Journal of Electrostatics 77 (2015) 1–7

Contents lists available at ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Effect of pollution severity class and service year on corona characteristics and electromagnetic environment degradation of aged conductors

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ARTICLE INFO

Article history:
Received 3 March 2015
Received in revised form
24 June 2015
Accepted 28 June 2015
Available online 9 July 2015

Keywords:
Corona discharge
Audible noise
Radio interference
Transmission lines
Aging
Pollution severity class

ABSTRACT

Corona discharge and electromagnetic environment on AC long-term operated conductors are important issues for extra-high-voltage transmission lines. To investigate the relation between conductor age and electromagnetic environment, including audible noise and radio noise, several groups of long-term operated conductors in China are selected for corona cage experiment. According to corona tests, corona discharge becomes more serious as the applied voltage improves. Difference of electromagnetic environment between conductors of different operated year increases. Corona discharge and electromagnetic noise become more serious as the service year lengthens. When the operated years are close, the general environment is important in electromagnetic environment degradation.

1. Introduction

After 10–30 years' service in outdoor atmospheric environment, physical characteristics of power transmission lines become worse, for example, the surface roughness may increase due to oxidation or erosion of the aluminum, acid rain, adherence of various substances [1]. The deterioration of aluminum stranded conductors may directly result in possible corona discharge [2]. When applying high voltage to transmission lines, strong electric field will be formed near the surface; if the electric field strength exceeds a critical value, corona discharge will occur near the conductor surface. Audible noise (AN) and radio interference (RI) come concomitantly with corona, either of which is technically and environmentally undesirable [3,4].

To study the effect of electromagnetic environment of AC transmission lines, artificially polluted conductors were used for aging experiments in several studies [5,6]. Overhead lines or practical conductors were used in some other studies [7–9]. Increase of corona inception voltage and decline in audible noise compared to new conductors was discovered. However, those conductors were exposed in the air without operation, or operated less than 3 years. In general, the transmission lines are designed for 30-year service life. It is unscientific to promote short-term operated conductor experiment results to long-term operated conductors. Bian and coauthors studied the electromagnetic environment of practical conductors of different service years using a corona cage [2,10]. However, the conductors used were taken from different areas, from north China to south China. Influence of service year and environment were not separately studied.

Beside the service year of the line, the local environment where the conductors are used also has significant influence on aging of transmission conductor. Little information is available on this subject. No detailed comparison was carried out for practical conductors operating in different environment. In this paper, two groups of conductors cut out from practical AC transmission lines serving in regions of different pollution severity classes (in Shandong Province, east China) were employed to investigate the long-term aging effects on electromagnetic environment.

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http://dx.doi.org/10.1016/j.elstat.2015.06.009

2. Test arrangement

Laboratory corona cage has an advantage of controllable experiment environment (e.g. temperature, humidity) [1,10–13] and was widely used for corona characteristic study of transmission lines. A small corona cage designed by Tsinghua University with a size of 1.7 m × 1.7 m was used in this study. The total length of the cage is 4 m. The central section for measurement is 3-m long. Two 0.5-m long grounded guard sections are used to eliminate the end effects (Fig. 1). Test conductor was placed concentrically inside the corona cage and connected to an AC power source.

The conductors used in the experiment were cut from practical 220 kV transmission lines in Shandong Province in east China. The area in the province includes 3 regions by pollution severity classes of ambient environment. Severity class C region is light saline area at least 3 km away from sea, commonly with fine atmospheric quality. Class D regions include heavy-fog area, heavy saline area, area where air quality is below average. Severity class E regions are those places where air quality is poor, close to chemical pollution sources or flue gas sources, concentration of industry, or with distance within 1 km from the sea.

The morphologies of the conductors were tested by a scanning electron microscope (FEI Quanta 200 FEG). To analyze the elements of the substances adhering to the conductor surface, energy-dispersive X-ray (EDX) spectrum analysis was employed. EDX analysis can give the composition of the adherence.

Daytime corona camera (Ofil Super B) with solar blindness UV filters and high sensitivity sensors was used to study the corona characteristics during the test. It has been widely used in corona discharge detection in power systems [14–16]. The corona camera was placed 4.5 m away from the corona cage (Fig. 2) to measure the photon generated by corona discharge.

Audible noise was measured using a sound level meter (Denmark B&K 2250). The sound effect of auditory sense was given by weighting network A, as dB (A). The sound level meter was placed 3.5 m away from the corona cage, at the level of the conductor in the corona cage [10]. A radio interference receiver (Narda PMM 9010) was connected to the cage via a 50 Ω resistor to measure the narrowband (0.5 MHz) radio interference (RI) level. In this research, quasi-peak (QP) data were obtained to represent RI level [16].

The experiments were carried out in the shielding HV testing hall in Beijing extra high voltage company, North China Grid Company Limited. The temperature was 25–28 °C and the relatively humidity was in the range of 60–80%.

Fig. 1. General views of the corona cage.

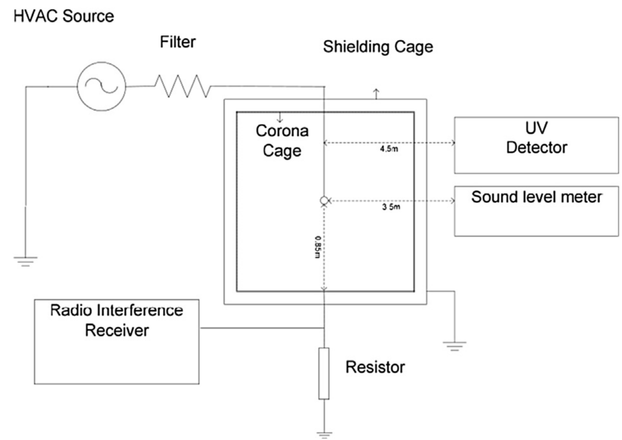

Fig. 2. Schematic diagram of the measured equipment and corona cage.

3. Experimental results

Table 1 lists the tested conductors (LGJ 400). C1 and C2 were cut from transmission lines served in regions of pollution severity class C, and the corresponding service years were 37 and 14 respectively. Relative information for the tested conductors are given in Table 1.

3.1. Photon counting

When the applied voltage was lower than the corona inception voltage, electrical discharges did not occur. No photon was observed by the corona camera. However once the corona discharge occurred, the photon count increase rapidly. Using the solar blind corona camera, it was convenient to find corona discharging points directly.

Fig. 3 showed photon counts of the aged conductor under different applied voltages. When the applied voltage of the conductor exceeded a critical value, electrical discharges appeared. Further increased the applied voltage, the photon counter jumped quickly to a very high value.

Discharging effects of different conductors under different voltages are different, as is shown in Figs. 4 and 5. When electric field of conductor surface exceeded the corona inception voltage, electrical discharge occurred. Further increase the applied voltage strengthened the coronas. For example, electric discharges of all aged conductors at 170 kV is more intense than 140 kV. In addition, conductors served in different pollution severity class exhibited different performance. For the same pollution severity class, corona discharge of the longer operated lines is more serious, especially for E1 and E2.

Comparison between C1, E1 and C2, E2 can tell the difference between regions of different pollution severity classes. Conductor C1 and E1 had been in service for a relatively long time. Although E1 was newer than C1, it suffered more from the increasing applied voltage. Another comparison between conductors in different region of different pollution severity classes was carried out and

Table 1
Information of the conductors.

Tested conductor	Age	Pollution severity class	Original location
C1	37	C	Jining City
C2	14	C	Jining City
E1	28	E	Yantai City
E2	17	E	Yantai City
New	–	–	–