans. on Power Delivery, vol. 5, no. 3, pp. 1436-1442, Jul. 1990.

[10] J. Tang, Y. P. Liu, X. Wu, G. Z. Zhang, Q. H. Guan , Y. J. Yang, and J. L. He, "Effect of Altitude on Radio

Interference Based on Corona Test Cage," High Voltage Engineering, vol. 35, no. 3, pp. 601-606, Mar. 2009. (in Chinese)
[11] A. A. AI-Arainy, N. H. Malik and M. I. Qureshi, "Influence of Sand/Dust Contamination on the Breakdown of Asymmetrical Air Gaps under Lightning Impulses," IEEE Trans. Electrical Insulation, vol. 27, no. 2, pp. 192-205, Apr. 2002.
[12] M. M. Awad, H. M. Said, B. A. Arafa, and A. E. H. Sadeek. "Effect of sandstorms with charged particles on the flashover and breakdown of transmission lines," in Proc. 2002 International Council on Large Electric systems Conf., pp. 306-309.
[13] B. He, H. Y. Jin, N. K. Gao, B. F. Cheng, Z. R. Peng, "Characteristics of dust deposition on suspended Insulators during simulated sandstorm," IEEE Trans. Dielectrics and Electrical Insulation, vol. 17, no. 1, pp. 100–105, Apr. 2010.
[14] W. X. Sima, Q. Yang, G. Q. Ma, "Experiments and analysis of sand dust flashover of the flat plate model," IEEE Trans. Dielectrics and Electrical Insulation, vol. 17, no. 2, pp. 572–581, Apr. 2010.
[15] B. Zhang, R. Zeng, J. L. He, "Influence of sand and dust storms and wind-sand electricity on electric field distribution around head of transmission tower," Shaanxi Electric Power, vol. 40, no. 1, pp. 6-10, Jan. 1998. (in Chinese)
[16] X. M. Bian, L. Chen, D. M. Yu, L. M. Wang, and Z. C. Guan. Impact of surface roughness on corona discharge for 30-year operating conductors ac power transmission line," IEEE Trans. Power delivery, vol. 27, no. 3, pp. 1693-1695, July. 2012.
[17] Radio interference characteristics of overhead power lines and high-voltage equipment. Part 2: methods for measurement and procedure for determining limits, TR CISPR-2, Jun. 2010.
[18] J. Tang, "Study on corona effects and electromagnetic environment of 1000 kV Ultra-high voltage AC transmission line," PhD dissertation, Tsinghua University, China, 2009.
[19] Y. J. Lei, X. N. Wang, L. Y. Li, "Discussion on questions existing in some partition criterion of sandstorm intensity," Journal of desert Research, vol. 26, no. 2, pp. 273-277, Mar. 2006. (in Chinese)
[20] G. W. Yue, H. X. Lin, X. Chang, "Scientific research of sand and dust storm," Lanzhou, China: Lanzhou University Press, pp. 44-45. (in Chinese)
[21] X. C. Zhao, M. Q. Zhao, S. Y. Wang, "Determination of dust-storm and its analytical research," Journal of Desert Research, vol. 2, no. 1, pp. 13-20, Apr. 1990. (in Chinese)
[22] L. J. Hagen, E. L. Skidmore, "Wind erosion and visibility problems," American Society of Agricultural Engineers, vol. 20, no. 5, pp. 898-903, Jan. 1977.
[23] W. S. Chepil, "Dynamics of wind erosion: I Nature of movement of soil by wind," Soil Science, vol. 60, no. 4, pp. 305-320, Oct. 1945.
[24] W. S. Chepil, "Properties of Soil Which Influence Wind Erosion: IV. State of Dry Aggregate Structure," Soil Science, vol. 72, no. 5, pp. 387-401, Nov. 1951.
[25] China Electricity Council, Code for design of 110kV~750kV overhead transmission line, Beijing: China Planning Press, , 2010, pp. 11-12.
[26] Y. P. Liu, S. H. You, F. C Lü, Q. F. Wan, X. M. Bian, L. M. Wang, "500-kV EHV Bundle Conductors' Corona Onset Voltage Calculation and Analysis in Corona Cage at Different Altitudes," IEEE Trans. Power Delivery, vol. 27, no. 4, pp. 2090-2097, Oct. 2012.
[27] F. Lu, Q. Z. Ye, "A dipole approximation for a dielectric mixture based on the equal field energy method," Journal of Electronics, vol. 68, no. 1, pp. 116-121, Dec. 2009.
[28] S. Adrian, D. Lucian, "Unipolar charging of cylindrical insulating particles near electrode surfaces," IEEE Trans. on Industry Application, vol. 34, no. 1, pp. 51-56, Jan. 1998.

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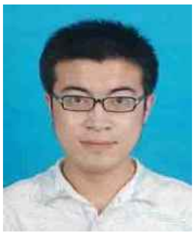

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